

VOLUME III: CHAPTER 1

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INTRODUCTION TO AREA SOURCE EMISSION INVENTORY DEVELOPMENT

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DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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ABBREVIATIONS AND ACRONYMS

ABBREVIATIONS

ACT	Alternative Control Techniques
AFS	AIRS Facility Subsystem
AIRS	Aerometric Information Retrieval System
AMS	AIRS Area and Mobile Subsystem
BEA	Bureau of Economic Analysis
BID	background information document
CAAA	Clean Air Act Amendments of 1990
CAS	Chemical Abstract Services
CD-ROM	compact disc read-only memory
CE	control efficiency
CHIEF	Clearinghouse for Inventories and Emission Factors
CO	carbon monoxide
CO ₂	carbon dioxide
CTC	Control Technology Center
CTG	Control Techniques Guidelines
DOT	Department of Transportation
DQOs	Data Quality Objectives
EFIG	Emission Factor and Inventory Group
EIA	Energy Information Administration
EIIP	Emission Inventory Improvement Program
EIQA	emission inventory quality assurance
EPA	U.S. Environmental Protection Agency
FIRE	Factor Information Retrieval System
FTP	file transfer protocol
GIS	Geographical Information System
GPO	Government Printing Office
HAPs	hazardous air pollutants
ID	identification
L&E	Locating and Estimating
LAEEM	Landfill Air Emissions Estimation Model
MACT	maximum achievable control technology
MPO	metropolitan planning organization
MSA	metropolitan statistical area
NAPAP	National Acid Precipitation and Assessment Program
NO _x	nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
OAQPS	Office of Air Quality Planning and Standards

ABBREVIATIONS AND ACRONYMS

(CONTINUED)

ORD	Office of Research and Development
PM	particulate matter
POTW	publicly owned treatment works
PSD	Prevention of Significant Deterioration
QA	quality assurance
QC	quality control
RE	rule effectiveness
ROP	rate of progress
RP	rule penetration
SAF	seasonal activity factor
SAMS	SIP air pollutant inventory management system
SARA	Superfund Amendments and Reauthorization Act
SCC	source classification code
SIC	standard industrial classification
SIMS	Surface Impoundment Modeling System
SIP	State Implementation Plan
SSCD	Stationary Source Compliance Division, now Office of Enforcement and Compliance Assurance (OECA)
TRIS	Toxic Release Inventory System
TSD	Technical Support Documents
TSDF	treatment, storage, and disposal facility
U.S.	United States
USDA	U.S. Department of Agriculture
VMT	vehicle miles traveled
VOCs	volatile organic compounds
XATEF	Crosswalk/Air Toxic Emission Factor Database

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1

INTRODUCTION

This chapter is one of a series of documents developed to provide cost-effective, reliable and consistent approaches to estimating emissions for area source inventories. Multiple methods are provided in the chapters to accommodate needs of state agencies with different levels of available resources and skills; and different levels of needs for accuracy and reliability of their estimates. More information about the EIIP program can be found in Volume 1 of the EIIP series, *Introduction and Use of EIIP Guidance for Emissions Inventory Development*.

Throughout this chapter and other EIIP area source methods chapters, we stress that area source categories should be prioritized by the inventory planners so that resources can be spent on the source categories that are the largest emitters, most likely to be subject to regulations or are already subject to regulations, or require special effort because of some policy reason. Prioritization is particularly important for area source inventories, because in some cases, a difficult to characterize source category may contribute very little to overall emissions and attempting a high quality estimate for that source category may not be cost effective.

EIIP chapters are written for the state and local air pollution agencies, with their input and review. EIIP is a response to EPA's understanding that state and local agency personnel have more knowledge about their inventory area's activities, processes, emissions, and availability of information; and require flexible inventory methods to best use their sometimes limited resources. These EIIP area source chapters are written as a set of options presented to inventory professionals capable of using their own experience and judgement to apply the method that best fits their overall needs and constraints.

Emissions from area sources are an important component of regional air pollution inventories. With the passage of the Clean Air Act Amendments (CAAA) in November 1990, the need for specific and standardized procedures for the preparation of area source inventories has increased. Over the years, the United States (U.S.) Environmental Protection Agency (EPA) Office of Air Quality Planning and Standards (OAQPS) has established several standard procedures for the preparation of State Implementation Plan (SIP) emission inventories. The Emission Inventory Improvement Program's (EIIP's) Area Sources Committee has sought to update and expand the EPA guidance through the development of this guidance document. The objectives of Volume III, Area Sources, are to:

- Establish standard procedures for the preparation of area source emission inventories;

- Present preferred and alternative methods for estimating emissions from selected area source categories; and
- Describe new and innovative emission estimation methods in addition to methods that have been commonly used.

1.1 OVERVIEW OF VOLUME

This chapter describes the process of planning and developing an area source inventory. Fundamental emission estimation approaches for area sources as well as data management, quality assurance, and documentation requirements are described. Subsequent chapters present preferred and alternative methods for specific area source categories, and include new and innovative estimation methods whenever they are available. Methods chapters in this volume describe and recommend procedures for estimating emissions from an area source category. Each methodology chapter is divided into eight sections.

In this chapter:

- Section 1 outlines the contents of this chapter and defines the area source category.
- Section 2 describes the planning process involved in developing an inventory.
- Section 3 provides an overview of available emission estimation approaches.
- Section 4 provides details on how to make adjustments to the emission estimates, and
- Section 5 discusses data management.
- Section 6 discusses the quality and uncertainty associated with each method.
- Section 7 is the reference section.

In addition, technical abstracts providing limited amounts of information are available for downloading from the EIIP Website www.epa.gov/ttn/chief/eiip. When it was recognized that inventory preparers needed assistance with a particular source category, yet limited information existed, that information was compiled into a brief technical document describing the category and how to estimate emissions. These documents are called abstracts.

1.2 DEFINITION OF AREA SOURCES

An area source may be defined as a collection of similar emission units within a geographic area. Commonly, area sources have been defined at the county level, and most area source methods are designed to estimate area source emissions at the county level. However, any specified area (e.g., city, town, or census division) could be used to define an area source. User-defined areas such as grid cells or polygons could also be used.

Area sources collectively represent individual sources that are small and numerous, and that have not been inventoried as specific point, mobile, or biogenic sources. Individual sources are typically grouped with other like sources into area source categories. These source categories are grouped in such a way that they can be estimated collectively using one methodology. For example, gasoline stations and dry cleaning establishments are often treated as area sources. The main reason not to treat them as point sources is that the effort required to gather data and estimate emissions for each individual facility is great although emissions per facility are generally small. For these sources, the distinction between point and area is usually defined by a cutoff point typically based on annual emissions. SIP ozone inventories, for example, define volatile organic compound (VOC) point sources as individual facilities emitting more than 10 tons of VOCs per year. Emissions from smaller facilities are treated as an area-source group.

True area-wide sources, such as pesticide use and commercial/consumer product use, are examples of this source type. The boundaries of the individual activities associated with these sources are often hard to determine or are, at best, arbitrary. Even within a point source facility, some activities occur that are more easily treated as area source emissions. Some emissions associated with surface coating operations such as equipment cleaning, for example, can be more practically estimated using area source methods even though other surface coating emissions may be reported as part of the point source inventory.

The main distinction between point and area sources is the methodology used to estimate emissions. Point sources are inventoried individually, and area sources are inventoried collectively. While all stationary sources could be treated as either point sources or area sources, for practical reasons some cutoff is usually set to distinguish between them. The end use of the inventory, the desired accuracy of the emissions, and the resources available for inventory development all affect where that cutoff is set. Volume III of this EIIP series provides guidance for area source emissions estimation methods for many common area source processes.

The term “process” is used here to name an operation or activity that produces emissions. Area sources include the following broad groups of processes:

- Commercial and consumer organic solvent usage (surface coating, dry cleaning, degreasing, graphic arts, rubber and plastics);

- Stationary fuel combustion (heating, including waste oil combustion);
- Material storage and distribution;
- Waste treatment and disposal;
- Miscellaneous industrial manufacturing operations;
- Comfort and industrial cooling towers;
- Miscellaneous sources (agricultural/forest burning, structure fires, mining or construction, for example);
- Gasoline service stations; and
- Hospital and laboratory sterilizers.

Each of these broad groups of processes contain a number of more specific groups that share similar emission processes and emission estimation methods.

Although mobile and biogenic sources could be inventoried as area sources, specialized methods have been developed for these categories. These methods are described in EIIP Volumes IV and V, respectively.

Finally, in this volume of EIIP documents, ozone precursors and the criteria pollutant particulate matter (PM) are emphasized. Where it was possible, emission factors or speciation profiles for other criteria pollutants, hazardous air pollutants (HAPs), and greenhouse gases were included. However, the lack of information for other pollutants in these methodologies should not be construed to mean that a source does not emit those pollutants.

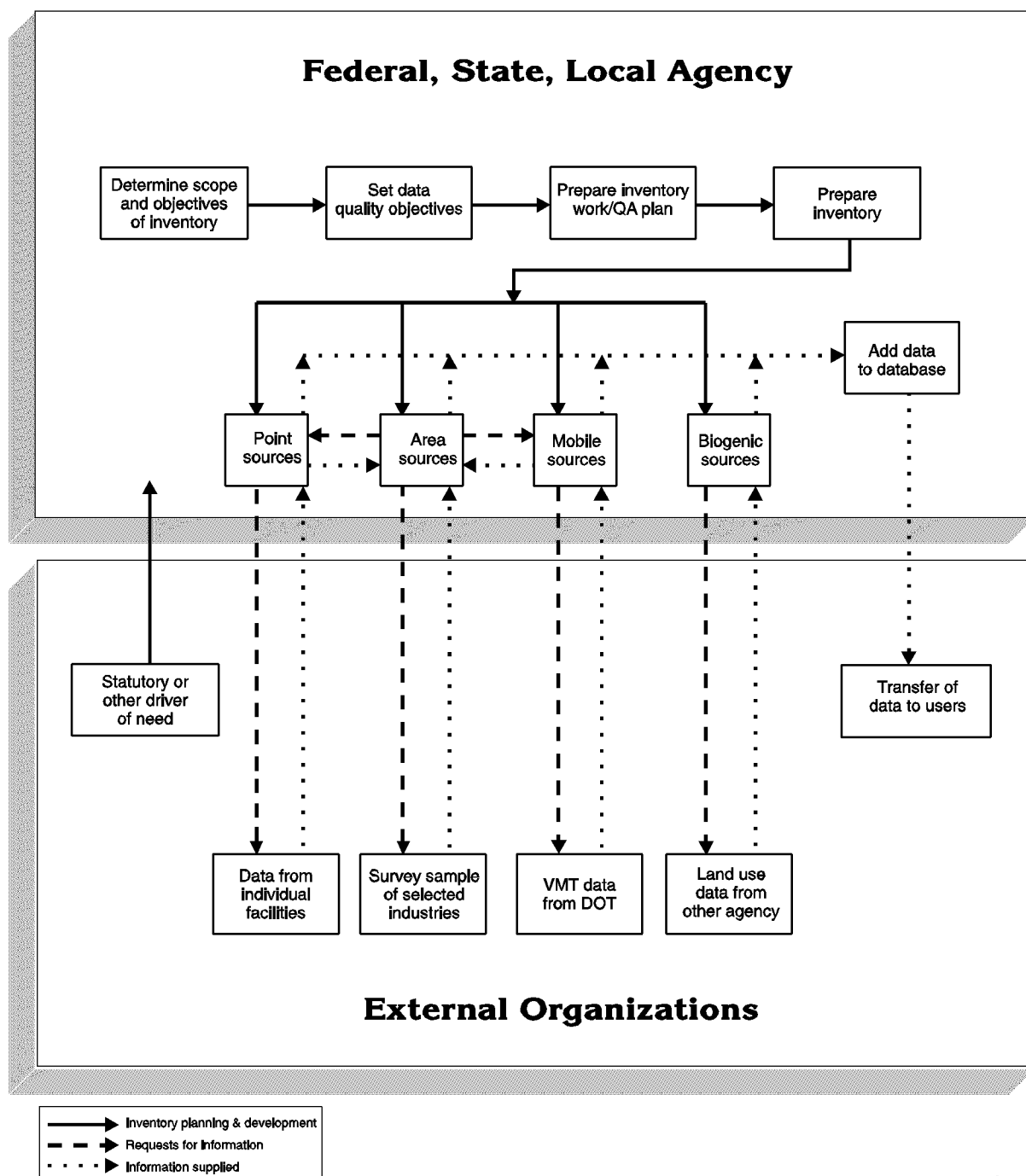
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INVENTORY PLANNING

Thorough planning at the beginning of the inventory development process is essential for the efficient development of sound emissions inventories. An essential part of the area source inventory planning process is to coordinate complementary point, mobile, and biogenic inventory activities to ensure that overall inventory requirements are met. The overall role of planning is discussed in some detail in Volume I of this series (*Introduction to Area Source Emission Inventory Development*, July 1997); the role of planning in the quality assurance (QA) program is described in Volume VI (Chapter 2). This section concentrates on issues relevant to area source inventories.

Figure 1.2-1 provides an overview of inventory planning and information flow at a typical agency. Note that the area source inventory group has more interactions with other groups than any other inventory group. Therefore, it is essential that the area source inventory team:

- Identify other departments or agencies that need to be contacted for inventory information;
- Define the role that the departments or agencies will have, and communicate their role clearly before work begins;
- Ensure that the other departments or agencies are aware of procedural and documentation requirements before work begins; and
- Identify points of contact in each department.



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FIGURE 1.2-1. COMMUNICATION AND INFORMATION SHARING DURING INVENTORY PREPARATION

The flow chart emphasizes the importance of good communication both among members of the inventory staff as well as between different agencies and individuals. Careful planning will facilitate good communication. The activities associated with the planning process can be classified into five general groups:

- Defining the scope of the inventory including the pollutants, geographic boundaries, sources, and end uses;
- Planning the quality assurance and control activities and documenting them in a QA plan;
- Choosing the appropriate methods for calculating emissions and identifying the data needed;
- Identifying the appropriate types and comprehensiveness of the documentation and preparing an inventory work plan; and
- Developing a plan for collecting and managing the data.

Many of these activities are performed by personnel outside of the area source inventory group or are provided by others at the beginning of inventory development. Specific area source inventory concerns within each of these groups are described in the remainder of this section.

2.1 DEFINING THE SCOPE

The overall inventory planning process should result in defining the end uses for the data, the data quality objectives (DQOs) for the pollutants of interest, the geographic area to be inventoried, and the appropriate spatial and temporal resolutions of the data. The next steps in defining the area source inventory scope are to identify source categories to be inventoried and to ensure that the area source inventory will completely cover sources that are not being inventoried as point, mobile, and biogenic sources. Then the sources that will be included in the inventory should be prioritized to facilitate efficient allocation of resources.

To determine which area sources to include:

- Compile a comprehensive and exhaustive list of sources from guidance documents, other inventories, business directories, EPA guidance, and any other information on emissions activities in the inventory area;
- Prioritize the list based on the expected magnitude of emissions or some other measure of importance;
- Review the list carefully and eliminate any sources that are not relevant or are insignificant sources in the inventory region; and

- Define and develop a good understanding of the process and industries that make up the source.

Table 1.2-1 gives an example list of potential area source categories for a state's ozone precursor inventory. Early in the process, the inventory preparers should eliminate any sources that are not found within the inventory area. For example, volcanoes and geysers are rarely of concern in most states. However, it is not always possible to determine the applicability of a source without some research. The initial list should, therefore, be as comprehensive as possible so that no source is overlooked.

Sources should be prioritized based on their importance in the inventory. The agency's resources should be allocated preferentially to the sources that are most important for meeting the inventory objectives. The sources can be prioritized by checking previous or other agencies' inventories to identify the largest-emitting area sources. Alternatively, the end-users may specify the sources that are most important to them. High-priority sources will include those that are:

- Known or inferred significant contributors;
- Regulated sources;
- Sources under consideration for future regulation;
- Sources of specific, targeted pollutants (e.g., photochemically reactive VOCs); and
- Sources most likely to impact human health.

If the source list is prioritized on the basis of the largest area-source emitters, information from a previous inventory may be used. An example of a prioritized list is shown in Example 1.2-1.

2.2 THE QA PROGRAM

Before any area source emission calculations take place, data collection, data handling, emission reporting, and documentation procedures should be carefully planned. Volume VI of this series provides detailed discussions on general QA issues for planning and documentation of inventories. This section will focus on the planning issues, including QA planning, that specifically pertain to area source inventories.

An essential component of planning is the development of a QA plan that specifies all QA and quality control (QC) procedures to be followed in preparing the inventory. Early in the planning

TABLE 1.2-1
POTENTIAL AREA SOURCES (BY EPA TRENDS TIER 1 CODE)
OF OZONE PRECURSOR EMISSIONS

Category (Tier 1 Code)	PM	VOC	NO _x	CO	HAPs	NH ₃
Fuel Combustion - Electric Utility (01)						
Internal Combustion		✓	✓	✓	✓	✓
Fuel Combustion - Industrial (02)						
Coal	✓	✓	✓	✓	✓	
Gas	✓	✓	✓	✓	✓	✓
Internal Combustion	✓	✓	✓	✓	✓	✓
Oil	✓	✓	✓	✓	✓	✓
Other	✓	✓	✓	✓	✓	✓
Fuel Combustion - Other (03)						
Commercial/Institutional Coal	✓	✓	✓	✓	✓	
Commercial/Institutional Gas	✓	✓	✓	✓	✓	✓
Commercial/Institutional Oil	✓	✓	✓	✓	✓	✓
Residential Wood	✓	✓	✓	✓	✓	✓
Residential Other	✓	✓	✓	✓	✓	✓
Miscellaneous Fuel Combustion except Residential	✓	✓	✓	✓	✓	
Chemical and Allied Products Manufacturing (04)						
Inorganic Chemicals			✓		✓	
Organic Chemicals			✓	✓	✓	
Pharmaceuticals			✓		✓	
Polymers and Resins		✓				
Metal Processing (05)						
Ferrous Metals			✓	✓	✓	
Nonferrous Metals		✓	✓		✓	
Metals Processing NEC	✓	✓	✓	✓	✓	
Petroleum and Related Industries (06)						
Asphalt Manufacturing		✓	✓	✓	✓	
Oil and Gas Production	✓	✓	✓	✓	✓	
Petroleum Refineries and Related Industries		✓			✓	

TABLE 1.2-1

(CONTINUED)

Category (Tier 1 Code)	PM	VOC	NO _x	CO	HAPs	NH ₃
Other Industrial Processes (07)						
Agricultural, Food, and Kindred Products	✓	✓	✓	✓	✓	✓
Machinery Products		✓	✓		✓	
Mineral Products	✓	✓	✓	✓	✓	
Rubber and Miscellaneous Plastic Products	✓	✓			✓	
Wood, Pulp and Paper, and Publishing Products	✓	✓	✓	✓	✓	
Construction	✓				✓	
Miscellaneous Industrial Processes	✓	✓	✓	✓	✓	✓
Solvent Utilization (08)						
Degreasing		✓			✓	
Dry Cleaning		✓			✓	
Graphic Arts		✓			✓	
Nonindustrial		✓	✓	✓	✓	
Other Industrial		✓			✓	
Surface Coating		✓	✓	✓	✓	
Solvent Utilization NEC					✓	
Storage and Transport (09)						
Bulk Terminals and Plants		✓			✓	
Organic Chemical Storage		✓			✓	
Petroleum and Petroleum Product Storage		✓	✓		✓	
Petroleum and Petroleum Product Transport		✓			✓	
Service Stations: Breathing and Emptying		✓			✓	
Service Stations: Stage I		✓			✓	
Service Stations: Stage II		✓			✓	
Waste Disposal and Recycling (10)						
Incineration	✓	✓	✓	✓	✓	
Industrial Waste Water		✓			✓	
Landfills		✓	✓	✓	✓	
Open Burning	✓	✓	✓	✓	✓	
POTWs		✓			✓	✓

TABLE 1.2-1

(CONTINUED)

Category (Tier 1 Code)	PM	VOC	NO _x	CO	HAPs	NH ₃
TSDFs		✓	✓	✓	✓	
Other		✓			✓	
Natural Sources (13)						
Biogenic		✓	✓		✓	✓
Geogenic, Wind Erosion	✓	✓				
Miscellaneous (14)						
Agriculture and Forestry	✓	✓			✓	
Other Combustion (Structure Fires, Forest Fires, Slash Burning, Prescribed Burning, Managed Burning)	✓	✓	✓	✓	✓	
Catastrophic/Accidental Releases		✓			✓	
Health Services		✓			✓	
Agricultural Crops (Tillage)	✓				✓	✓
Paved Roads	✓					
Unpaved Roads	✓					
Other Fugitive Dust (e.g., Mining and Quarrying)	✓					

References: EPA. 1999. Emissions Inventory Guidance for Implementation of Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) and Regional Haze Regulations. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

EPA. 2000. National Air Pollutant Emission Trends, 1900-1998. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

PM = Particulate matter
VOC = Volatile organic compounds
NO_x = Nitrogen oxides
CO = Carbon monoxide
HAP = Hazardous air pollutant
NH₃ = Ammonia

Example 1.2-1

Based on summaries of data submitted for the CAAA-mandated 1990 SIP VOC inventories, the following area sources reported in the Aerometric Information Retrieval System (AIRS) Area and Mobile Subsystem (AMS) are responsible for 90 percent of the VOCs from area sources:

- Architectural surface coating
- Gasoline service stations
- Consumer solvents
- Degreasing
- Auto refinishing
- Commercial pesticide application
- Industrial surface coating
- Graphic arts
- Dry cleaning
- Traffic marking
- Residential fuel use
- Open burning
- Managed burning and forest wildfires

Many of the above categories have subcategories that contribute to the total.

process, the area source inventory developers may be asked to specify estimation methods or QC procedures that will ensure that the inventory meets its DQOs. The agency should also include a discussion in the QA plan that addresses how QC checks will be used for the different emissions estimation methods. The inventory documentation should also clearly describe the QA and QC procedures, checks, and results. QA activities for a particular emissions estimation method may include a detailed review of the data sources, documentation of procedures, and the development of specific QC checks, such as verifying emissions calculations. Examples of QC checks can be found in Chapter 3 of EIIP *Quality Assurance Procedures* (Volume VI) and in Section 6 of this chapter.

The best possible emissions estimation method to use for a particular source can vary depending on the source category and local conditions. Within each source category, several estimation methods and emission factors may be available. The agency should identify in the inventory work plan the procedures it will use to ensure that the methods and emission factors used are the

best choice considering the DQOs, the constraints on the inventory, and the priority of the source. The agency should identify the requirements for each method, including time frame, funds, data, and the availability of experienced personnel available for inventory preparation.

In planning the QA/QC program for area sources, the following elements should be considered:

- Ensure that double counting does not occur;
- Determine if temporal adjustment to emissions were done appropriately;
- Determine how the peak seasons for the inventory pollutants were defined; and
- Determine how emissions will be projected and the projection period, including end year and intermediate years for projection inventories.

Double counting is an especially important issue for area sources. It is caused by overlaps between inventoried area source categories, or overlaps between area source and point source categories. For example, emissions from large dry cleaners (major point sources) are included in an inventory. Emissions from small dry cleaners (below some specified cutoff) have been treated as an area source using a top-down estimation approach. The area source inventory must be adjusted downward by subtracting the major source contributions to avoid double counting. Double counting leads to inaccuracies in the final inventory and should be avoided.

The inventory work plan needs to identify and eliminate potential double counting of emissions with the following steps:

- Identify categories that have a point source component. The area source activity must be adjusted to account for point source activity in order to avoid double counting emissions; and
- Identify potential overlap among area source categories and document how to avoid it.

The QA plan should include procedures to ensure that these specified steps were done correctly.

2.3 EMISSION ESTIMATION METHODS

Emission estimation methods should be determined for each source during the planning phase. The choice of methods will be based on a number of factors, including agency resources, source category priority, and the information needs of the inventory. The preferred methods specified in this volume will yield a higher-quality estimate of emissions and should be used when a

source is ranked as a high priority or when a specific local characteristic would skew the results obtained from an alternative method. In contrast, alternative methods usually will yield lower-quality estimates of emissions and are best used for source categories that are not highly prioritized.

For each area source category, the rationale for the method used should be stated in the work plan. This can be as simple as stating that the preferred method is from EIIP Area Source Preferred and Alternative Methods guidance. More explanation is warranted if the method used deviates from the preferred method. If alternative emission factors or activity data are available, the reason for using the factors or data chosen should be stated in the work plan. Similarly, any assumptions used in developing the activity data or emission factors should also be clearly stated.

Area sources subject to regulatory controls should be identified in the inventory planning process so that the appropriate control information will be collected. Control information may include the portion of the category affected by the regulation (rule penetration), the type of control, the amount of emissions that are controlled (control efficiency), and the estimated effectiveness of the control (rule effectiveness). Controls are discussed further in Section 4 of this chapter.

2.4 DOCUMENTATION

Documentation is an integral part of an emissions inventory, and is of critical importance for QA/QC activities. All inventory documentation should fulfill some basic requirement. The guiding principle is reproducibility. It should be possible for anyone reading the document to reproduce the results. Complete and well-organized documentation will result in a more reliable and technically defensible inventory. Internal review of the written documentation of an inventory's data sources and procedures by an agency's QA and technical personnel will uncover errors in assumptions, calculations, or methods.

More information on the role of QA/QC review of inventory documentation can be found in *Quality Assurance Procedures* (Volume VI) of this series. General guidance on documentation is given in Volume I. Area source inventories rely on more diverse types of data sources than any other type of inventory. It is very important that all sources be thoroughly documented, including databases or information from other agencies.

Reporting requirements for inventory data are usually specified by the agency or regulation requiring the inventory. In general, the data used to develop the input variables should be supplied if at all possible. For example, where employment in several standard industrial classification (SIC) Codes is summed to produce the activity parameter, the original employment data by SIC Code should be shown in an appendix unless prohibited by the size of

the data set or confidentiality issues. Alternatively, if the data were derived from a published data set, the source should be referenced (supplying page and table numbers, if necessary). All conversion factors used should be explicitly stated.

If models are used in any part of the calculations, the input data used for the model should be provided. Any statistical analyses should also be clearly documented; the complete data set used and the output from the statistical analysis should be provided. Similarly, survey results should be provided in as much detail as possible along with, at a minimum, the survey questionnaire, the number of facilities surveyed, the percentage responding, and some descriptive statistics of the results.

Sufficient information should be given to document the completeness of the area source inventory. Categories excluded should be specified, and the reasons for their exclusion stated. Some explanation of the process used to identify source categories also must be provided.

In addition to text explaining the process used to develop the inventory, sample calculations should be provided. This is particularly important for complicated calculations or if several steps were required to develop the estimates.

Referencing of all data sources and assumptions is part of reproducibility. The sources of all data, methods, and assumptions should be fully documented. If the source is a person at a government agency, trade group, or other organization, that person's name, affiliation, and the date of the contact should be documented, at a minimum. Reports and other documents should be referenced by author (if known), year, title of document, publishing agency, and location. Documents published by most government agencies usually have an identifying number that should be included.

2.5 DATA COLLECTION/MANAGEMENT

To some extent, overall data management decisions are made by personnel who specialize in data consolidation and transfer, and the final repository of the area source data may not be under the control of the area source team. However, collection and management of data that will ultimately become part of the area source inventory are usually under the control of the area sources staff. Consider the following in planning data collection and management for an area source inventory:

- Determine the role of existing inventory data and ensure that any previously omitted data and sources have been identified;
- Select data collection methods that are most appropriate to the estimation methods; and

- Review overall inventory data management system requirements to ensure compatibility.

An important planning consideration is whether and to what extent information contained in existing emissions inventories can be used. Existing inventories should be examined to determine whether the appropriate emission sources have been included and if the emissions data represent current conditions. Existing inventories serve as a starting point for developing lists of sources. They also should provide extensive data and support information, such as documentation of procedures and data ranges for identifying outlier values. Simple sensitivity analyses of existing inventories can be used to prioritize categories and identify key data needs (see Section 6, *Sensitivity Analysis*, in Chapter 3 of Volume VI of the EIIP series).

The data for a new inventory may or may not be available from a previous inventory in the correct level of detail depending upon the objectives and degree of success of prior inventory efforts. Even though some data are not required in the basic inventory, an agency may find it expedient to collect additional information as part of a routine update of the inventory. If the agency anticipates the need for special data (for use in a photochemical model, for instance) it is more efficient to collect that data at the same time as the required data for the basic inventory.

Any needs or restrictions of the data management system should be identified in the planning phase and compared to the form of the information produced by the various emission estimation methods. The data management system will be used to store inventory information and to transfer the information to other users, such as photochemical modelers, so the further uses of this information should be considered. Issues of particular concern for area sources are mismatches in source identification codes, units, or levels of detail, and incompatibility between the data management system's data input formats and the format of the data generated by the area source estimation method. An example of the latter is when emissions are estimated using a computer model, but the data management system uses an emission factor and activity data.

3

EMISSION ESTIMATION APPROACHES

Emissions from area sources are nearly always estimated using some type of calculation procedure. Direct measurement of area source emissions is hardly ever practical because of technical and cost considerations. This section describes the methods that are commonly used to estimate area source emissions. There are four basic approaches for developing an area source emission estimate:

- Extrapolation from a sample set of the sources (surveys, permit files, or other databases);
- Material balance method
- Mathematical models; and
- Emission factors applied to activity levels. Detailed descriptions of emission estimation methods and example calculations for specific area sources are included in the following chapters of this volume.

As described in the previous section, an emission estimation approach should be chosen during the inventory planning phase and depends on inventory objectives, available resources (including availability of quality data needed), source category priority, intended use of the inventory, and the available methods for a source. Information needed for choosing emission estimation approaches is:

- The source's ranking in the prioritization scheme (see Section 2.1);
- The schedule for completing the inventory and the resources available;
- The level of detail needed (based on current or future regulations, knowledge about local differences, modeling and data storage needs, etc.); and
- Descriptions of the source categories and the methods that can be used to estimate emissions from them.

A list of decisions for choosing among area source methodologies is shown in Example 1.3-1.

Example 1.3-1

- Identify the priority sources for the inventory area;
- Assign resources based on prioritization of the sources;
- Investigate possible emission estimation methods for area sources;
 - Reject methods that obviously cannot be used (e.g., using a mathematical model or permit information for architectural surface coating).
- Compare the needs of the inventory with the information that the available methods produce;
 - The method calculates the pollutant at the required level of detail in terms of speciation, and temporal or spatial allocation; and
 - The method results reflect economic or regional differences that would affect emissions, (e.g., if the inventory area is mostly high-density housing with a lower than average per capita architectural coating use).
- Consider subcategorizing sources and using different methods for the subcategories;
 - Subcategorization of a source may allow more detailed estimation of the most significant portion of a source, and may be the most efficient way to achieve inventory goals of more accurate emission estimates, more detailed inventory information, or other quality goals that improve the estimate.
- If available methods vary in the amount of resources that they require, rank them according to the amount of resources that they need. Determine if the increase in needed resources is justified by an increase in accuracy or detail.

3.1 EXTRAPOLATING FROM A SAMPLE OR OTHER DATABASE

For many area sources, the EIIP preferred approach is to extrapolate from a sample set of data for the industry/activity to the entire population. This often requires a survey of a statistically valid sample set, but sometimes existing data sets can be used as a starting point. An agency may have files or databases that can be accessed for use in emissions inventory development. Permits are typically required for construction, startup, and modifications of an emission source. Permit applications generally include enough information about a potential source to describe the nature of the source and to estimate the magnitude of emissions that will result from its operations. Some permits also include source test data. These files are often used for point sources but may include information that is useful for area source estimation as well.

Permits for emissions of pollutants not included in a particular inventory can also be useful. Permits for emissions of air toxics may be useful to identify or characterize sources of VOCs, for example. Rules unrelated to air emissions may be useful if they require facilities to report information that could be used in the inventory. Title V permits, solid waste permits, and National Pollutant Discharge Elimination System (NPDES) permits could be useful sources of information. A category may be subdivided to use information where available and use another approach for the remaining sources.

If an agency has previously estimated emissions based on a survey of the industry, those data can sometimes be used to estimate emissions for the newer inventory. This may be as simple as applying a growth factor to the emissions, or it may require further adjustments to account for other changes in the industry. If possible, a survey of a representative cross-section of the sources should be used to update information. For example, more sources may be controlled than were previously, new types of controls may be in use, or processes may have changed.

For some source categories, an industry-wide survey may be warranted. If the category represents a significant proportion of emissions, has the potential for further controls, or is poorly characterized by other methods, the agency should consider surveying the population of sources. If this includes a very large number of facilities, a statistically valid sampling method can be used. Figure 1.3-1 illustrates the decision-making process that might be followed to arrive at this method.

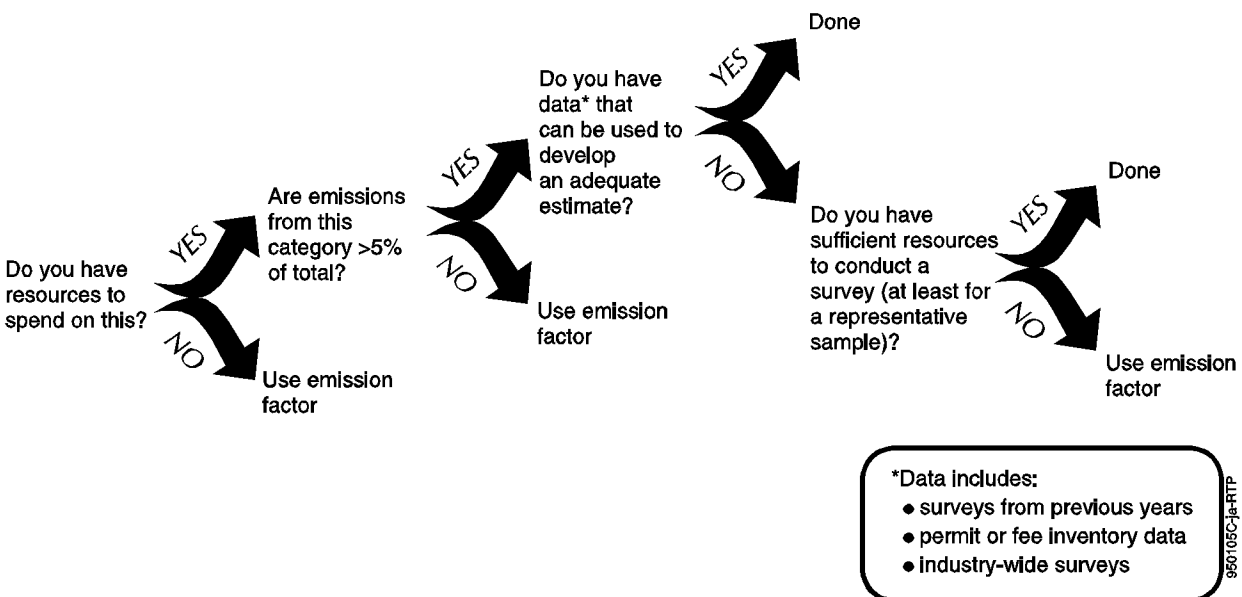


FIGURE 1.3-1. EXAMPLE DECISION TREE FOR CHOOSING AN ESTIMATION METHODOLOGY

3.2 MATERIAL BALANCE METHOD

An agency can, in some cases, use a material balance technique to develop emission factors or total emissions for an inventory period. For some sources, a material balance is the only practical method of estimating VOC emissions; it also can be the most accurate, especially when the balance covers the entire inventory period, and the nonair losses are small or easily quantified. Source testing of low-level, intermittent, or fugitive VOC exhaust streams can be difficult, costly, and highly variable in many instances. Emissions from these and other solvent evaporation sources are most commonly determined by the use of material balances.

Use of material balances involves the examination of a process to determine whether emissions can be estimated solely upon knowledge of operating parameters, material compositions, and total material usage. The simplest material balance assumes that all solvent used in a process will evaporate to become air emissions somewhere at the facility. For instance, for many surface coating operations, it can be assumed that all of the solvent in the coating evaporates to the atmosphere during the application and drying processes. In such cases, emissions equal the amount of solvent contained in the surface coating plus any added thinners and cleanup solvents.

Material balances are greatly simplified and very accurate in cases where all of the consumed solvent is emitted to the atmosphere. But many situations exist where a portion of the evaporated solvent is captured and routed to a control device such as an afterburner (incinerator) or condenser. In these cases, the captured portion must be measured or estimated by other means and the disposition of any recovered material must be accounted for. As a second example, in degreasing operations, emissions will not equal solvent consumption if waste solvent is removed from the unit for recycling or incineration. A third example is where some fraction of the diluent (which is used to liquify cutback asphalt, for example) is believed to be retained in the substrate (pavement) rather than evaporated after application. In these examples, a method of accounting for the nonemitted solvent is required to avoid an overestimation of emissions.

Material balances cannot be accurately employed at a reasonable cost for some evaporation processes because the amount of material lost is too small to be determined accurately. As an example, applying material balances to petroleum product storage tanks is not generally feasible because the losses are too small relative to the uncertainty of any metering devices. In these cases, using emission factors or equations from EPA's *Compilation of Air Pollution Emission Factors, Volume I: Stationary Point and Area Sources*, commonly referred to as AP-42 (EPA, 1995), is recommended.

3.3 MATHEMATICAL MODELS

A model may be used to estimate emissions when emissions are not directly related to any one parameter. A model may be a simple equation, but is typically in the form of a computer program. This facilitates the processing of a large number of equations and interactions. Data requirements for models vary, depending on the model. Mathematical models used for predicting area source emissions attempt to reproduce the “real world” behavior of processes that generate emissions. A model will incorporate mathematical relationships derived from experimental data and/or some statistical or advanced computational intelligence technique. Models that have been thoroughly tested and validated should be capable of estimating area source emissions to a high level of accuracy. However, when using any model, please remember that the accuracy of the results will depend on the accuracy of the data entered into the model and the suitability of the model to the particular emissions source.

Some examples of available emissions models are shown in Table 1.3-1. All of these and other emission estimation models are available through the Clearinghouse for Inventories and Emission Factors (CHIEF) website. A detailed summary of these models may also be found in Volume II, *Point Sources*, of the EIIP series. See Section 3.4.2 of this chapter for more information about CHIEF.

3.4 EMISSION FACTORS

One of the most useful tools available for estimating emissions from area sources is the emission factor. An emission factor is an estimate of the quantity of pollutant released to the atmosphere as a result of some activity such as combustion or industrial production, divided by the level of that activity. In most cases, emission factors are expressed simply as a single number, with the underlying assumption that a linear relationship exists between emissions and the specified activity level over the probable range of application. Thus, emission factors may be thought of as simple forms of emission models where there is a direct relationship between emissions and a single parameter.

An emission factor relates a quantity of an air pollutant to a process parameter, or a surrogate parameter, so that if the parameter is known, an estimate of emissions can be made. For example, an emission factor in the form of pounds of VOCs per ton of solvent used in a process can be used to estimate VOC emissions from a source if the weight of the solvent used is known or can be determined. In this case, the emission factor and activity are parameters for direct estimation of emissions from a source. However, area sources sometimes are not easily estimated by a direct measure of throughput. In that case, an emission factor that is based on a surrogate measure for activity level such as population or employment in an industry will need to be devised.

TABLE 1.3-1

EMISSION ESTIMATION MODELS USEFUL FOR AREA SOURCES

Model Name	Description/Features	Contact/Reference
CHEMDAT8	<ul style="list-style-type: none"> Estimates VOC emissions from TSDF processes. Lotus 1-2-3® spreadsheet. Default input parameters provided to demonstrate calculations. 	Elaine Manning, EPA Emissions Standards Division, (919) 541-5499
WATER8	<ul style="list-style-type: none"> Estimates emissions from wastewater treatment systems. Menu-driven computer program. 	Elaine Manning, EPA Emissions Standards Division, (919) 541-5499
Landfill Air Emissions Estimation Model (LAEEM)	<ul style="list-style-type: none"> Estimates HAP, VOC, methane, and CO₂ emissions from a landfill. Computer model. Site-specific data can be entered; defaults (conservative) provided. 	Susan Thorneloe-Howard, EPA Air Pollution Prevention and Control Division, (919) 541-2709
TANKS, version 2.0	<ul style="list-style-type: none"> Estimates organic chemical emissions from storage tanks. Variety of tank types included. User enters site-specific data; defaults provided. Computer model. 	Info CHIEF (MD-14) United States Environmental Protection Agency Research Triangle Park, NC 27711,
MECHANICAL	<ul style="list-style-type: none"> Estimates fugitive PM emissions from roads, materials handling, agricultural billing, and construction/demolition. 	<i>Control of Open Fugitive Dust Sources</i> , EPA-450/388-008
WIND	<ul style="list-style-type: none"> Estimates PM emissions from wind erosion. 	<i>Control of Open Fugitive Dust Sources</i> , EPA-450/388-008

3.4.1 EMISSION FACTOR ACCURACY

Because emission factors are typically averages obtained from data with wide ranges and varying degrees of accuracy, emissions calculated this way for a given source are likely to differ from that source's actual emissions. Because they are averages, factors will indicate higher than actual emissions for some sources and lower than actual emissions for others. Only specific source measurement can determine the actual pollutant contribution from a source under conditions existing at the time of the test. For the most accurate emissions estimate, it is recommended that source-specific data be obtained whenever possible. This is rarely possible for area sources that represent a collection of sources in an area that are usually individually small. In an area source inventory, emission factors are appropriately used to estimate the collective emissions of a number of small individual sources that would be difficult or impossible to estimate using other methods. If factors are used to predict emissions from new or proposed sources, an agency should review the latest literature and technology to determine whether such sources would likely exhibit emissions characteristics different from those of typical existing sources.

When the information used to develop an emission factor is based on national data, such as a wide range of source tests or national consumption estimates, the inventory preparer should be particularly careful with potential local variations. Emissions calculated using national emission factors may vary considerably from actual values at a specific source or within a specific geographic area. National emission factors should be used either when no locally derived factor exists, the local mix of individual sources in the category is similar to the national average, or the source is a low priority in the inventory.

A locally derived emission factor is preferred when either a national-level emission factor does not account for local variations or the category is a high priority in the area. These emission factors are developed either through local surveys or measurements, are based on local consumption for solvent categories, or are adapted from emission information in permits or another inventory. Typically, the information gathering necessary for developing a local emission factor can be significant, but the benefits are that the emissions for the source will be well characterized, and the emission factor or the information used to develop it can be used in subsequent inventories.

3.4.2 EMISSION FACTOR REFERENCES

The following emission references may also be sources for other information needed for emission calculations, like VOC speciation, source controls, rule effectiveness and rule penetration, and fuel loading. Other databases and documents that contain emission factors for use in inventories are listed in the individual source methodology chapters.

Factor Information Retrieval (FIRE) System

The EPA's FIRE System is a consolidation of emissions estimation data (factors) for criteria and HAPs that currently includes the information contained in the EPA databases such as Crosswalk/Air Toxic Emission Factor (XATEF), the Air Emissions Species Database SPECIATE, and the AIRS Facility Subsystem (AFS), as well as emission factors from EPA documents such as *AP-42* and the EPA's Locating and Estimating (L&E) series of emission factor documents. These databases and documents are the basic sources of emission factors that have been used in the preparation of inventories, as well as economic analyses, permit preparation for Prevention of Significant Deterioration (PSD) and New Source Review applications, and other federal, state, and local agency assessments of air pollution sources.

Additional emission factors for FIRE have been collected from the literature, material balance calculations, and source tests. Each emission factor in FIRE includes information about the pollutant (Chemical Abstract Services [CAS] numbers and chemical synonyms) and about the source (SIC Codes and descriptions, and source classification codes [SCCs] and descriptions). Each emission factor includes comments about how it was developed in terms of the calculation methods and/or source conditions, as well as the references where the data were obtained. The emission factor also includes a data quality rating.

The FIRE database is divided into two main sections. One section contains all the emissions data as described above, as well as any additional data that are collected by the EPA. This section is called the "Repository Subsystem." The other section will contain only a single emission factor that is recommended for each source/pollutant combination. This section is called the "Distribution Subsystem" and is provided to users for loading onto their own computers or local area network.

The FIRE database has been designed to be very user friendly. Data can be searched in many different ways and can be downloaded to print or data files, or can be printed in a report format that is designed by the user. The FIRE database can be downloaded from the EPA's CHIEF electronic system (see below). FIRE is also available in a compact disc read-only memory (CD-ROM) form from Air CHIEF (see below).

CHIEF

CHIEF is maintained by the Emission Factors and Inventory Group (EFIG) of EPA's Emissions, Monitoring and Analysis Division in Research Triangle Park, North Carolina. As a clearinghouse, CHIEF is the repository of the most up-to-date information on inventories and emission estimation data, such as emission factors. The original method of relaying this information to the public was through a newsletter. Currently, CHIEF maintains a site on the Internet, <http://www.epa.gov/ttn/chief>.

CHIEF contains all of the *AP-42* stationary source volume and draft revisions, the SPECIATE database, and the L&E series of documents, all of which can be used as sources of emission factors. CHIEF also contains the models mentioned in this section, the MOBILE5a model, and the AFS database.

Fax CHIEF

Fax CHIEF provides emission calculation information through fax.

Air CHIEF

Air CHIEF is designed to combine parts of the emission estimation information from CHIEF into CD-ROM. Currently, Air CHIEF includes some data from FIRE, the SPECIATE database, emission factors from *AP-42*, and the L&E documents. Copies of the Air CHIEF CD-ROM and the user's manual are available from the Emission Factor and Inventory Group, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711

AP-42

AP-42 compiles source descriptions, process descriptions, emission factors, and control information for processes resulting in emissions from combustion, waste disposal, solvent evaporation, industry and manufacturing, agricultural operations, and miscellaneous sources. *AP-42* is a primary reference for the information needed to estimate emissions.

EPA's Emission Factor Inventory Group recently released a major update and expansion of factors in *AP-42*, including a more detailed breakout of VOCs and other organic emissions by compound or compound class, PM, and additional factors for greenhouse gases where data are available. It is expected that this more detailed breakout of VOCs and other pollutants will better meet the needs of inventory compilers for generating speciated VOC, HAP, PM and greenhouse gas emission inventories.

A paper copy of the entire *AP-42* can be ordered from the Government Printing Office (GPO), Box 371954, Pittsburgh, Pennsylvania 15250-7954, Stock No. 055-000-00500-1, \$56.00 total. Telephone orders can be made to (202) 512-1800, and orders by via facsimile to (202) 512-2250. *AP-42* can also be found on Air CHIEF. Sections of the *AP-42* can be downloaded from the CHIEF and by using Fax CHIEF. EPA's EFIG develops and maintains the *AP-42* series.

3.4.3 UPDATING EMISSION FACTORS

An updated emission factor may be needed when the rate of emissions from a source has changed relative to the activity. For instance, if industrial solvent use per employee has been reduced through the 1980s because of the substitution of water-based products, then an older employee-based emission factor will not reflect that change. The keys to developing an updated emission factor are:

- Identify the nature of the change;
- Estimate the amount of change in emissions;
- Apportion the emission factor to reflect the change, and
- Document the reasoning behind the change, the assumptions, and calculations used.

In the case of the altered solvent use Equation 1.3-1:

$$\frac{\text{New emission factor}}{\text{Old emission factor}} = \frac{\text{Current amount of solvent used in the process}}{\text{Old amount of solvent used in the process}} \quad (1.31)$$

3.4.4 EMISSION FACTOR CALCULATIONS

Part of the appeal of the emission factor method is its simplicity. To calculate emissions, the activity and emission factor are multiplied. Corrections for rule effectiveness, rule penetration, and control efficiency, and seasonal adjustments or point source emissions still need to be applied. The calculation for emissions is shown in Equation 1.3-2:

$$\text{Emissions} = \frac{\text{Activity}}{\text{Level}} * \frac{\text{Uncontrolled Emission Factor}}{\text{Factor}} \quad (1.3-2)$$

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4

ADJUSTMENTS TO EMISSION ESTIMATES

In the previous section, emission estimation methods were discussed. This section presents general procedures for refining area source emissions estimates to account for point sources, emission controls, pollutant speciation, spatial and temporal allocation of emissions, and general information about projection of emissions estimates. In the simplest case of emissions estimation, area source emissions are estimated using Equation 1.3-2. In other cases, an emissions model may be used, which incorporates calculation procedures to account for some or all of the factors noted above.

Adjustments are needed to make emissions estimates reflect the local conditions that differ in some way from the average conditions on which an emission factor is based or for which an estimation model is designed. Adjustments may compensate for regional meteorologic differences or seasonal activity differences, or they may be used to weight the allocation of emissions to subdivisions of an area such as counties in a region or grid cells in a modeling domain. Emission estimates will sometimes need to be corrected to reflect emission controls or to show the effect of projected growth.

For maximum flexibility, it is desirable to perform these adjustments in separate, independent steps. This facilitates the ability to calculate emissions for different scenarios (e.g., different levels of control, different species profiles). Keeping each step separate allows one factor to be easily changed while all others are held constant. Inventory documentation also benefits from clear, discrete calculations using factors that are each well defined.

4.1 ACCOUNTING FOR POINT SOURCE EMISSIONS

When a point source inventory and an area source inventory estimate emissions from the same process, there is the possibility that emissions could be double counted. For example, emissions from large dry cleaning establishments may be included in the point source inventory. Emissions from small dry cleaners (below some specified cutoff) may be treated as an area source. The area source inventory must be adjusted to avoid double counting.

Certain area sources such as consumer solvent use and architectural surface coating do not require any point source adjustments, but many other source categories should at least be examined for possible double counting. Examples of area sources that may share processes with point sources are shown in Table 1.4-1.

TABLE 1.4-1

SOURCE CATEGORIES THAT MAY HAVE AREA AND POINT SOURCE CONTRIBUTIONS^a

Process	Category Examples	AMS Source Category Codes
Fuel Combustion		
	Electric Utilities	21-01-
	Industrial Fuel Combustion	21-02-
Industrial Processes		
	Chemicals and Allied Products	23-01-
	Metals Production	23-03- 23-04-
	Rubber and Plastics	23-08-
	Oil and Gas Production	23-10-
	Mineral Processes, Mining and Quarrying	23-25-
	Construction/Demolition	23-11-
	Machinery	23-12-
	Petroleum Refining	23-06
Solvent Utilization		
	Graphic Arts	24-25-
	Surface Coating	24-01-
	Dry Cleaning	24-20-
	Degreasing	24-15-

TABLE 1.4-1**(CONTINUED)**

Process	Category Examples	AMS Source Category Codes
Storage and Transport		
	Petroleum and Petroleum Product Storage and Transport	25-01- 25-05-
	Organic Chemical Storage and Transport	25-10- 25-15-
	Inorganic Chemical Storage and Transport	25-10- 25-15-
	Rail and Tank Car Cleaning	25-**-***-900
Waste Disposal, Treatment and Recovery		
	Commercial and Industrial Incineration	26-01-
	Industrial and Municipal Open Burning	26-10-
	Wastewater Treatment	26-30-
	TSDFs	26-40-
	Scrap and Waste Materials	26-50-
	Landfills	26-20-
Miscellaneous Sources		
	Cooling Towers	28-20-
	Health Services	28-50-
	Firefighting Training	28-10-035-
	Engine Testing	28-10-040-

^a Common examples based on AIRS source codes are listed. Any category could include point sources. Coordination between point and area source inventory developers is required to ensure that all sources are properly accounted for.

If the potential for double counting exists, the area source emission estimate must be adjusted. This is best done by subtracting the point source activity from the total activity as shown in Equation 1.4-1:

$$\text{Area Source Activity} = \text{Total Activity of Source Category} - \text{Sum of Point Source Activity} \quad (1.4-1)$$

From Equation 1.4-1, area source activity represents whatever activity is not accounted for as point source activity. Area source activity is estimated by subtracting out the point source activity total.

Where area source emissions are calculated using employment data, the employment at the point sources should be subtracted from the inventory region employment to give the area source employment. If the exact employment at the point sources is unknown, it can be approximated using *County Business Patterns*.^a Details of this procedure are provided in the relevant area source category sections of this volume.

If the resulting area source activity is less than zero, the point source data should be reviewed for errors and any errors found should be corrected. If area source activity is still less than zero, then the area source activity is assumed to be equal to zero. The geographic area for which this adjustment is done may have an effect on the results. Subtracting state totals is less likely to produce negative results than subtracting at the county level, for example, especially if data were collected at the state level. Often, the county-level data used for each source has been allocated to counties using a surrogate. Thus, the county-level data are less reliable.

Sometimes the activities used to calculate point and area source emissions for the same category are not similar. Emissions from area sources are often estimated using surrogate activity factors, such as population, while for the comparable point sources direct measurement or direct activity applied to several emission factors may be used. The area source emission factor may also be combined with activity data in order to estimate total uncontrolled emissions (for point as well as area sources). This results in emissions estimates for total uncontrolled emissions (developed using the area source emission factor) plus the emissions calculated for the point sources using point source methods. In these cases, total and point source uncontrolled emissions can be used to estimate the contribution of uncontrolled area sources as Equation 1.4-2 shows:

$$\text{UAE}_A = \left[\begin{array}{c} \text{Total} \\ \text{Uncontrolled} \\ \text{Emissions} \end{array} \right] - \left[\begin{array}{c} \text{Uncontrolled} \\ \text{Point Source} \\ \text{Emissions} \end{array} \right] \quad (1.4-2)$$

^a See the most recent publication, which can be obtained from the U.S. Bureau of Census, Department of Commerce, Washington, D.C.

where:

UAE_A = uncontrolled area emissions of pollutant A

Please note that this equation takes into account the difference in the level of control between area and point sources. When activity levels are adjusted for their point source components before area source emissions are calculated, it is unnecessary to subtract out point source controls.

4.2 CONTROL, RULE EFFECTIVENESS, AND RULE PENETRATION

Inventories performed before 1987 assumed that regulatory programs would be implemented with full effectiveness, achieving all required or intended emissions reductions and maintaining the reduction level over time. However, experience has shown regulatory programs to be less than 100 percent effective for most source categories in most areas of the country.

Control efficiency (CE), rule effectiveness (RE), and rule penetration (RP) are applied to an area source emission estimate if regulations are in place that affect any of the individual sources within a source category. CE, RE, and RP are used to estimate the effect of controls being applied in an imperfect world. Sources that are completely uncontrolled do not have CE, RE, or RP applied.

4.2.1 CONTROL EFFICIENCY

CE is the emission reduction efficiency, and is a percentage value representing the amount of a source category's emissions that are controlled by a control device, process change, or reformulation. For area sources in particular, controls can vary widely. CE values for area sources represent the weighted average control for the category.

4.2.2 RULE EFFECTIVENESS

RE is an adjustment to the CE to account for failures and uncertainties that affect the actual performance of the control. For example, control equipment performance may be adversely affected by age of the equipment, lack of maintenance, or improper use. A default value of 0.80 for RE is recommended by EPA if information cannot be acquired to substantiate the true value of RE.

Although RE reflects the assumption that regulations are rarely 100 percent effective, when controls are irreversible process changes or reformulations, RE can be set to 100 percent. RE can be developed for area sources in the following ways:

- Assume an 80 percent default value for all sources;
- Perform a survey (with EPA approval for SIP inventories) to determine a source-specific RE value; or
- Use a Stationary Source Compliance Division (SSCD) (now Office of Enforcement and Compliance) Protocol Study specific to a category and geographic area, and in accordance with SSCD procedures to calculate RE.

Alternative methods of developing RE values should be approved by the statutory authority guiding or dictating the inventory requirement.

4.2.3 RULE PENETRATION

RP is the percentage of the area source category that is covered by the applicable regulation or is expected to be complying to the regulation. The RP value can be based on a percentage of the source that is regulated, a cutoff level, or regulation of an activity. Both RE and RP are applied to entire source categories when calculating area source emission estimates.

RP is a measure of the extent to which a regulation covers a source category. For example, regulations on gasoline underground tank filling may apply only to stations above a specified size cutoff, or the regulation may apply to facilities built after a certain date. Rule penetration is calculated by Equation 1.4-3:

$$\text{Rule Penetration} = \frac{\text{Uncontrolled Emissions Covered by Regulation}}{\text{Total Uncontrolled Emissions}} * 100 \quad (1.4-3)$$

For example, if a rule only affects sources built since 1987 and 20 percent of the facilities have been built since that time, then RP is equal to 0.2. Default values are not feasible for RP because it is highly category- and location-dependent.

4.2.4 EXAMPLE SHOWING APPLICATION OF CE, RP, AND RE

Area source controls are less common than point source controls except in a few large urban areas. Area sources that are most likely to be controlled are:

- Industrial surface coating;

- Gasoline marketing (Stage I);
- Cutback asphalt use;
- Surface cleaning;
- Autobody refinishing;
- Automobile refueling (Stage II);
- Architectural surface coating;
- Open burning; and
- Printing processes.

If an area source is controlled, emissions are calculated by Equation 1.4-4:

$$CAE_A = (EF_A)(Q) [(1 - (CE)(RP)(RE)] \quad (1.4-4)$$

where:

CAE_A = Controlled area source emissions of pollutant A
 EF_A = Uncontrolled emission factor for pollutant A
 Q = Category activity
 CE = % Control efficiency/100
 RP = % Rule penetration/100
 RE = % Rule effectiveness/100

Alternatively, in the case where only uncontrolled area source emissions are known, such as those where the point source correction has been made, Equation 1.4-5 can be used to calculate controlled area source emissions:

$$CAE_A = (UAE_A) [(1 - (CE)(RP)(RE)] \quad (1.4-5)$$

where:

UAE_A = Uncontrolled area estimate of pollutant A

The values for RE and RP need to be known to perform these calculations.

In practice, Equations 1.4-4 and 1.4-5 are difficult to apply in some situations. CE is not always clear-cut and must sometimes be calculated. Table 1.4-2 lists example sources where special consideration is required when calculating area source VOC emissions because of difficulty determining CE and, in some cases, RP, as well. CE, RE, and RP for these source categories are discussed in their respective methodology chapters. Where CE, RE, and RP for a source category require special consideration, this is also discussed in its respective methodology chapter.

TABLE 1.4-2
EXAMPLES OF AREA VOC SOURCES REQUIRING SPECIAL
CONSIDERATION WHEN CALCULATING EMISSIONS

Special Calculation Issue	Example Sources
VOC content control device by regulation	Architectural Surface Coating Industrial Surface Coating Autobody Refinishing Commercial/Consumer Solvent Use Emulsified Asphalt Paving
Activity is banned	Cutback Asphalt Paving Open Burning
Controls reduce consumption, not emission rate	Degreasing (Surface Cleaning)
Emission factor based on control device emissions	Gasoline Stage I Marketing (Submerged Balance Fill Method) Automobile Refueling (Stage II) Landfill Flares

4.2.5 TEMPORAL ADJUSTMENTS

Temporal adjustments are made because of seasonal differences in the rate of emissions or activity, or to apportion emissions to a particular season, day or hour. The need to make these adjustments will be based on the needs for the particular inventory. A SIP ozone inventory, for instance, will need to have emissions either calculated for just one typical ozone season day, or have emissions corrected for the season, and apportioned for the typical ozone season day.

The best method to get the most accurate emission estimates for an inventory day or period is to directly collect the emission information or the activity data for that particular time period.

Because area source inventories rarely have sufficient resources to do this detailed level of data collection, the preferred method for temporal adjustment is the one that produces the most accurate activity or adjustment factors for a source category reflecting the inventory time period and locality. If a survey is being used to collect emission or activity data, then the questionnaire can also be used to gather information about working hours and production for the inventory time period. Other less direct sources of information, such as state or national business and labor statistics, or Department of Energy statistics, may also be used, but may not reflect local variations. If no information is available that is recent or representative of local conditions, then national average adjustment factors can be used. These approaches are discussed further in the following section.

4.2.6 SEASONAL ACTIVITY

Source activity for many categories fluctuates on a seasonal basis. Because emissions are generally a direct function of source activity, seasonal changes in activity levels should be examined. For all categories, seasonal variations in activity must be considered if seasonal or daily emissions are to be estimated. A VOC inventory covers an ozone season typically defined as the months of June, July, and August. A carbon monoxide (CO) season will be the coldest months of the year, December, January and February. The months covered by an ozone or CO season may vary by region. Emission factors for some categories may also be dependent on seasonal variables. The type of information needed to calculate emissions depends on the source category and the desired temporal resolution of the emissions estimates.

Some operations, such as architectural surface coating, might be more active in the warmer months in some inventory regions because of the warmer weather, and may be more active because there are more hours of daylight for the activity. In some cases, a activity may take place *only* during the warmer months. On the other hand, some sources, because of summer vacation shutdowns or decreased demand for the product, may be less active during the ozone season. Such sources (e.g., residential heating), may exhibit greater activity in colder months and, thus, emissions are greater for a typical CO season. However, many sources, particularly industrial facilities, will show no strong seasonal change in activity and little adjustment will need to be made to estimate the seasonal emissions component.

An important seasonal variable is temperature. Sources such as petroleum product handling and storage operations, breathing losses from fixed-roof tanks, and loading of rail tank cars, tank trucks, and marine vessels are significantly influenced by temperature changes. Empirical formulas and reference tables can be found in *AP-42* to calculate these losses, and the TANKS model can be used to estimate emissions from fixed-roof storage tanks under varying temperatures.

There are several other source categories with emissions that are affected by variations in temperature for which temperature-dependent equations are not currently available. EPA is currently investigating methods for use in future inventories to estimate these emissions that will

reflect the effects of both temperature and vapor pressure. For more information, contact the EPA Emission Factor and Inventory Group at (919) 541-4676.

4.2.7 ACTIVITY DAYS PER WEEK

If daily emissions are to be calculated, the activity days per week must be identified so they can be used in the emission equation. For most industrial sources, the number of days per week is five. For many consumer or commercial activities, six or seven days are generally used. Table 1.4-3 shows the activity days per week for some common area source categories.

4.2.8 CALCULATIONS FOR TEMPORAL ADJUSTMENTS

Seasonal or percent period throughput, discussed above, is required to calculate daily or seasonal emissions. Of course, the best situation is to obtain activity data that are specific for the season of interest.

The best way to calculate daily or seasonal emission estimates is to obtain activity data that are specific for the season of interest. However, if this is not possible, an estimate of seasonal activity can be calculated using an adjustment factor applied to the annual activity. In cases where a surrogate activity factor is used to calculate emission estimates, an adjustment factor is applied to the calculated annual emission estimates. Factors for making seasonal adjustments may be expressed as fractions, percentages, or ratios. Thus, an adjustment factor is typically expressed as:

- A fraction: seasonal activity factor (SAF) representing the amount of annual activity or emissions within a period (such as $4/12 = 0.33$);
- A percentage: percent period throughput, the percent value of the SAF for a period (such as $0.33 * 100 = 33$); or
- A ratio: seasonal adjustment factor, the ratio of seasonal activity or emissions to average period activity or emissions (such as $0.33/0.25 = 1.33$).

For example, if a VOC source category has one third more emissions during the 3-month ozone season than the rest of the year, the SAF would be 0.33, the percent period throughput would be 33 percent, and the seasonal adjustment factor would be 1.33. If annual estimated emissions are 2,000 tons of VOCs, the calculation for the ozone season using a SAF (0.33) would be as shown in Equation 1.4-6:

$$\begin{aligned} AE_{\text{VOC},O} &= 0.33 * 2,000 \text{ tons VOCs} \\ &= 666 \text{ tons VOCs} \end{aligned} \quad (1.4-6)$$

TABLE 1.4-3

**AREA SOURCE SEASONAL ACTIVITY FACTORS AND
DAYS PER WEEK FOR THE PEAK OZONE AND CO SEASONS**

Area Source	Seasonal Activity Factors		Activity Days Per Week
	Ozone	CO	
Gasoline Service Stations			
Tank Trucks in Transit	Seasonal variations in throughput vary from region to region. Use average temperature for a summer day where appropriate.		6
Tank Truck Unloading (Stage I)			6
Vehicle Fueling (Stage II)			7
Storage Tank Breathing Losses			7
Solvent Usage			
Degreasing	0.25		6
Dry Cleaning	0.25		5
Surface Coatings			
Architectural	0.33		7
Auto Refinishing	0.25		5
Other Small Industrial	0.25		5
Graphic Arts	0.25		5
Cutback Asphalt	Refer to local regulations and practices		
Pesticides	0.33		6
Commercial/Consumer	0.25		7
Waste Management Practices			
POTWs	0.35		7

TABLE 1.4-3

(CONTINUED)

Area Source	Seasonal Activity Factors		Activity Days Per Week
	Ozone	CO	
Hazardous Waste TSDFs	0.30		7
Municipal Landfills	0.25		7
Stationary Source Fossil Fuel Use			
Residential	0.08	0.43	7
Commercial/Institutional	0.15	0.35	6
Industrial	0.25	0.25	6
Solid Waste Disposal			
On-site Incineration	0.25	0.25	7
Open Burning	Refer to local regulations and practices	Refer to local regulations and practices	7
Structural Fires	0.20	0.33	7
Field/Slash/Prescribed Burning	Refer to local regulations	0.10	7
Wildfires	Refer to local fire conditions	0.05	7

where:

$$AE_{VOC,O} = \text{Area emissions of VOCs for ozone season}$$

The calculation using a percent period throughput factor would be quite similar as shown in Equation 1.4-7:

$$\begin{aligned} AE_{VOC,O} &= 33/100 * 2,000 \text{ tons VOCs} \\ &= 666 \text{ tons VOCs} \end{aligned} \quad (1.4-7)$$

However, the calculation using the seasonal adjustment factor must take the number of months into account, as shown in Equation 1.4-8:

$$\begin{aligned} AE_{VOC,O} &= 1.33 * (3/12 * 2,000 \text{ tons VOCs}) \\ &= 666 \text{ tons VOCs} \end{aligned} \quad (1.4-8)$$

Further adjustments to the emission estimate would be made to calculate a daily emission estimate. To determine daily emission estimates from facilities with uniform annual production or throughput, the Equation 1.4-9 can be used:

$$\begin{aligned} \text{Typical Annual} \\ \text{Emissions} \\ \text{per day} \end{aligned} = \frac{\begin{aligned} \text{Emissions} \\ \text{per year} \end{aligned}}{\left(\begin{aligned} \text{Operating} \\ \text{days/week} \end{aligned} \right) \left(\begin{aligned} \text{Operating} \\ \text{weeks/year} \end{aligned} \right)} \quad (1.4-9)$$

For sources that require a seasonal adjustment, seasonal daily emission estimates can be calculated as in Equation 1.4-10:

$$\begin{aligned} \text{Typical Seasonal} \\ \text{Emissions} \\ \text{per day} \end{aligned} = \frac{\begin{aligned} \text{Emissions} \\ \text{per season} \end{aligned}}{\left(\begin{aligned} \text{Operating} \\ \text{days/week} \end{aligned} \right) \left(\begin{aligned} \text{Operating} \\ \text{weeks/season} \end{aligned} \right)} \quad (1.4-10)$$

An example calculation of a peak ozone season daily emission estimate where the peak ozone season is the 3 months of summer, is shown in Equation 1.4-11:

Example:	Annual Emissions	= 1.3 tons of VOCs
	SAF	= 0.28 (28 percent)
	Peak Ozone Season	= 0.25 (25 percent or 3 months)
	Operating Schedule	= 6 days per week, 52 weeks per year

$$\text{Typical Ozone Season Daily Emissions} = \frac{\left(\frac{1.3 \text{ tons}}{\text{year}} \right) \left(\frac{2,000 \text{ lb}}{\text{ton}} \right) \left(\frac{0.28}{0.25} \right)}{(6 \text{ days/week}) (52 \text{ weeks/year})} = 9.3 \text{ lb VOCs per day} \quad (1.4-11)$$

Table 1.4-3 shows default SAF values for some area source categories.

In some cases the season affects the calculation of emission factors, rather than, or in addition to, activity factors. The volatility of VOCs depends partly on temperature so that the temperature relationship must be included in emission factor calculation.

It is important to bear in mind that although temperature enters into many different calculations, the temperature used may vary depending on the source category. For gasoline distribution emission factors, the temperature of the product--not the ambient temperature--is the input variable. However, as an example, the evaporative losses from automobile gas tanks (usually included in the mobile sources) may use temperatures closer to ambient. Therefore, although some coordination of seasonal variables is needed, the values used may not necessarily be the same for all area sources in the inventory region.

If an agency wishes to develop its own SAF, it must establish the peak period (in number of months) for its area, choose the inventory year for its investigation, identify the sources within the source category under consideration, and develop an approach for collecting seasonal activity information for these sources. Approaches include questionnaires, researching more recent SAFs, or researching trade groups, or labor or economic statistics.

A questionnaire for collecting SAF information should request data for the inventory year, including annual process activity data, peak period activity data, and, if possible, the emission factor or estimate. The agency can then develop its own seasonal activity factor for the source category for any inventory season using the following equation:

$$\text{SAF} = \left[\frac{\text{Peak Period Activity}}{\text{Annual Activity}} \right] * \left[\frac{\text{Months of Inventory Season}}{\text{Months of Peak Activity}} \right] \quad (1.4-12)$$

This SAF can then be applied to annual activity information to estimate seasonal emissions, just as *AP-42* emissions factors are applied to estimate annual emissions. The SAF can be converted to the percent period throughput (PPT) by multiplying by 100.

A study to improve and augment existing temporal allocation factors using data from more current data sources has been completed by EPA's Office of Research and Development (EPA,

1994). This study developed new temporal allocation factors and amended previous allocation factors for a significant number of point source categories to better represent the intended source categories. Information was gathered from the literature, state and local regulatory air pollution agencies, and other government and private organizations. In many cases, source test data were used to develop the new or improved temporal allocation factors files. When the point source process and the area source category are well matched, point source factors would be suitable to use for an area source emission inventory.

The report (EPA, 1994) describes all of the available data in detail. A temporal allocation factor file, based on the results of the study, is available from the Emissions Characterization and Prevention Branch, Research Triangle Park, North Carolina (phone: (919) 541-4593). Temporal allocation factors for seasonal, weekday/Saturday/ Sunday and hourly periods are recorded for most AIRS AFS SCCs and AIRS AMS area source category codes.

These data may be used as default factors for temporal allocation when no local data are available. For the most part, the area source factors represent temporal allocation factors that were derived for the 1985 National Acid Precipitation and Assessment Program (NAPAP) national emissions inventory.

Labor and economic statistics can also be used to develop default temporal allocation factors. The statistics are published on varying temporal resolutions: seasonally, monthly, and weekly. Data may be supplemented by industry surveys for further temporal resolution to an hourly basis. The basic assumption is that operating or economic statistics are surrogate indicators of industrial processes releasing pollutants. For example, the number of hours worked by employees or the industry's production rate are assumed to be directly related to that industry's potential emissions during that time frame.

The following data sources may provide sufficient information to support development of temporal allocation factors:

- Business and labor statistics data;
- Department of Energy data pertaining to production/consumption from various energy industries;
- State source test reports;
- State stationary source operating schedule data;

- Waste-to-energy data;^a
- *Business Statistics*;^b
- *Employment and Earnings*;^c and
- *Commodity Research Bureau Year Book*.^d

4.3 SPATIAL ALLOCATION

Spatial allocation factors can be applied to the activity levels used to calculate emission estimates, or the emission estimates themselves. An instance when activity may need to be allocated to a smaller geographic area would be when state-level gasoline sales need to be apportioned to the county level. Spatial allocation of emissions estimates is done when the emissions need to be assigned to a more specific and smaller area. This may need to be done when using the information from a base year SIP inventory for an air quality model that needs gridded emissions data, or when activity data apply to a larger area than that needed for the inventory. The techniques for allocating activity and emissions are typically the same for a particular source category and emissions estimation method.

Area source inventories are often prepared for state or county geographical extents. In some cases, it may be desirable to allocate these emissions to smaller individual geographic areas, either subsections of a county or grid cells for use in a model. The amount of effort required to implement this resolution will vary depending on the type of source. Emissions that have been estimated by an individual facility may be reported to within a fraction of a kilometer in the existing inventory; hence, assigning emissions from these sources to the appropriate grid cell is simple.

By contrast, spatial resolution of more diffuse area source emissions requires substantially more effort. Two basic methods can be used to apportion area source emissions to grid cells. The most accurate (and resource-intensive) approach is to obtain area source activity level data directly for each grid cell. This information is possible to collect when the activity data are of a

^a Found in the annual *Resource Recovery Yearbook, Directory and Guide*, Governmental Advisory Associates, Inc., New York, New York.

^b Obtained from the Bureau of Economic Analysis, U.S. Department of Commerce, Washington, D.C.

^c Obtained from the Bureau of Labor Statistics, U.S. Department of Labor, Washington, D.C.

^d Obtained from the Commodity Research Bureau, Chicago, Illinois.

type that can be directly assigned to a specific geographic area. Examples of these types of activity data would be population when detailed census data are available, or land use that can also be assigned to grid cells. This approach is the preferred approach, when it can be used. The alternative (and more commonly employed) approach is to apportion the county-level emissions from the existing annual inventory to grid cells using representative apportioning factors for each source type.

This latter approach requires:

- Identification of a spatial surrogate indicator of emission levels or activity such as population, census tract data, or type of land use for each grid cell that is appropriate for the source category;
 - A surrogate apportioning factor takes the place of the actual activity level, but is assumed to be a reasonable indicator of the actual activity level.
- Creation of apportioning factors based on the distribution of these spatial surrogates; and
- Application of these factors to the county-level emissions.

These steps will yield estimates of emissions from that source category by grid cell. The process can also be applied to state or regional activity or emissions to yield activity or emissions at the county or subcounty level. The major assumption underlying this method is that emissions from each area source behave spatially in the same manner as the spatial surrogate indicator. In developing spatial apportioning factors, the agency should emphasize the determination of accurate factors for the more significant sources. The purpose of the inventory and the capabilities of the agency may also need to be considered when choosing an apportioning method. For most large urban areas, local planning agencies can provide the agency with detailed land use or population data, or in some cases employment statistics at the subcounty level; these data can be used to spatially apportion most of the area source emissions in the inventory.

A Geographical Information System (GIS) can be a useful tool in handling spatially distributed data. A GIS uses sophisticated computer technology to store, retrieve, analyze, update, and display spatially arranged data (maps). This type of system can locate each point source, define the boundaries around each area source, and map road networks. Map coverages are available in digital formats from transportation departments, tax offices, planning/zoning offices, and emergency response agencies. Information stored in a GIS can be the most direct method of spatially allocating activity data and may allow the use of more detailed surrogates that would be

too labor-intensive to use without a GIS. In most cases, using a GIS with good quality map coverages and well-chosen surrogates will be the preferred spatial allocation method.

Further information about the potential applications of the GIS technologies in emissions inventory preparation can be obtained from the Air Quality Modeling Group of the EPA Office of Air Quality Planning and Standards (OAQPS) and the EPA Office of Research and Development (ORD), both in Research Triangle Park, North Carolina; local colleges or universities with geography, civil engineering, or natural sciences departments; state and local land/resource management agencies or environmental protection agencies; and private organizations that provide mapping services.

Commonly used spatial surrogate indicators include land use parameters, employment in various industrial and commercial sectors, population, and dwelling units. Different surrogate indicators may be used to apportion emissions for the various area source categories depending on which of the available indicators best describes the spatial distribution of the emissions. EPA guidance and good engineering judgment should be used to select appropriate indicators for apportioning area source emission totals. Local authorities should be contacted to verify the applicability of the source category/spatial surrogate indicator pairings for a particular inventory region.

The table in Example 1.4-1 lists example spatial allocation surrogate indicators for area source categories as utilized in various urban areas. These indicators could be used to spatially apportion emissions from these source types in the absence of more detailed or locally specific data; however, the agency should make a special effort to choose spatial surrogate indicators for the various source categories that accurately reflect the distribution of activity for those sources in the inventory region. Other references that contain useful information for developing spatial resolution for some specific source categories are:

- *Census of Business Selected Services Area Statistics* (for county-level gasoline handling source categories);^a and
- *Sales of Fuel Oil and Kerosene* (for state-level commercial and institutional fuel combustion).^b

Other resources, which will be addressed in detail below, include land use patterns (from maps and/or computerized databases) and Census Bureau demographic statistics by traffic zone or census tract. Planning, land use, and transportation models are already in use in many regions, and can provide the agency with much of the data necessary to allocate emissions. Local agencies and metropolitan planning organizations should always be contacted during the

^a Obtained from the U. S. Department of Commerce, Bureau of the Census, Washington, D.C.

^b Obtained from Mineral Industry Surveys, Bureau of Mines, Washington, D.C.

Example 1.4-1**EXAMPLE SPATIAL ALLOCATION SURROGATE INDICATORS FOR SELECTED AREA SOURCE CATEGORIES**

Emissions Category	Surrogate Indicators
Residential fuel combustion	Housing
Commercial/institutional fuel combustion	Urban land use
Industrial fuel combustion	Urban land use
Gasoline marketed	Population, VMT
Unpaved roads	County area, land use
Unpaved airstrips	County area, airport location
Forest wildfires	Composite forest
Managed burning--prescribed	Composite forest
Agricultural operations	Agricultural land use
Structural fires	Housing
Degreasing	Population, employment
Dry cleaning	Population, employment
Graphic arts/printing	Population, employment
Rubber and plastic manufacturing	Population, employment
Architectural coating	Population, employment
Auto body repair	Population, employment
Motor vehicle manufacturing	Population, employment
Paper coating	Population, employment
Fabricated metals	Population, employment
Machinery manufacturing	Population, employment

Example 1.4-1

(CONTINUED)

Emissions Category	Surrogate Indicators
Furniture manufacturing	Population, employment
Flat wood products	Population, employment
Other transportation equipment manufacturing	Population, employment
Electrical equipment manufacturing	Population, employment
Ship building and repair	Water proximity, employment
Miscellaneous industrial manufacturing	Population, employment
Miscellaneous solvent use	Population, employment
Publicly owned treatment works (POTWs)	Population, employment
Cutback asphalt paving operation	Population, VMT
Fugitive emissions from synthetic organic chemical manufacturing	County area, employment
Bulk terminal and bulk plants	Population, employment
Fugitive emissions from petroleum refinery operations	Population, employment
Process emissions from bakeries	Population, employment
Process emissions from pharmaceutical manufacturing	Population, employment
Process emissions from synthetic fibers manufacturing	Population, employment
Crude oil and natural gas production fields	Population, employment
Hazardous waste treatment, storage, and disposal facilities (TSDFs)	Population, land use

inventory planning process to determine what planning models are being utilized and how the data available from these models can be used in the emissions inventory effort. Trying to independently develop all the necessary information that should be available from local planning boards requires much redundant effort on the part of the agency. Additionally, any subsequent conclusions drawn from the inventory might likely be challenged if there is inconsistency with other information available to the public.

4.4 APPLYING GROWTH FACTORS FOR PROJECTIONS

General projection issues for inventories are discussed in Volume I of this series.

Area source projections can be made using local studies or surveys or through surrogate growth indicators, such as Bureau of Economic Analysis (BEA) data, to approximate the rise or fall in indicators activity. The most commonly used surrogate growth indicators are those parameters typically projected by the local metropolitan planning organization (MPO) such as population, housing, land use, and employment. Regardless of the growth indicator employed, the calculation is the same: the ratio of the value of the growth indicator in the projection year to its value in the base year is multiplied by the area source activity level in the base year to yield the projection year activity level.

The EIIP Projections Committee has developed a series of guidance documents containing information on options for forecasting future emissions. You can refer to these documents at <http://www.epa.gov/ttn/chief/eiip/project.htm>.

If activity is not used in emission calculations, which would be the case if base year emissions were measured directly, or material balance methods or mathematical models are used, then a growth factor reflecting the change from the base year to the projection year can be calculated.

The purpose of developing a projection inventory is to either determine the emissions reductions that will be needed to attain air quality standards or to project future compliance. In general, projection year emissions are based on base year allowable emissions, but in certain circumstances, it may be appropriate to use base year actual emissions. For CAAA 15 percent Rate of Progress (ROP) Plans, actual emissions can be used for source categories that are currently subject to a regulation and for which the state does not anticipate subjecting the source to additional regulation, or for source categories that are currently unregulated and are not expected to be subject to future regulations.

Actual emissions are based on a source's actual operating hours, production rates, and control equipment for processes at the source. Allowable emissions are based on the expected future operating rates or throughput and maximum emissions limits. Maximum emission limits may be process-based emissions factors, capture and/or control device efficiencies, or emission rate limits. Emission factor limits and capture and/or control device efficiency limits should take

Example 1.4-2**EXAMPLE GROWTH INDICATORS FOR PROJECTING EMISSIONS
FOR AREA SOURCES**

Source	Growth Indicators	Information Sources
Gasoline marketing	Projected gasoline consumption	MOBILE fuel consumption model
Dry cleaning	Population: retail service employment	Solvent suppliers; trade associations
Degreasing (Cold cleaning)	Industrial employment	Trade associations
Architectural refinishing	Population or residential dwelling units	Local MPO
Automobile refinishing	Industrial employment	BEA
Small industrial surface coating	Industrial employment	BEA
Graphic arts	Population	State planning agencies; local MPO
Asphalt use: Paving	Consult industry	Consult state DOT and industry
Asphalt use: Roofing	Industrial employment; construction employment	Local industry representatives
Pesticide applications	Historical trends in agricultural operations	State department of agriculture; local MPO
Commercial/Consumer solvent use	Population	Local MPO; state planning agencies
POTWs	Site-specific information	State planning agencies
Hazardous waste TSDFs	State planning forecasts	State planning agencies; local MPO
Municipal solid waste landfills	State Waste Disposal Plan	Local MPO; state planning agencies

Example 1.4-2**(CONTINUED)**

Source	Growth Indicators	Information Sources
Commercial/Industrial fuel combustion	Commercial/Institutional employment; population	Local MPO; land use projections
Industrial fuel combustion	Industrial employment (SIC Code 10-14, 50-51); or industrial land use	Local MPO; land use projections; state planning agencies
Construction equipment	Industry growth (SIC Code 16)	Local MPO
On-site incineration	Based on information gathered from local regulatory agencies	Local agencies; state planning agencies; local MPO
Fires: Managed burning agricultural field burning, frost control (Orchard heaters)	Areas where these activities occur	U.S. Forest Service, state agricultural extension office
Forest wildfires	Historical average	Local, state, and federal forest management officials
Structural fires	Population	Local MPO; state planning agencies

precedence over emission rate limits when they are available. In determining the maximum emissions limit, existing regulations must be considered in addition to future planned regulations.

A major difference between making area source projections for the basic, county-wide inventory and for a detailed, photochemical inventory is that, in the latter, emission estimates must be resolved at the grid-cell level. This adds a dimension of complexity to the projection effort, since changing growth patterns may require that different apportioning factors be determined for the projection years. Fortunately, in most large urban areas where photochemical models are employed, the local MPO will be able to provide land use maps, as well as detailed zonal projections of employment, population, etc., for future years. Hence, these projections can be used directly, as described above, to determine changes in spatial emission patterns.

If the surrogate indicators used for apportioning certain area source emissions are not projected at a subcounty level, engineering judgment must be used to decide whether spatial distributions of various activities will change enough to warrant the effort of identifying new patterns. Changes may be warranted in rapidly growing areas for the more important area source emitters. For regions where little growth is expected, and especially for minor area sources, the same apportioning factors can be used in baseline and projection inventories.

5

DATA COLLECTION AND MANAGEMENT

Data management comprises data collection, data storage, and updates to the database, as well as the planning and QA/QC of the process. The collection and storage of data, particularly as it applies to area sources, is addressed in this section. The development and implementation of surveys as a data collection method merit particular attention in this section. Inventory QA/QC is addressed in Volume VI of this series, *Quality Assurance Procedures*, and in Volume I of this series, *Introduction to the EIIP*.

5.1 DATA COLLECTION AND STORAGE

5.1.1 DATA RESOURCES

Area source inventory data can come from a number of diverse sources. Surveys and agency pollution files are methods typically used for point sources that may also be useful in collecting data for area source emissions, activity, and control data. Other commonly used area source data resources are U.S. Census Bureau documents such as *County Business Patterns*, *Census of Agriculture*, *Census of Manufactures*, and *Current Industrial Reports*; documents and reports from other federal agencies such as the Energy Information Administration (EIA); locally collected activity information, trade contacts, journals, and databases; and data compilations such as the Frost & Sullivan *Industrial Solvents* report or the *Chemical Marketing Reporter*. Accessing these types of market research reports is discussed below. Sources for inventory procedural guidance include *AP-42* and guidance manuals such as this one. Data sources for source category characterization include EPA reports such as Background Information Documents (BIDs), Control Technique Guidelines (CTG) documents, Locating and Estimating (L&E) documents, emission model manuals, Technical Support Documents (TSDs), Alternative Control Techniques (ACT) documents, and *AP-42*.

Market research reports are one source for information on the past sales of, and future trends in the use of, different products. Occasionally, these reports can be found in a business school library or large university library, but because they can be quite expensive, not many libraries collect them. On-line bibliographic utilities such as Knight Ridder's DIALOG, offer databases containing the full text of market research reports. These databases include Freedonia Market Research, BCC Market Research, and Frost & Sullivan Industrial Solvents.

Some state libraries offer on-line literature search services, and should be able to locate the information needed. If not, information brokers who do literature searches for a fee will be able to help. These services can be found in the telephone directory under the headings "Information Brokers," "Information Processing and Retrieval Systems & Services," or "Information Search and Retrieval."

Rather than purchasing an entire report, the librarian or information broker can retrieve the information needed, usually at a fraction of the cost of the whole report. On-line computer charges for the databases listed above run about \$60.00 per hour plus \$16.00 per item typed or printed out (as of July 1995).

Because charges are usually based on time spent on-line plus the per-item cost, it helps to be as precise as possible in explaining information needs to the librarian or information specialist. Some background on the context of the request (i.e., how the information is to be used) can be very useful and cost-effective.

5.1.2 DATA HANDLING

Typically, the data used for area source emissions estimates are retrieved from a variety of sources. Data collection methods for area sources vary much more than those for point sources. Specific data collection methods and data sources are provided for a number of area source categories later in this volume. Often, data availability (or unavailability) determines the method that must be used to estimate emissions.

If the area source inventory is being prepared by more than one person, coordination is needed to assure consistency of activity data and to avoid duplicating effort. A table showing the area source category, estimation procedure, activity data needed, and activity data source should be prepared. Table 1.5-1 gives an example for a hypothetical ozone inventory. Note that categories may use common activity data; for example, emissions for three source categories can be calculated using population data. Where alternative sources of information exist, the preferred source of information should be identified and used consistently throughout the inventory.

All data collected, regardless of the source, should be documented and logged into a central file. In particular, information gathered over the telephone needs to be well documented in writing, including the date of the call and the names of the participants. These procedures are covered in more detail in the Volume I of this series. It is very important to begin data collection as soon as possible because obtaining data is not always straightforward. If the data are not already published, contacting the right person and then eliciting the information in the required format can take weeks or even months.

TABLE 1.5-1

ACTIVITY DATA EXAMPLE SOURCES FOR AN OZONE INVENTORY

Area Source Category	Estimation Procedure	Activity Data	Source of Activity Data
Commercial/Consumer Solvent Use	Per capita	Population	U.S. Census data
Architectural Surface Coating	Survey	Gallons of paint	Paint manufacturers
Gasoline Distribution	Gasoline consumption	Gallons of gasoline	State Department of Transportation (DOT), State Energy Office
Industrial Surface Coating	Per employee	Employment by SIC	State Labor Department
Surface Cleaning Operations	Per employee	Employment by SIC	State Labor Department
Dry Cleaning Operations	per employee	Employment by SIC	State Labor Department
Automobile Refinishing	Per capita	Population	U.S. Census data
Graphic Arts Facilities	Per employee	Employment by SIC	U.S. Census data
Asphalt Paving	Consumption	Barrels of asphalt	State DOT, paving contractors
Traffic Paints	Consumption	Gallons of paint	State DOT
Agricultural Pesticides Application	Application rate, acres of crops	Crop type by acre, types of pesticides	State Agriculture Office, U.S. Department of Agriculture (USDA)
Commercial Bakeries	Per capita	Population	U.S. Census data

TABLE 1.5-1

(CONTINUED)

Area Source Category	Estimation Procedure	Activity Data	Source of Activity Data
Structure Fires	Per fire	Number of fires	Fire marshall
Municipal Landfills	Statistical models	Tons of refuse, landfill age	State Solid Waste Management Agency
Residential Fuel Combustion	Fuel use	Amount of fuel used	State Energy Office, Energy Information Administration (EIA)
Industrial Fuel Combustion	Fuel use	Amount of fuel used	State Energy Office, EIA
Commercial/Institutional Fuel Combustion	Fuel use	Amount of fuel used	State Energy Office, EIA
Petroleum Vessel Loading/Unloading	Petroleum products loaded/unloaded	Gallons of fuel	Port Authority, Waterborne Commerce
Aircraft Refueling	Aviation fuel consumption	Gallons of fuel	State Energy Office, airports
Wastewater Treatment	Surface impoundment modeling system (SIMS)	Gallons of wastewater and portions of industrial wastewater	Publicly owned treatment works (POTW) operators
Hospital Sterilizers	Per hospital bed	Hospital beds	State Health Department
Forest Fires	Acres burned	Acres burned	State Forester
Breweries	State beer production	Barrels of beer	State Commerce Office, trade groups

TABLE 1.5-1

(CONTINUED)

Area Source Category	Estimation Procedure	Activity Data	Source of Activity Data
Barge, Tank Car, Railcar, Drum Cleaning	Survey	Vessels cleaned, material cleaned out of vessels	Trade groups, drum-cleaning facilities
Medical Waste Incinerators	Survey	Waste incinerated	State Health Department
Asphalt Roofing Kettles	Per square paper	Material throughput	Trade groups
Orchard Heaters	Fuel consumption	Amount of fuel used	Extension agents, agricultural schools
Distilleries	Distilled spirits production	Barrels of spirits	State Commerce Office, trade groups
Agricultural/Slash Burning	Acres burned	Acres burned	Extension agents, agricultural schools
Wineries	Wine production	Barrels of wine	State Commerce Office, trade groups
TSDFs	Survey	Material type, material throughput, treatment type	State Environmental Office
Superfund Sites	Survey	Material type, material throughput, treatment type	State Environmental Office
Open Burning	Survey	Occurrence of burning	State Environmental Office

In addition to those staff members usually responsible for compilation and maintenance of emission inventories, the agency should enlist the services of: (1) a computer programmer or systems analyst to plan the storage and manipulation of the large amounts of emission data needed, (2) an urban or regional planner to analyze land use data from local planning agencies, and (3) a chemist familiar with the various classes of chemicals that will need to be speciated into the individual components.

5.1.3 DATA STORAGE

Computerized data handling is preferable to paper files for large areas with diverse sources. Computerized data handling becomes significantly more cost-effective as the database, the variety of tabular summaries, or the number of iterative tasks increase. In these cases, the computerized inventory requires less overall time involvement and has the added advantage of forcing organization, consistency, and accuracy.

Some activities that can be performed efficiently and rapidly by computer include:

- Printing mailing lists and labels;
- Maintaining status reports and logs;
- Calculating and summarizing emissions;
- Performing error checks and other audit functions;
- Storing source, emissions, and other data;
- Sorting and selectively accessing data; and
- Generating output reports.

Phone logs, paper copies of notes, references, and other noncomputerized data should be stored in a project file that allows access by the inventory staff and safety from loss. The inventory staff should be issued notebooks that are used exclusively for the inventory preparation. These notebooks can become a useful history of the inventory process.

Additional data management concerns are discussed in the following sections.

5.1.4 NECESSARY DATA ELEMENTS

The data elements needed for a source category will be determined by the emission estimation method and the information requirements of the inventory. The inventory preparer should check the EPA website (<http://www.epa.gov/ttn/chief/>) for the latest information (codes) available to characterize emission estimates from the source category. A complete list of Source Classification Codes (SCC) can be retrieved at <http://www.epa.gov/ttn/chief/codes/>.

Available codes and process definitions influence and help guide the preparation of emission estimates for a category. Data transfer formats should be taken into account when an inventory preparer plans for data collection, calculation, and inventory presentation. Consistent categorization and coding will result in greater continuity between emission inventories for use in regional and national scale analyses.

5.1.5 SPECIAL ISSUES

For modeling inventories that are more detailed in terms of speciation and spatial or temporal allocation, additional data may need to be collected for assigning emissions to grid cells, for determining temporal distributions, or for selecting the appropriate speciation factors to be assigned to the compound classes. Ideally, emissions data (including speciation information) would be available for each source for each hour of any day selected. In practice, however, this degree of detail is neither necessary nor practical for all sources because of the inordinate amount of effort required to procure such data and because for many sources and applications inclusion of these data would have little effect on the end use of the data.

As a general rule, the maximum degree of source category resolution from the annual inventory should be maintained in the modeling inventory. For example, if separate emissions estimates have been prepared for dry cleaners using perchloroethylene and dry cleaners using petroleum-based solvents, this distinction should be maintained in the modeling inventory because it will permit more accurate speciation of the emissions associated with these sources.

Some area source categories may be treated as point sources in a modeling inventory; other source categories may be represented in both the point and area source inventories depending on the emissions cutoff level used to make this distinction. The agency should be aware of all such distinctions for the existing inventory and may need to institute certain changes to ensure that the modeling inventory meets its objectives.

Projection inventories also require collection of data beyond that needed for a base-year inventory. The primary difference is the need for growth factors and indicators, which are applied to the base-year emissions, as discussed in Section 4.4 of this chapter.

5.1.6 NATIONAL EMISSIONS INVENTORY (NEI) INPUT

If the category emissions data will be transferred to EPA for incorporation into the national criteria and toxics air pollutant inventory, specific data transfer formats are acceptable. The acceptable data transfer format(s) are described and available for download at <http://www.epa.gov/ttn/chief/net/>. The acceptable data transfer formats contain the data elements necessary to complete the data set for use in regional or national air quality and human exposure modeling. The inventory preparer should review the area source portion of the acceptable file format(s) to understand the necessary data elements. The EPA describes its use and processing of the data for purposes of completing the national inventory, in its Data Incorporation Plan, also located at <http://www.epa.gov/ttn/chief/net/>.

5.2 SURVEYS

For some area source categories, a survey of a representative sample of facilities within the source category may be necessary. Although it is beyond the scope of this document to thoroughly address survey and sample design, guidance on conducting area source surveys is provided in Chapter 24 of this volume, *“Conducting Surveys for Area Source Inventories.”*

6

INVENTORY QUALITY AND UNCERTAINTY

The EIIP QA guidance stresses the importance of distinguishing between data quality and uncertainty. Area source emissions estimates tend to be more uncertain than point sources; given this, the data quality can (and should) be high. Inventory data quality is specified in the data quality objectives (DQOs), and is attained by following a prescribed set of QC and QA activities. The details of developing DQOs and QA plans, and QA/QC methods are covered in Volume VI of this series.

The Data Attribute Rating System (DARS) has been developed as a tool to rate emission inventories. A description of the system and the EIIP recommendations for its use can be found in Appendix F of EIIP Volume VI, Quality Assurance Procedures. The following discussion uses the DARS rating system as a way to compare the estimation approaches presented in this chapter and analyze their strengths and weaknesses.

6.1 QA/QC DATA VERIFICATION PROCEDURES FOR AREA SOURCE INVENTORIES

In this section, some QA/QC issues particularly relevant to area sources are discussed. In general, QA/QC procedures for an area source inventory involves (1) data verification to ensure that the information being used is complete, accurate, and current and produces reasonable estimates; (2) checks of data entry to minimize transcription errors when data are entered into an electronic format, and (3) calculation checks to verify that arithmetic errors were not made.

Data verification involves the use of QA procedures at critical stages in the inventory development to ensure that completeness, consistency, double counting, and reasonableness evaluations are conducted. The procedures usually are facilitated by using checklists (see Figure 1.6-1). The QA procedures also should be described in the inventory report. Data validation procedures can be implemented manually or electronically. The QA Plan should state how and when these will be used during the inventory process.

Completeness Checks

Completeness checks are designed to ensure that all emission sources have been represented in the inventory. Manual completeness checks may include comparing the agency's list of area

Inventory Identification _____ Assessed By _____
 _____ Date _____

Provide the information requested along with the corresponding resource document [ref] or data. After completing the checklist, indicate the actions to be taken, deadline for completion, and date the actions are completed.

SOURCE CATEGORY:

Defined before data collection? [ref] _____	Yes	No
Were definitions adhered to during data collection?	Yes	No
Inclusive of all listed pollutants? [ref] _____	Yes	No

POINT SOURCE CUTOFFS:

Identified during data collection? [ref] _____	Yes	No
Documented and reported to people involved in area source inventory?	Yes	No

Report
ID

Date

SURVEY RESULTS:

Was the response rate determined? _____	Yes	No
rate		

Was the percentage of missing information per returned survey estimated?	Yes	No

percent		

EMISSIONS CALCULATIONS VERIFICATIONS:

Were nonreactive VOC emissions excluded from each source category emissions estimates? [ref] _____	Yes	No
EPA recommended estimation methodology used?	Yes	No

FIGURE 1.6-1. INTERNAL SOURCE CATEGORY CONSISTENCY AND ACCURACY CONTROL CHECKS

Emissions calculations checked? _____	Yes	No
checked by _____		
date _____		
Are equations explicitly shown? [ref] _____	Yes	No

REASONABLENESS CHECKS:

Were magnitudes of calculated emissions compared with other source categories? Identify second source reference or reference location of data in file. [ref] _____	Yes	No
--	-----	----

Were magnitudes compared with national/state ranks of source categories?	Yes	No
--	-----	----

_____	_____
compared by	date

Were other inventories and/or national averages compared to AIRS? List other inventories or reference data in master file.	Yes	No
--	-----	----

Were findings reported and documented?	Yes	No
--	-----	----

SOURCE DATA:

Were area source activity data reliability verified using available data sources? _____	Yes	No
verified by _____		
date _____		

Are emissions factor sources documented? _____	Yes	No
where _____		

Are local emission factors within national range? [ref] _____	Yes	No
---	-----	----

Were facilities whose emissions and activity levels are known compared against generic emission factors to check emission factor reasonableness? _____	Yes	No
compared by _____		
date _____		
project file no. _____		

Are assumptions documented for scaling-up source category emissions and seasonal adjustment factor corrections? [ref] _____	Yes	No
---	-----	----

Were point sources subtracted from area source emissions estimates? [ref] _____	Yes	No
---	-----	----

Are point source corrections to area source emission estimates documented in the category calculations? [ref] _____	Yes	No
---	-----	----

Use the worksheet on page 3 of 3 to record the actions to be taken in response to any problems found. Set a deadline for the completion of the action and indicate when the actions are implemented.

FIGURE 1.6-1. (CONTINUED)

INTERNAL SOURCE CATEGORY CONSISTENCY
AND ACCURACY QUALITY CONTROL CHECKS (Continued)

Actions To Be Taken	Deadline	Completion Date

FIGURE 1.6-1. (CONTINUED)

sources with the area source categories shown in Section 2 of this chapter, or comparing with independent listings (local business directories) of facilities by source category to ensure that all the significant types of sources in the metropolitan statistical area (MSA) are included.

Consistency Checks

Consistency checks for data should also be implemented by the agency. Figure 1.6-1 is an example inventory consistency and accuracy checklist. These example consistency checks for a VOC inventory are designed to ensure that: (1) the same geographic area was used for all source categories; (2) only reactive VOCs were counted in the inventory; (3) potential double counting of point and area source categories was taken into consideration; and (4) the use of emission factors, units of measurement, year(s) of data and information, and apportioning and distribution techniques were consistent. The agency's plan to implement these checks should be included in the QA Plan.

Double Counting

An important data verification step is to ensure that double counting of emissions does not occur in the inventory. Double counting can occur because of overlaps between point and area source inventories, and overlaps in area source groups. Inventory preparers should compare their lists of point and area emission sources to see if any emission sources have been inventoried under both point and area inventory tasks. If the emissions from a process at a facility are included in both the point and area inventories, then the area source inventory should be adjusted downward to exclude the emissions calculated for this facility's process in the point source inventory.

Overlaps in area source calculations can be minimized by careful definition of the emission sources covered by each grouping, and an understanding of the processes that take place at a source. For example, a category whose emissions are estimated using material balance may account for 100 percent of the solvent used by a facility. However, some of the solvent may actually be disposed of in wastewater and as solid waste in a landfill. Emissions estimated from the wastewater and landfill categories, then, would include a double counting of the emissions from these solvents.

Further discussion of the correction for double counting can be found in Section 4, *Adjustments to Emission Estimates*, of this chapter.

Reasonableness

The data obtained or calculated for the inventory also should be checked for reasonableness. Reasonableness checks--which should not be confused with consistency checks--are needed to ensure individual data element values and emission estimates fall within reasonable or

acceptable ranges. The primary method to check for reasonableness is the comparison of the data collected with that from similar inventories or inventories from previous years.

The following questions should be considered by agency staff members, peer reviewers, and QA personnel to ensure that all data provided are reasonable:

- Were the data representative of the region being inventoried?
- Is the information up to date? If not, can reliable adjustment factors be found?
- Are data from an appropriate time frame used (e.g., annual, or CO and ozone seasons)?
- Are the collection techniques documented?

Data Entry Errors

Once the data are in the inventory format, individual data elements should be checked for data entry errors. Error checks can be random checks of a small percentage of the entries, with a higher percentage of checks being made if errors are found. All entries should be subject to error checks. Errors to check for will include missing entries, typographical errors, and misassignment of codes.

6.2 QA/QC FOR INVENTORY CALCULATIONS

Calculations should be done with computerized spreadsheets as much as possible to reduce errors. If handwritten calculations are necessary, they should be performed on worksheets or in project notebooks. Calculations should be peer reviewed for accuracy and checked to ensure that all emission and activity factors are used correctly. The agency should identify in the QA Plan (see Section 2, *Inventory Planning*) how the following QC steps will be ensured and who will perform the QA audits:

- Equations are accurately used and are consistent within each method or procedure; if not consistent, a justification is provided;
- Assumptions and engineering judgments used in the calculations are documented and reviewed;
- Correct units are used and unit conversions are accurate;

- Calculations are reviewed for data entry problems, such as transposition of digits and entering of incorrect numbers into calculators or computers;
- Procedures used to record calculations are consistent; and
- Misinterpretation of either the emission factors or their use is not done.

Random selection and duplication of calculations should be an integral part of the QC evaluations. The number or percentage of calculations that should be checked depend on the difficulty and importance of the source and the DQOs. If significant errors are found, the number of checks should be increased. In addition, the process used to derive the calculations should be checked. The frequency of these checks will depend on staff experience, staff size, inventory size, etc.

Another QA audit procedure for calculations is to check that all assumptions and engineering judgments used in the calculations are recorded in the project notebooks. The notebooks should contain all of the calculations used to develop the inventory and should contain the references for the data sources. The auditor should be able to perform QC checks on the calculations solely from the information recorded. If the data are calculated using computers, a hard copy of the program or algorithms used for all calculations and input files should be maintained in the project files.

The use of a computerized system for calculations can facilitate the QA process by assisting in inventory submittal tracking, edit checking, and data and calculation review. Chapter 3, Section 5, of EIIP Volume VI, describes some automated checks and audit tools that can be built-in to spreadsheets or database programs. CHIEF should be checked periodically for new QA information or software.

6.3 UNCERTAINTY IN AREA SOURCE INVENTORIES

Area source emissions are generally held to be highly uncertain and less accurate than point source emission estimates. While both criticisms are somewhat warranted, they are probably overstated in many cases. The first step towards reducing the uncertainty associated with area source emissions is to understand the causes of variability and inaccuracies in area source emission estimates. As this discussion indicates, although some uncertainty is unavoidable in area sources inventories, it can be minimized.

To better understand the sources of uncertainty in area source emissions, it is necessary to identify uncertainties associated with specific aspects of the estimation methods. Basically, three general forms of uncertainty are potentially applicable: variability, parameter uncertainty, and model uncertainty. Table 1.6-1 summarizes the discussion and provides examples of each

TABLE 1.6-1

SOURCES OF UNCERTAINTY IN AREA SOURCE EMISSION ESTIMATES

Source of Uncertainty	Examples	Ways to Minimize
Variability	<ul style="list-style-type: none"> Fluctuation in VOC emissions for pesticide use caused by environmental conditions. Daily/weekly variations in activity (dry cleaner, commercial fuel combustion, individual surface coating, etc.). Seasonal variability in activity (residential fuel combustion). Process or activities included in the category are not uniform (e.g., product formulations vary). 	<ul style="list-style-type: none"> Quantify variability if possible. Make sure averaging time of emission factor and activity are appropriate for temporal scale of inventory. If possible, subdivide category to create more uniform subcategories.
Parameter Uncertainty		
Measurement errors	<ul style="list-style-type: none"> Incorrect response on a survey form. Misclassification of data (e.g., facility in SIC Code group that does not accurately define activities). 	<ul style="list-style-type: none"> QA audits of survey data.
Sampling error	<ul style="list-style-type: none"> Inadequate sample size. Underlying data not normally distributed. 	<ul style="list-style-type: none"> Ensure adequate sample size by increasing response rate or increasing distribution of survey. Consider distribution of data in sample design and statistical analysis.

TABLE 1.6-1

(CONTINUED)

Source of Uncertainty	Examples	Ways to Minimize
Systematic error	<ul style="list-style-type: none"> Inherent bias in a survey (for example, if only largest facilities are surveyed and they do not reflect activities at smaller facilities). Incorrect assumption (such as assuming 100% compliance with rules and ignoring rule effectiveness). 	<ul style="list-style-type: none"> External review of methods and assumptions by a qualified expert on the industry. Make sure that characteristics of source population are understood and accounted for in methods.
Model Uncertainty		
Surrogate variables	<ul style="list-style-type: none"> Use of population or number of employees as surrogate for emission activities that do not correlate to those surrogates. 	<ul style="list-style-type: none"> Use surveys of local sources instead. Develop emission factors based on statistically correlated surrogate.
Exclusion of variables/model oversimplification	<ul style="list-style-type: none"> Potentially a problem for area source estimates based on emission factors or models. 	<ul style="list-style-type: none"> Validate model for specific use if possible (i.e., use model to predict a known value). Avoid use of oversimplified methods if at all possible.

type of uncertainty. More information on uncertainty can be found in EIIP Volume VI, Chapter 4, *Evaluating the Uncertainty of Emission Estimates*.

6.4 VARIABILITY

Uncertainty is often equated with variability, which is the natural fluctuation in the value of a variable. These are nonrandom fluctuations although they may appear random if the causal mechanisms are unknown. Emissions due to the application of pesticides, for example, are highly variable. They are affected by the volatility of the solvents in the pesticide, meteorological conditions, the amount of vegetation sprayed, and the effect of biological organisms (some of which metabolize the pesticide). Pesticide use and other area sources that are affected by biological or other environmental processes are extreme examples of variable sources. However, most sources show some sort of temporal variation because of variability in activity patterns. For example, residential fuel consumption is higher in the winter than in the summer. Commercial or industrial activity may be greater on weekdays than on weekends.

Preferred area source methods should minimize uncertainty due to variability whenever possible. For most sources, the main source variability is in the temporal fluctuations in activity, and is usually greatest on a daily or weekly basis (e.g., weekday versus weekend activity rates). Some sources vary significantly between years, particularly if they are driven by extreme events (spills, for example).

Good area source inventories will minimize the uncertainty due to temporal variability by assuring that factors and activity data match the scale of the inventory. If factors or activity have to be scaled up or down, adjustments must be made that account for temporal variability. Similarly, any other adjustments to the calculation to account for variability should be made.

6.5 PARAMETER UNCERTAINTY

Parameter uncertainty is caused by three types of errors: measurement errors, sampling errors, and systematic errors (nonrandom errors). Measurement errors occur because of the imprecision of the instrument or method used to measure the parameters of interest. Where emissions are measured directly, the measurement error of a particular method is usually known; EPA typically uses the concept of relative accuracy to describe the performance of a measurement method (or device) with respect to a EPA Reference Method. A more common measurement error for area sources occurs from misclassification. For example, area source categories are frequently identified by SIC Code group, and the number of employees or facilities in a particular SIC group are used as the activity data. However, some SIC groups encompass a wide variety of industrial processes and activities, not all of which are emissions sources. For example, the number of office workers at one plant may cause emission estimates to be too high

if the emissions are estimated using a per employee factor. This can be a problem even when a survey is used if the sample design does not account for subpopulations adequately. In addition, facilities are sometimes listed under an incorrect SIC Code or more than one SIC Code may apply. Any of these errors results in misclassification of data and adds to uncertainty about the emissions estimates.

Sampling error is an important factor when one or more of the parameters (i.e., activity, factors, or emissions) are to be estimated from a sample of the population. Although most people recognize the importance of an adequate sample size, obtaining an adequate sample size is often not feasible. Furthermore, sample data are usually used to estimate a mean value from which the population total is extrapolated. This approach assumes that the underlying data are normally distributed--an assumption that is often violated. Again, sampling error can be minimized if proper statistical approaches are used, quality assurance procedures are followed, and sample sizes are adequate and properly obtained.

Systematic (or nonrandom) errors are the most problematic sources of parameter uncertainty because they are the most difficult to detect and reduce. They occur primarily because of an inherent flaw in the data-gathering process or in the assumptions used to estimate emissions. A common way that this happens is if the population to be sampled is not well-defined, and a sample (thought to be random) is actually nonrandom. This is a fairly common problem for certain types of industries. Take, for example, a local survey of solvent use by autobody refinishing shops. One approach would be to develop a list of facilities from business registrations, or other state/local business listings. However, this industry has a very large number of "backyard" operations that are not identified in these official lists. Therefore, any sample that did not recognize this fact would have systematic sampling errors. A solution in this case is to identify retailers or suppliers for the industry.

6.6 MODEL UNCERTAINTY

This type of uncertainty applies to nearly all area sources. A model is a simplified representation of reality. The simplest type of model uses activity multiplied by an emission factor to estimate emissions. More complex computer models such as the Landfill Air Emissions Estimation Model (LAEEM) and the Surface Impoundment Modeling System (SIMS) are also used to estimate emissions. Model uncertainty stems from the use of surrogate variables, exclusion of variables, and oversimplification of processes.

The use of surrogate variables is common in area source methods where population or the number of employees are used as surrogates for emission activities. The uncertainty in using these surrogates is especially high when emissions for a small region (i.e., county or smaller area) are estimated using a national average factor. Local variations in activity are not necessarily accounted for by using population or employment as an activity, and emissions. A

common example is found in large cities that have the corporate headquarters for an industry. The number of employees may be high, but all of the manufacturing may be occurring in other areas.

Per capita emission factors are often an oversimplification of emission processes. An example would be an emission factor developed from national solvent use figures and material balance. If this type of factor is used, recognize that issues like a correspondence between emissions and population or disposal of the product may not have been addressed.

This discussion of uncertainty in area source emissions is by no means exhaustive. More details are provided in the specific area source chapters. EIIP has encouraged the reduction in uncertainty by recommending methods better than per capita or per employee factors wherever possible. Unfortunately, this is not always practical. It is important that inventory preparers recognize the sources of uncertainty, quantify it, and reduce it as much as is practical.

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VOLUME III: CHAPTER 2

RESIDENTIAL WOOD COMBUSTION

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Area Sources Committee
Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

This chapter is one of a series of documents developed to provide cost-effective, reliable and consistent approaches to estimating emissions for area source inventories. Multiple methods are provided in the chapters to accommodate needs of state agencies with different levels of available resources and skills; and different levels of needs for accuracy and reliability of their estimates. More information about the EIIP program can be found in Volume 1 of the EIIP series, *Introduction and Use of EIIP Guidance for Emissions Inventory Development*.

This chapter describes the procedures and recommended approaches for estimating emissions from residential wood combustion. Section 2 of this chapter contains a general description of the residential wood combustion category, and an overview of available control techniques. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation method for residential wood combustion, while Section 5 presents alternative emission estimation techniques. Quality assurance/quality control are discussed in Section 6. Data coding procedures are discussed in Section 7, and Section 8 is the reference section.

Throughout this chapter and other EIIP area source methods chapters, we stress that area source categories should be prioritized by the inventory planners so that resources can be spent on the source categories that are the largest emitters, most likely to be subject to regulations or are already subject to regulations, or require special effort because of some policy reason. Prioritization is particularly important for area source inventories, because in some cases, a difficult to characterize source category may contribute very little to overall emissions and attempting a high quality estimate for that source category may not be cost effective.

EIIP chapters are written for the state and local air pollution agencies, with their input and review. EIIP is a response to EPA's understanding that state and local agency personnel have more knowledge about their inventory area's activities, processes, emissions, and availability of information; and require flexible inventory methods to best use their sometimes limited resources. These EIIP area source chapters are written as a set of options presented to inventory professionals capable of using their own experience and judgement to apply the method that best fits their overall needs and constraints.

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2

SOURCE CATEGORY DESCRIPTION

The area source category of residential wood combustion is defined as wood burning that takes place primarily in woodstoves and fireplaces. Residential wood burning occurs either as a necessary source of heat or for aesthetics. In the 1980's, woodstoves became more popular and fireplaces became standard equipment in houses, townhouses, and some resorts. Residential wood combustion could be a significant contributor of pollution in many areas of the country, particularly in Colorado and states in New England and the Pacific Northwest. Pollutants emitted from residential wood combustion include particulate matter (PM), volatile organic compounds (VOC), hazardous air pollutants (HAPs), nitrogen oxides (NO_x) and carbon monoxide (CO).

2.1 EMISSION SOURCES

The following descriptions of wood-burning devices are derived from *Compilation of Air Pollutants Emission Factors, AP-42* (EPA, 1995a). More information about these sources can be found in the primary references and background documents for the *AP-42* sections pertaining to wood combustion, Chapter 1, Sections 9 and 10.

2.1.1 FIREPLACE TYPES

Fireplaces can be divided into 2 broad categories: (1) masonry (generally brick and/or stone, assembled on site, and integral to a structure) and (2) factory-built (usually metal, installed on site as a package with appropriate duct work).

Masonry fireplaces typically have large fixed openings to the fire bed and have dampers above the combustion area in the chimney to limit room air and heat losses when the fireplace is not being used. Some masonry fireplaces are designed or retrofitted with doors and louvers to reduce the intake of combustion air during use.

Factory-built fireplaces are commonly equipped with louvers and glass doors to reduce the intake of combustion air, and some are surrounded by ducts through which floor level air is drawn by natural or forced convection, heated, and returned to the room. Many varieties of factory-built fireplaces are now available on the market. One general class is the freestanding fireplace, the most common of which consists of an inverted sheet metal funnel and stovepipe directly above the fire bed. Another class is the "zero clearance" fireplace, an iron or heavy gauge steel firebox

lined inside with firebrick and surrounded by multiple steel walls with spaces for air circulation. Some zero clearance fireplaces can be inserted into existing masonry fireplace openings, and thus are sometimes called "inserts." Some of these units are equipped with close fitting doors and have operating and combustion characteristics similar to woodstoves.

Masonry fireplaces usually heat a room by radiation, with a significant fraction of the combustion heat lost in the exhaust gases and through fireplace walls. Moreover, some of the radiant heat entering the room goes toward warming the outside air that is pulled into the residence to make up for that drawn up the chimney. The net effect is that masonry fireplaces are usually inefficient heating devices. Indeed, in cases where combustion is poor, where the outside air is cold, or where the fire is allowed to smolder (thus drawing outside air into a residence without producing appreciable radiant heat energy), a net heat loss may occur in a residence using a fireplace. Fireplace heating efficiency may be improved by a number of measures that either reduce the excess air rate or transfer back into the residence some of the heat that would normally be lost in the exhaust gases or through fireplace walls. As noted above, such measures are commonly incorporated into factory-built units. As a result, the energy efficiencies of factory-built fireplaces are slightly higher than those of masonry fireplaces.

Fireplace emissions are highly variable and are a function of many wood characteristics and operating practices. In general, conditions which promote a fast burn rate and a higher flame intensity enhance secondary combustion and thereby lower emissions. Conversely, higher emissions will result from a slow burn rate and a lower flame intensity. Such generalizations apply particularly to the earlier stages of the burning cycle, when significant quantities of combustible volatile matter are being driven out of the wood. Later in the burning cycle, when all volatile matter has been driven out of the wood, the charcoal that remains burns with relatively few emissions.

2.1.2 WOODSTOVE TYPES

Woodstoves are commonly used in residences as space heaters. They are used both as the primary source of residential heat and to supplement conventional heating systems.

There are five different woodstove categories:

- The conventional woodstove;
- The catalytic woodstove;
- The noncatalytic woodstove;
- The pellet stove; and

- The masonry heater.

Among these categories, there are many variations in device design and operation characteristics.

The conventional woodstove category comprises all woodstoves without catalytic combustors that are not included in the other noncatalytic categories (i.e., noncatalytic and pellet). Conventional stoves do not have any emission reduction technology or design features and, in most cases, were manufactured before 1988. Stoves of many different airflow designs may be in this category, such as updraft, downdraft, crossdraft, and S-flow.

Catalytic woodstoves are equipped with a ceramic or metal honeycomb device, called a combustor or converter, that is coated with noble metals such as platinum and palladium. The catalyst material reduces the ignition temperature of the unburned VOCs and CO in the exhaust gases, thus augmenting their ignition and combustion at normal stove operating temperatures. As these components burn, the temperature inside the catalyst increases to a point at which the ignition of the gases is essentially self-sustaining.

Noncatalytic woodstoves do not employ catalysts but do have emission reducing technology or features. Typical noncatalytic design includes baffles and secondary combustion zones.

Pellet woodstoves are fueled with pellets of sawdust, wood products, and other biomass materials pressed into manageable shapes and sizes. These stoves have active air flow systems and unique grate design to accommodate this type of fuel. Some pellet stove models are subject to the 1988 New Source Performance Standards (NSPS), while others are exempt due to a high air-to-fuel ratio (i.e., greater than 35-to-1).

Masonry heaters are large, enclosed chambers made of masonry products or a combination of masonry products and ceramic materials. These devices are exempt from the 1988 NSPS due to their weight (i.e., greater than 800 kg). Masonry heaters are gaining in popularity as a cleaner burning and heat efficient form of primary and supplemental heat, relative to other types of woodstoves. In a masonry heater, a complete charge of wood is burned in a relatively short period of time. The heat released is stored in the large thermal mass of masonry materials. This "stored" heat is then slowly released to the surrounding area for many hours after the fire has burned out.

2.2 FACTORS INFLUENCING EMISSIONS

2.2.1 PROCESS OPERATING FACTORS

Fireplace and woodstove emissions are highly variable and are a function of many wood characteristics and operating practices. In general, conditions which promote a fast burn rate and a higher flame intensity enhance secondary combustion and thereby lower emissions. Secondary combustion is especially important in wood burning because of the high volatile matter content of wood, typically 80 percent by dry weight. Conversely, higher emissions will result from a slow burn rate and a lower flame intensity. Such generalizations apply particularly to the earlier stages of the burning cycle, when significant quantities of combustible volatile matter are being driven out of the wood. Later in the burning cycle, when all volatile matter has been driven out of the wood, the charcoal that remains burns with relatively few emissions (EPA, 1996).

2.2.2 REGULATORY ISSUES

The Clean Air Act Amendments of 1990 (CAAA) required that all areas in the country achieve the National Ambient Air Quality Standard (NAAQS) for PM_{10} by December 31, 1994. The EPA published technical guidance for reasonably available control measures (RACM) and best available control measures (BACM) for control of particulate matter (PM) from woodstoves to achieve this goal of reducing PM_{10} emissions. Those areas that do not achieve PM_{10} attainment by December 31, 1994, must apply BACM and develop a plan to meet the NAAQS by December 31, 2001. The only exceptions are those areas that were reclassified as serious after 1990; these areas must attain the NAAQS for PM_{10} no later than the end of the tenth calendar year after the area's designation as nonattainment. The BACM requirements include combinations of the following control measures: the use of new technology woodstoves, improvements in wood burning performance (e.g., control of wood moisture content, weatherization of homes), the use of "no burn" days, public awareness and education programs, replacement or installation of gas-burning equipment in fireplaces, and total banning of burning. The use of these BACM will reduce VOC, HAPs, and CO along with PM, for measures that produce more complete combustion of wood; for measures that reduce the occurrence of combustion, NO_x will also be reduced.

Considerations for projecting emissions from residential wood combustion should include the potential applicability of RACM and/or BACM to the inventory region. Projection of emissions should also address the potential for an increase in new homes in the inventory region, since fireplaces are standard in many new homes. The future use of woodstoves is a more complicated issue that is affected by weather patterns, electricity prices, increased public awareness, environmental concerns, and socioeconomic factors.

3

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATIVE METHODOLOGIES

Selection of the appropriate estimation method depends on the relative significance of emissions from this source in the inventory area and the data quality objectives (DQOs) of the inventory plan. Refer to EIIP Volume VI, Quality Assurance Procedures, Sections 2.1 and 2.4 for discussions of inventory categories and DQOs. This section discusses the methods available for calculating emission estimates from residential wood combustion and identifies the preferred emission estimation method. A discussion of the data elements needed for each method is also provided.

3.2 AVAILABLE METHODOLOGIES

The preferred and alternative methods to estimate activity factors for residential wood combustion are as follows:

- Preferred Method: Residential Wood Survey
- Alternative Method: Census Bureau and Energy Information Administration (EIA) Data Method

If an inventory is being prepared only for warm weather months--when wood burning is at a minimum, if not nonexistent--the Preferred Method described below would not be a good use of resources. In this case, the alternative method should be used.

3.3 DATA NEEDS

3.3.1 DATA ELEMENTS

The data elements required to estimate emissions from residential wood combustion depend partly on the method used and the level of detail required in the inventory.

The data elements needed to calculate emissions for this category when using the survey method are:

- Wood burned, in tons;
- Fireplace or woodstove type;
- Information needed for scaling up the inventory information (any or a combination of the following):
 - distribution of rural/urban population in inventory area
 - landuse
 - economic distribution
 - age of residences
- Information on state and local regulations; and
- Degree heating days for inventory area.

The survey should also request information on seasonal variability.

The data elements needed to calculate emissions by the Census data method are:

- Distribution of rural/urban population in inventory area or Census data on households heating with wood;
- Wood burning equipment type, if possible;
- Information on state and local regulations; and
- Degree heating days for inventory area.

3.3.2 APPLICATION OF CONTROLS

Controls for this category may be:

- Use of new technology woodstoves;
- Improvements in wood burning performance;
- Use of "no burn" periods;
- Public awareness and education programs;

- Replacement or installation of gas-burning equipment in fireplaces; and
- Total banning of burning.

An evaluation of applicable state or local regulations will give an indication of the adjustments that should be made to emission estimates calculated by the Census data method. If the survey method is used, the state and local regulations affecting this source category should be reviewed during the inventory planning stage, and the survey should be prepared so that information about new technology, lower-emitting woodstoves can be collected.

Since the use of lower-emitting woodstoves represents an irreversible process change, rule effectiveness (RE) usually can be assumed to be 100 percent for those households with the new woodstoves. However, it is unlikely that rule penetration will be 100 percent within an area. Factors that will affect rule penetration will include:

- Residences with woodstoves installed before the regulations came into effect;
- The ease in which consumers can purchase and install woodstoves that do not conform to the current regulations; and
- The consumer's understanding and willingness to purchase and use the lower-emitting woodstoves.

Control efficiency is reflected in the lower emission factors of the new technology woodstoves. However, from field tests it is apparent that control efficiencies of the new, low emission stoves drop after only a few years of use if preventative maintenance is not performed (EPA, 1994b).

3.3.3 SPATIAL ALLOCATION

Spatial allocation may be needed during the inventory preparation to allocate:

- State or regional activity to local level; and
- County-level emission estimates to a modeling grid cell.

Spatial allocation issues for the Census data method are included in the description of the alternative method in Section 5. Information that is typically used for spatial allocation can also be used to develop surrogate factors for scaling up the information gathered by the survey method. Scaling up survey information is discussed in Section 4.

3.3.4 TEMPORAL RESOLUTION

Seasonal Apportioning

Residential wood combustion is strongly dependant on the season temperature. If the preferred method is used, the survey should attempt to collect information about wood burned during only the inventory months. The alternative to survey information is allocation using heating degree days.

The method for allocating residential wood burning using heating degree days is as follows:

- Obtain the number of heating degree days for the inventory season and for the entire year.
 - A heating degree day is a measure of the amount of heating necessary for a particular day. One heating degree day is registered for each degree below 65° F that the day's average temperature is.
 - This information can be obtained from state climatological offices, airport meteorology stations, or National Oceanographic and Atmospheric Administration (NOAA) climate data¹.

$$\begin{array}{l} \text{Seasonal Fuel} \\ \text{Consumption} \\ \text{Space Heating) } \end{array} = \begin{array}{l} \text{Annual Fuel} \\ \text{Consumption} \\ \text{For Space Heating} \end{array} \cdot \left(\frac{\begin{array}{l} \text{Number of Heating} \\ \text{Degree Days in Season} \end{array}}{\begin{array}{l} \text{Total Heating} \\ \text{Degree Days Annually} \end{array}} \right) \quad (2.3-1)$$

For example, if the heating degree days for an entire year in an inventory area are 2430, and the heating degree days for the inventory period (90 days) are 1800, then the apportioning factor for the inventory area is:

$$0.74 = \frac{1800 \text{ inventory period heating degree days}}{2430 \text{ annual heating degree days}} \quad (2.3-2)$$

A seasonal activity factor of 0.43 can be used for the 3 month winter wood-burning season, if other approaches are not possible (EPA, 1991).

¹ See the most recent publication, which can be obtained from the National Climatic Data Center, Asheville, NC; refer to <http://www.ncdc.noaa.gov/>.

Daily Resolution

Residential wood combustion is assumed to occur seven days a week during the heating season.

3.3.5 PROJECTING EMISSIONS

Residential wood combustion is unlike many other area source categories in that population growth and development may not necessarily be reflected in growth for this source category. Projections of wood combustion activity should be based on the same factors used to spatially allocate activity. The EIIP Projections Committee has developed a series of guidance documents containing information on options for forecasting future emissions. You can refer to these documents at <http://www.epa.gov/ttn/chief/eiip/project.htm>.

If the survey method is used to collect activity data for this category, and the data can be broken down to types of woodstoves in use, then controls will be reflected in the emission factors used. Rule effectiveness must be considered to account for failures and uncertainties that may affect the actual performance of the control. Some woodstove designs may not need any consideration of RE. However, some designs such as woodstoves equipped with catalytic converters may degrade over time if preventive maintenance is not performed.

If detailed information about the types of woodstoves used, especially lower-emitting woodstoves, has not been collected, then projecting emissions is more complex. Estimates of the amount of wood being burned in lower-emitting woodstoves in comparison to the total amount of wood being burned are used to develop a value for rule penetration. Rule penetration, control efficiency and rule effectiveness are discussed in more depth in Chapter 1, *Introduction to Area Source Emission Inventory Development*.

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4

PREFERRED METHOD FOR ESTIMATING EMISSIONS

The preferred method for calculating emission estimates from residential wood combustion is a survey of residences in the inventory area. The main steps in developing an emission estimate through a survey are: (1) survey planning, (2) survey preparation, (3) survey distribution, (4) survey compilation and scaling, and (5) emission estimation. These steps will be discussed below.

4.1 SURVEY PLANNING

Planning a survey for this source category will include many of the same survey considerations discussed in Chapter 1, *Introduction to Area Source Emission Inventory Development* under Surveys, in Section 6. (The reader is also encouraged to review Chapter 24 for more information in conducting an area source survey). However, some source-specific issues apply. An example of a multi-state survey of resident wood fuel use can be found in *Residential Fuelwood Consumption and Production in the Plains States, 1994* (USDA, 1996). A survey of residences will need to be a representative sample of all of the residences in the inventory area so that information gathered on residential combustion can be scaled up (refer to the *EIIP QA* volume for more information on scaling up surveys). Issues that should be determined at this stage are:

- The necessary sample size;
- The number of surveys that will need to be sent in order to achieve the sample size;
- The demographic factors that will be used to scale up the survey results to the entire survey area, including how to collect that information; and
- The level of detail needed, for instance:
 - Is the inventory for an average day, an average week, or the entire season, thus requiring activity data for one of those time periods?

- Should the inventory include information about the use of controls or other factors that would require data on the different types of woodstoves being used?

Details about how to conduct a residential wood burning survey may be obtained by contacting the state and local air pollution agencies in the areas of high wood burning in the United States (e.g., Seattle, Washington; Portland, Oregon; Denver, Colorado; or Montana).

4.2 SURVEY PREPARATION

Survey questions should be tailored to suit the inventory region and the needs of the inventory. General points that should be included in a survey sent to a representative sample of residences are:

- An explanation of why the survey is necessary, and how more information is beneficial to the public;
- Questions that request the information needed to scale up the inventory (this should be simple, a zip code may suffice); and
- An attachment that describes the different woodstove types.

Example questions for a residential wood survey are shown in Example 4-1.

4.3 SURVEY DISTRIBUTION

Survey distribution will be determined by the budget for this category. Surveys can be distributed by a mailing, or the information can be collected through a telephone survey. Initial contacts and followup contacts may also be undertaken as part of the survey. Survey distribution issues are discussed in Chapter 1, *Introduction to Area Source Emission Inventory Development* under Surveys, in Section 6 and in Chapter 24, *Conducting Surveys for Area Source Inventories*.

4.4 SURVEY COMPILATION AND SCALING

Survey compilation and scaling is discussed in the *EIIP QA* volume of this series.

Scaling up the survey may be done using the following types of information:

- Distribution of rural/urban population in inventory area;

- Landuse;
- Household economic distribution; and
- Age of residences.

Example 4-1

- Do you have a fireplace or woodstove? (If not, please return the survey without answering any more questions)
- What type of wood-burning equipment do you have? (See descriptions of woodstove types at the end of this survey)
 - Fireplace
 - Conventional woodstove
 - Noncatalytic woodstove
 - Catalytic woodstove
 - Pellet stove
 - Masonry heater
 - Woodstove, do not know what type
- How often do you burn wood in a winter week?
_____ times per week _____ all week
- How much wood do you burn in an average winter week?
_____ cords* (example: 1/4 cord)
- How often do you burn wood in the rest of the year, per week?

***Note:** One cord is equal to a stack of wood 4x4x8 feet. One full-size pickup truck load is about one-half of a cord.

Planning prior to the survey should include an investigation of the best surrogate for scaling the survey information. Then, the survey can request the necessary information.

In addition to the QA/QC issues common to all survey efforts, checks should be put into place for the woodstove types entered and the amount of wood used. These entries will probably be the most likely to be in error. The conversion from wood used in cords to wood used in tons, which is dependant on wood species, could also be a source of error.

4.4.1 EMISSION ESTIMATION

After data from the surveys have been compiled and scaled up to the inventory area, the resulting activity data, in the form of wood burned in tons for each equipment type, should then be applied to emission factors provided in Tables 2.4-1 through 2.4-3. Residential woodstoves are classified as Phase I, Phase II and Pre-Phase I. Phase II stoves are those certified to meet the July 1, 1990, EPA standards; Phase I stoves meet only the July 1, 1988, EPA standards; and Pre-Phase I stoves do not meet any of the EPA standards but in most cases do necessarily meet the Oregon 1986 certification standards. *AP-42* contains PM_{10} and CO emission factors for catalytic and noncatalytic woodstoves in each of these classifications, but only emission factors for Phase II are presented here. Information on how the *AP-42* emission factors were developed can be found in the *AP-42* woodstoves section. Factors from the latest edition *AP-42* should be used for emission estimates. At the time of this writing, no factors for $PM_{2.5}$ are available. If $PM_{2.5}$ emission estimates are required for an inventory, it can be assumed that all of the PM_{10} is $PM_{2.5}$ (EPA, 1997). Emissions estimated using this assumption should not be perceived to be of the same level of quality as the factors found in *AP-42*, and if new *AP-42* factors became available, they should supersede emission factors that are presented here.

Table 2.4-4 gives density conversion factors for hardwoods and softwoods by typical forest type within a region. These generalized factors represent a weighted average density of the three most common (in terms of volume) softwood or hardwood species within the forest type. Forest types are identified by the primary tree species or tree species groups, but will include other tree species that are typically found in that biome. Local or state forestry service personnel should be able to identify an typical forest type for an area. Although densities for softwoods are provided, it is most likely that wood used for fuel will be hardwoods.

One cord of wood can be assumed to be about 79 cubic feet of solid wood (no air spaces). *AP-42* Appendix A also contains more general conversion factors. The more detailed factors in Table 2.4-4 are preferred.

TABLE 2.4-1

**CRITERIA POLLUTANT EMISSION FACTORS FOR
RESIDENTIAL WOOD COMBUSTION (LB/TON)^a**

Process Description	Criteria Pollutant Emission Factors				
	PM ₁₀	NO _x	CO	VOC	SO _x
Residential Total Woodstoves and Fireplaces ^b	34.6	2.6	252.6	229.0	0.4
Residential Fireplaces ^c	34.6	2.6	252.6	229.0	0.4
Residential Woodstoves - Catalytic Phase II	16.2	2.0	107.0	15.0	0.4
Residential Woodstoves - Noncatalytic Phase II	14.6		140.8	12.0	0.4
Residential Woodstoves - Conventional	30.6	2.8	230.8	53.0	0.4
Residential Woodstoves - Pellet/Certified ^d	4.2	13.8	39.4		0.4
Residential Woodstoves - Pellet/Exempt ^e	8.8		52.2		
Masonry Heaters ^f	5.6		149.0		

^a Source: EPA, 1995a.

^b These emission factors are for fireplaces and should be used when information separating wood burning equipment types is not available.

^c Exempt from the 1988 New Source Performance Standards for woodstoves because of air: fuel ratio > 15:1 and/or minimum burn rate > 5 kg/hr.

^d Certified pursuant to the 1988 New Source Performance Standards for woodstoves.

^e Exempt from the 1988 New Source Performance Standards for woodstoves because of air: fuel ratio >35:1.

^f Exempt from the 1988 New Source Performance Standards for woodstoves because of weight > 800 kg.

TABLE 2.4-2

**HAP EMISSION FACTORS FOR
RESIDENTIAL WOOD COMBUSTION (LB/TON)^a**

HAP	Woodstove Type		
	Conventional	Noncatalytic	Catalytic
Benzene	1.94E-00		1.46E-00
Cadmium	2.2E-05	2.0E-05	4.6E-05
Chromium	<1.0E-06	<1.0E-06	<1.0E-06
Manganese	1.7E-04	1.4E-04	2.2E-04
Methyl Ethyl Ketone	2.9E-01		6.0E-02
Nickel	1.4E-05	2.0E-05	2.2E-06
Phenol		<1.0E-03	
Toluene	7.3E-01		5.2E-01
O-Xylene	2.0E-01		1.9E-01

^a Source: EPA, 1995a

TABLE 2.4-3

**POLYCYCLIC AROMATIC HYDROCARBON (PAH) EMISSION FACTORS FOR
RESIDENTIAL WOOD COMBUSTION (LB/TON)^A**

Pollutant	Stove Type			
	Conventional	Noncatalytic	Catalytic	Exempt Pellet ^b
PAH				
Acenaphthene	0.010	0.010	0.006	
Acenaphthylene	0.212	0.032	0.068	
Anthracene	0.014	0.009	0.008	
Benzo(a)Anthracene	0.020	<0.001	0.024	
Benzo(b)Fluoranthene	0.006	0.004	0.004	2.60 E-05
Benzo(g,h,i)Fluoranthene		0.028	0.006	
Benzo(k)Fluoranthene	0.002	<0.001	0.002	
Benzo(g,h,i)Perylene	0.004	0.020	0.002	
Benzo(a)Pyrene	0.004	0.006	0.004	
Benzo(e)Pyrene	0.012	0.002	0.004	
Biphenyl		0.022		
Chrysene	0.012	0.010	0.010	7.52 E-05
Dibenzo(a,h)Anthracene	0.000	0.004	0.002	
7,12-Dimethylbenz(a)Anthracene		0.004		
Fluoranthene	0.020	0.008	0.012	5.48 E-05
Fluorene	0.024	0.014	0.014	
Indeno(1,2,3,cd)Pyrene	0.000	0.020	0.004	
9-Methylanthracene		0.004		
12-Methylbenz(a)Anthracene		0.002		
3-Methylcholanthrene		<0.001		
1-Methylphenanthrene		0.030		
Naphthalene	0.288	0.144	0.186	
Nitronaphthalene		0.000		
Perylene		0.002		
Phenanthrene	0.078	0.118	0.048	3.32 E-05
Phenanthrol		0.000		
Phenol		<0.001		
Pyrene	0.024	0.008	0.010	4.84 E-05
PAH Total	0.730	0.500	0.414	2.38 E-04

^a Source: EPA, 1995a

^b Only the woodstoves exempt from the 1988 New Source Performance Standards for woodstoves because of air fuel ratio > 35:1.

TABLE 2.4-4

**FACTORS TO CONVERT WOOD VOLUME (CUBIC FEET) TO
WEIGHT (POUNDS)^a**

Region	Forest Type	Density Conversion Factors	
		Softwood	Hardwood
Southeast and South Central	Pines	31.8	39.9
	Oak-Hickory	33.4	39.9
	Oak-Pine	32.6	39.9
	Bottomland Hardwoods	28.7	36.2
Northeast and Mid Atlantic	Pines	23.6	33.8
	Spruce-Fir	23.0	32.8
	Oak-Hickory	23.3	39.7
	Maple-Beech-Birch	24.0	37.4
	Bottomland Hardwoods	28.7	36.2
North Central and Central	Pines	26.3	33.1
	Spruce-Fir	21.9	30.0
	Oak-Hickory	26.0	39.4
	Maple-Beech	23.2	35.9
	Aspen-Birch	23.1	29.0
	Bottomland Hardwoods	28.7	36.2
Rocky Mountain and Pacific Coast	Douglas Fir	29.5	23.7
	Ponderosa Pine	26.0	23.7
	Fir-Spruce	21.8	23.7
	Hemlock-Sitka Spruce	27.1	27.0
	Lodgepole Pine	26.4	23.7
	Larch	31.7	27.0
	Redwoods	26.0	36.2
	Hardwoods	26.5	24.0

^a Source: EPA, 1995b.

5

ALTERNATIVE METHOD FOR ESTIMATING EMISSIONS

The alternative method to estimate activity factors for residential wood combustion uses information on residential wood data compiled by state or federal agencies, and apportioned using data from the U.S. Census Bureau and the U.S. Energy Information Administration. The emission factors used for the preferred method are also used for the alternative method.

The preferred source of information on residential wood burning is the state energy office, or state forest service. Available information may be estimates of wood burned for residential heating at the state, regional or county level. Inventory personnel should try to collect the most detailed and area-specific information possible.

If the state energy office does not have information on residential wood burning, other sources of information for area-wide wood use, or per household wood use should be identified. USDA Forest Service regional experiment stations may compile information that may be useful. One such document is a special study prepared by the North Central Forest Experiment Station in St. Paul, Minnesota (USDA, 1996). This study compiled residential wood use statistics for Kansas, Nebraska, North Dakota, and South Dakota, including average per household fuelwood consumption.

Other information resources are documents compiled by the U.S. Department of Energy (DOE), Energy Information Administration (EIA). Statistics for wood fuel use can be found in the EIA's *Residential Energy Consumption Survey: Household Energy Consumption and Expenditures*¹, published triennially, and state wood use data can be found in the *State Energy Data Report*, which is published annually by the EIA.

¹ See the publication for the year closest to the inventory year, which can be obtained from the U.S. DOE, EIA, Washington, DC. The EIA maintains a Web site at: <http://www.eia.doe.gov/index.html>.

The wood burned at the state level is apportioned to the county level using U.S. Census¹ data on households that use wood as a primary fuel. The equation is:

$$\text{County Wood Use} = \text{State Wood Use} * \frac{\text{County Wood-Burning Households}}{\text{State Wood-Burning Households}} \quad (2.5-1)$$

State level wood use (in cords) is available in the EIA's *State Energy Data Report*. State and county statistics on wood-burning households are available from the U.S. Census Bureau. Cords of wood are converted to pounds of wood using factors in Table 2.4-4 or AP-42 Appendix A. Example 5-1 shows this process for one county.

If desired, determine the type of wood burning equipment in the inventory region by performing a survey to apportion the wood used in fireplaces and woodstoves, by type.² In some areas with homogeneous housing (by age and economic level), a survey of a representative number of households can be performed and scaled-up to the inventory area. Information on the use of new technology woodstoves can be obtained from the state environmental agency, woodstove vendors in the area, and the Hearth Products Association.³

5.1 EMISSION FACTORS

The preferred emission factors for estimating emissions from residential wood combustion are shown in Tables 2.4-1 through 2.4-3. Emission factors for the relevant criteria pollutants are shown in Table 2.4-1; emission factors for the relevant HAPs are shown in Tables 2.4-2 and 2.4-3. When information about the different woodstove types is not available, use the emission factors for conventional woodstoves. If no distinction has been made between fireplaces and woodstoves, use the emission factors for fireplaces.

¹ See the publication for the year closest to the inventory year, which can be obtained from the U.S. Commerce Department, Census Bureau. The Census Bureau also maintains a Web Site which allows for interactive queries of Census data: <http://venus.census.gov/cdrom/lookup>. The Census Summary Tape File 3 (STF3A) contains this information.

² Conventional, catalytic, noncatalytic (new technology), masonry, or pellet fired.

³ Located in Washington, DC, the Heart Products Association maintains a web at <http://www.heartassoc.org/>.

Example 5-1:

For a 1993 inventory, the wood used in State A is obtained from the EIA's *State Energy Data Report* for that year. The wood used for residential energy is listed in Table 18, Residential Energy Consumption Estimates, under the classification of Biofuels, and is 622 thousand cords. U.S. Census data on house heating fuel is available for the year 1990, and that data will be used to apportion the state wood use data to the county level. There are 80,047 households using wood as a primary fuel at the state level, and 1242 households using wood as a primary fuel at the county level. To apportion the state level wood usage:

$$\begin{aligned}\text{County Wood Use} &= 622,000 \text{ cords} * \frac{1,242}{80,047} \\ &= 9,651 \text{ cords}\end{aligned}$$

To calculate the wood weight from the number of cords, one cord is estimated to be about 79 ft³ solid wood (air spaces are removed). State A is a southeastern state, so the specific gravity of the wood is estimated to be 0.639 for a southeastern hardwood, and the specific gravity is multiplied by the weight of a cubic foot of water (62.4 lbs). The calculation is:

$$\begin{aligned}\text{Wood Weight} &= 9,651 \text{ cords} * 79 \text{ ft}^3 * 0.639 * 62.4 \text{ lb} \\ &= 30,400,789 \text{ lb} \\ &= 15,200 \text{ tons}\end{aligned}$$

5.2 SPECIAL EMISSION CALCULATION ISSUES

To calculate wood use for a season day from annual wood use, the wood used for heating should be separated from wood used for other year-round purposes and apportioned to the season according to the number of days where space heating is needed. The method is as follows:

If wood is used for appreciable amounts of water heating and cooking as well as space heating in an inventory area, a survey should be performed to apportion wood use between space heating and the other uses. The use of wood for cooking and water heating is negligible in most regions.

The use of wood for space heating can be apportioned from the annual amount of wood burned to that burned for a season-day by one of the methods listed in Section 3 under *Temporal Resolution*. These methods are, in order of preference:

- Survey of residences;
- Heating degree days allocation; and
- Seasonal activity factor.

Section 3 discusses the heating degree day and seasonal activity factor methods.

6

QUALITY ASSURANCE/QUALITY CONTROL

During the inventory planning process, the agency should define the data quality objectives for the inventory, and set data quality goals for the emission estimates developed for this source category. Quality assurance and quality control methods may vary based on the data quality objectives for the inventory. The Quality Assurance Source Document of this series of volumes discusses methods to be used to ensure the development of a quality inventory. Quality assurance for area source inventories is also discussed in Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development*.

When using the preferred survey method, the survey method, sample design, and data handling should be planned and documented in the Quality Assurance Plan. Special care should be taken when compiling surveys for this source to ensure that equipment types are properly assigned, that wood use units are correct, and conversions of wood use are correct. When using the alternative method, data handling for all activity and emission factor data should be planned and documented in the Quality Assurance Plan.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

The preferred method will produce the most accurate and detailed estimate of emissions; however, surveys can be an expensive undertaking. Furthermore, the success of the survey depends heavily on the rate and completeness of the responses. The level of effort required for the Census data method is considerably lower, but the potential accuracy and detail in regard to the equipment type in use will be lower.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The Data Attribute Rating System (DARS) has been developed as a tool to rate emission inventories. A description of the system and the EIIP recommendations for its use can be found in Appendix F of EIIP Volume VI, *Quality Assurance Procedures*. The following discussion uses the DARS rating system as a way to compare the estimation approaches presented in this chapter and analyze their strengths and weaknesses. The DARS scores for each method are summarized in Tables 2.6-1 and 2.6-2. All scores assume that good QA/QC

measures are performed and no deviations from good inventory practice have been made. If these assumptions are not met, new DARS scores should be developed according to the guidance provided in the QA Source Document.

TABLE 2.6-1**PREFERRED METHOD DARS SCORES: LOCAL SURVEY OF A SAMPLE OF RESIDENCES**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	5	7.5	0.375
Source Specificity	7	7	0.49
Spatial	9	8	0.72
Temporal	9	8	0.72
Composite Scores	0.75	0.76	0.58

Comments: Temporal scores will go down for the factors as time increases (i.e., the further you get from survey date).

TABLE 2.6-2**ALTERNATIVE METHOD DARS SCORES: NATIONAL EMISSION FACTORS AND APPORTIONED CENSUS BUREAU ACTIVITY**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	5	6	0.3
Source Specificity	5	6	0.3
Spatial	9	3-6	0.27-0.54
Temporal	9	7.5	0.68
Composite Scores	0.7	0.23-0.64	0.16-0.46

Both of the methods presented in this chapter use the same emission factors, so the DARS scores for the emission factor attributes are the same, except for the source specificity category. The Census data activity method will not provide information about the types of woodstoves in use in an area. If a limited survey is performed to provide that level of detail, then source specificity will be equivalent to that for the preferred method. The key difference between the two methods is the collection of the activity data, and in particular, assigning activity to the correct location.

6.1.2 SOURCES OF UNCERTAINTY

Another way to assess the emission estimates is to look at the associated uncertainty. For estimates derived from survey data, the uncertainty can be quantified (see the QA Source Document, Chapter 4). Statistics needed to quantify the uncertainty for emissions derived by the Census data activity method are incomplete.

The uncertainty for emission estimates derived from the survey method is affected by several variables. These variables are:

- The sample size;
- Whether the surrogate used for scaling up the survey data is appropriate for the source category activity;
- Accurate description of the woodstove type;
- Accurate estimation and unit conversion for the wood burned; and
- Unquantifiable degradation of the control efficiency of lower emission woodstoves, especially catalytic woodstoves (EPA, 1994b).

Uncertainty of emission estimates developed by using the Census data method depend on the level of detail that the inventory preparer goes to in collecting activity information. The activity can be viewed as a combination of information, all of which could be more or less reliable. This method requires:

- An estimate of wood use in the state or region;
- Information that can be used to apportion the wood use to the inventory area, and to the individual counties within the inventory area;
- The choice of collecting woodstove type information in the inventory area; and

- The choice of using survey, heating degree days or a seasonal activity factor for seasonal apportioning of the emission estimates.

Thus, decisions regarding the source and quality of the state or regional wood use data, and the spatial and temporal apportioning will determine the uncertainty of the resulting emission estimates.

DATA CODING PROCEDURES

The inventory preparer should check the EPA website (<http://www.epa.gov/ttn/chief/>) for the latest information (codes) available to characterize emission estimates from residential wood combustion. A complete list of Source Classification Codes (SCC) can be retrieved at <http://www.epa.gov/ttn/chief/codes/>. Table 2.7-1 lists the applicable SCCs for residential wood combustion.

Available codes and process definitions influence and help guide the preparation of emission estimates for this category. Data transfer formats should be taken into account when an inventory preparer plans for data collection, calculation, and inventory presentation. Consistent categorization and coding will result in greater continuity between emission inventories for use in regional and national scale analyses.

7.1 NECESSARY DATA ELEMENTS

If the category emissions data will be transferred to EPA for incorporation into the national criteria and toxics air pollutant inventory, specific data transfer formats are acceptable. The acceptable data transfer format(s) are described and available for download at <http://www.epa.gov/ttn/chief/net/>. The acceptable data transfer formats contain the data elements necessary to complete the data set for use in regional or national air quality and human exposure modeling. The inventory preparer should review the area source portion of the acceptable file format(s) to understand the necessary data elements. The EPA describes its use and processing of the data for purposes of completing the national inventory, in its Data Incorporation Plan, also located at <http://www.epa.gov/ttn/chief/net/>.

TABLE 2.7-1

**AREA AND MOBILE SOURCE CATEGORY
CODES FOR RESIDENTIAL WOOD COMBUSTION**

Process Description	Source Category Code
Residential Wood Combustion - Total: Wood Stoves and Fireplaces	21-04-008-000
Residential Wood Combustion - Fireplaces	21-04-008-001
Residential Wood Combustion - Woodstoves: General	21-04-008-010
Residential Wood Combustion - Catalytic Woodstoves: General	21-04-008-030
Residential Wood Combustion - Non-Catalytic Woodstoves: General	21-04-008-050
Residential Wood Combustion - Non-Catalytic Woodstoves: Conventional	21-04-008-051
Residential Wood Combustion - Non-Catalytic Woodstoves: Low Emitting	21-04-008-052
Residential Wood Combustion - Non-Catalytic Woodstoves: Pellet Fired	21-04-008-053

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ARCHITECTURAL SURFACE COATING

November 1995



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Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

This chapter describes the procedures and recommended approaches for estimating emissions from architectural surface coating. Section 2 of this chapter contains a general description of the architectural surface coating category, and an overview of available control technologies. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation method for architectural surface coatings, while Section 5 presents alternative emission estimation techniques. Quality assurance and control procedures are described in Section 6. Coding procedures used for data input and storage are discussed in Section 7, and Section 8 is the reference section.

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2

SOURCE CATEGORY DESCRIPTION

Architectural surface coating operations (SIC 17) consist of applying a thin layer of coating such as paint, paint primer, varnish, or lacquer to architectural surfaces, and the use of solvents as thinners and for cleanup. Architectural surface coatings protect the substrates to which they are applied from corrosion, abrasion, decay, ultraviolet light damage, and/or the penetration of water. Some architectural coatings also increase the aesthetic value of a structure by changing the color or texture of its surface. Architectural coatings are also important in construction of structures. Examples of the latter are concrete form release compounds, which prevent concrete from sticking to forms, and concrete curing compounds, which allow concrete to cure properly (Brandau, 1990). It should be noted that this category does not include auto refinishing, traffic marking, surface coating during manufacturing, industrial maintenance coatings, special purpose coatings, or paints used in graphic arts applications.

A wide range of coatings are used to cover both the interior and exterior surfaces of architectural structures. The majority of architectural surface coatings are applied by homeowners and painting/surface coating contractors to domestic, industrial, institutional, and governmental structures throughout a geographic area. Because the emissions from this source category are likely to be scattered throughout the inventory region, it is recommended that this source category usually be treated as an area source. However, emissions from this category may also be estimated as one of many processes occurring at a point source, for the purposes of permitting and emission trade offs.

Because the coated architectural surface dries or cures in the ambient air, the use of exterior architectural coatings may be limited to periods when local climatic conditions facilitate acceptable coating curing. Although interior coating applications are less influenced by outdoor conditions, complete curing of these coatings also can be hampered by cool, moist weather (i.e., when evaporation rates are reduced).

EMISSION SOURCES

Volatile organic compounds (VOCs) that are used as solvents in the coatings are emitted during application of the coating and as the coating dries.^a The amount of coating used and the VOC content of the coating are the factors that primarily determine emissions from architectural surface coating operations. Secondary sources of VOC emissions are from the solvents used to clean the architectural coating application equipment and VOC released as reaction byproducts while the coating dries and hardens. VOC emitted from this chemical reaction is determined by the resins used in a particular coating. The VOC emitted from any of these sources could include HAP (EPA, 1993a).

Emission factors and area source estimation methods have been developed for VOC and HAP emissions but not for PM emissions. If all architectural surface coatings are applied using brushes and rollers, then it is reasonable not to consider PM emissions. However, many commercial paints use spray guns; if a significant amount of the paint is applied in this manner (particularly to exterior surfaces), then inventories of PM may need to address emissions from this source category. Point source methods and factors can be used to estimate PM emissions from architectural surface coatings.

FACTORS INFLUENCING EMISSIONS

PROCESS OPERATING FACTORS

Structural maintenance practices indirectly influence VOC emissions by controlling the total coating consumption on a long-term basis. Regular inspection and maintenance programs can be used to reduce the need for entire surface recoating (Brandau, 1990).

CONTROL TECHNIQUES

Since the use of organic solvents in architectural surface coatings is the primary source of emissions, control techniques for this source category involve either product substitution or product reformulation. These alternate formulations include low-solvent-content coatings, waterborne coatings, and powder coatings. In certain situations, recycling of unused coatings may also be considered a form of control.

^a There are many solvents that may be used in architectural surface coating operations. Some compounds may be considered nonreactive and should not be counted in an ozone (VOC) inventory, but would need to be quantified for air modeling, or HAP inventory.

Coating types may be considered to be solvent based or water based, depending on whether the principle flow controller is an organic solvent or is water. Solvent based coatings are defined by the U.S. EPA as coatings that only contain organic solvents, with water, if it is present at all, only present in trace quantities. Water based coatings have more than 5 weight percent water as their volatile fraction. Another way of looking at the distinction between the two types of coatings is that solvent based coatings have resins dissolved in organic solvents and water based coatings have resin systems suspended in water as liquid emulsions of solid dispersion (EPA, 1993a).

The EPA is using regulatory negotiation to prepare a national rulemaking for controlling VOC emissions from architectural and industrial coatings. Currently, no federal EPA regulations are in place to limit VOC content or VOC emissions from architectural surface coatings. However, since Occupational Safety and Health Administration (OSHA) regulations limit worker exposure to solvents, OSHA rules can indirectly affect the VOC content of coatings and the solvents used in them. The OSHA exposure limits vary with compound toxicity and as a result, manufacturers must consider the composition of coatings during product development to minimize the exposure hazards (EPA, 1993a).

Five states—Arizona (AZ), California (CA), New Jersey (NJ), New York (NY), and Texas (TX)—have coating regulations that affect architectural surface coatings; Maryland has a draft rule. The various state regulatory limits are summarized in Table 2-1. For a coating to be in compliance with most state regulations, the VOC content when applied must be below the specified VOC limit, regardless of whether any thinning followed, or whether the manufacturer's recommended thinning rate was exceeded (EPA, 1993a).

TABLE 2-1

STATE VOC LIMITS (GRAMS VOC/LITER COATING, LESS WATER)^a

Coating Categories	AZ ^b (07/13/91) ^c	CA-CARB ^d (09/01/92) ^c	NJ ^e (08/08/90) ^c	NY ^f (07/01/89) ^c	TX ^g (01/01/91) ^c
All other architectural coatings			250		
Bond breakers		350	600	600	
Concrete-curing compounds	350	350	350	350	
Enamel undercoaters	350				
Flat architectural coatings			250		
Form-release compounds		250			
General primers, sealers, and undercoaters	350	350	350	350	
Lacquers	680	680	680	680	
Magnesite cement coatings		600			
Mastic texture coatings		300	200	200	
Nonflat architectural coatings			380		
Opaque stains	350	350	350	350	
Pretreatment wash primer		780			
Quick-dry enamels	400				
Quick dry primers, sealers, and undercoaters			500	500	
Roof coatings	300	300	300	300	
Sanding sealers		550			
Semitransparent stains	350	350	550	550	
Shellac (clear)		730	730	730	
Shellac (pigmented)		550	550	550	
Specialty flat products	400				

TABLE 2-1 (CONTINUED)

Coating Categories	AZ^b (07/13/91)^c	CA-CARB^d (09/01/92)^c	NJ^e (08/08/90)^c	NY^f (07/01/89)^c	TX^g (01/01/91)^c
Specialty primers, sealers, and undercoaters	350				
Varnishes	350	350	450	450	
Waterproof mastic coating	300		300	300	
Waterproof sealers	400	400	600	600	
Wood preservatives (all)	350		550	550	
Wood preservatives (opaque)		350			
Wood preservatives (semitransparent and clear)		350			
Wood preservatives (below ground)		600			
Alkyd varnishes					540
Epoxy paints					540
Exterior alkyd paints					480
Exterior stains					720
Interior alkyd paints					420
Interior stains					840
Nitrocellulose-based lacquers					670
Nonflat and flat latex paints					260
Urethane coatings					540

^aBlanks indicate that no definition and/or limit exists for that category.

^bArizona Regulation III—Control of Air Contaminants, Rule 335-Architectural Coatings, Section 300—Standards. Applies only to Maricopa County.

^cEffective date.

^dARB-CAPCOA Suggested Control Measures for Architectural Coatings; a model rule that applies to the whole state.

^eNew Jersey Administrative Code Title 7, Chapter 27, Subchapter 23—Volatile Organic Substances in Consumer Products, Section 7:27-23.3 Architectural Coatings. Applies to the whole state.

TABLE 2-1 (CONTINUED)

^fNew York Title 6, Chapter III—Air Resources, Part 205, Section 205.4, Prohibitions and Requirements. Applies only to the New York City Metropolitan Area.

^gTexas resin categories listed at the end of the table. Texas Air Control Board, Regulation V (31 TAC Chapter 115)—Control of Air Pollution from Volatile Organic Compounds, Section 115.191. Applies to the following counties: Brazoria, Chambers, Collin, Dallas, Denton, El Paso, Fort Bend, Galveston, Hardin, Harris, Jefferson, Liberty, Montgomery, Orange, Tarrant, and Waller.

3

OVERVIEW OF AVAILABLE METHODS

EMISSION ESTIMATION METHODOLOGIES

There are several methodologies available for calculating emissions from architectural surface coatings. The method used is dependent upon the degree of accuracy required in the estimate, available data, and available resources. Since architectural surface coatings can be the largest single area source in an area source ozone inventory, this category warrants the time and effort needed to calculate emission estimates for it.

This section discusses the methods available for calculating emission estimates from architectural surface coatings and identifies the preferred calculation method. A discussion of the data elements needed for each method is also provided.

AVAILABLE METHODOLOGIES

VOLATILE ORGANIC COMPOUNDS

Most VOC released into the air by architectural surface coating use are from the evaporation of the VOC contained in the coating, coating thinners, and thinners used for cleanup. Determining the amount of the VOC in coatings and thinners should provide a good estimate of the VOC emitted by this source category. There are two approaches to estimating the amount of VOC emitted from this source category:

- Surveying architectural surface coating use in the inventory area; and
- Using one of two population-based estimation methods:
 - National average per-gallon emission factors applied to national per capita usage rates, or;
 - Regulatory state or local per-gallon emission limits applied to national per capita usage rates.

The survey method is the preferred approach for emission estimation. It will most accurately reflect the actual use and content of coatings in the inventory area, and thus also reflect any controls applied. The survey method can also be used to determine separately the amount of paint that is recycled or sent to a landfill. The level of detail provided by this method allows

for control strategies to be more accurately modeled.

If off-site disposal is part of an emission reduction program, or is a potentially significant factor in estimated emissions, a survey directed at a subset of the disposal facilities could be used to estimate the emission reduction from the unused coating.

The alternate approaches—population-based estimates—do not provide the same level of detail in terms of the specific amounts and types of paints used in the inventory area as the survey method does. Calculating a per capita usage for the inventory year and applying to it national emission factors will not take into account variability between regions, but will take into account the variability of usage at the national level from year to year. This method is best used if controls are limited or nonexistent and no further controls are anticipated for the source category. The population-based method using local emission limits will create an emission factor that will probably be very conservative. This method is acceptable if the source category is judged to be less important, or if resources and time are not sufficient to allow use of the survey method.

HAZARDOUS AIR POLLUTANTS

HAP emissions from this source can be estimated using two methods:

- Surveying architectural surface coating use in the inventory area; or
- Applying speciation profiles to the VOC emission estimate, obtained by using either the preferred or alternative methods for VOC.

The survey method is the preferred method, because it will provide that most accurate information on coating usage and content. The effect of VOC controls on HAP emissions should also be apparent when using this method.

Speciation profiles can be used as an alternate approach when a detailed survey is not practical. Although specific profiles will be provided in Section 5, updated or local speciation profiles should be used when available.

DATA NEEDS

DATA ELEMENTS

The data elements used to calculate emission estimates for the architectural coatings category will depend on the methodology used for data collection. The data elements that are necessary for an emission calculation and should be requested in a survey of paint distributors

include:

- Product type;
- Product amount distributed by type (gallon);
- Product density (lb/gallon);
- VOC content of product or, solvent content by type and VOC percentage of solvents (weight percent); and
- HAP content of product or solvent by type (weight percent) for all HAP in product.

A survey respondent may have information on the VOC content, but not the solvent content or VOC fraction of the various solvents in a paint type. Fewer data elements will be needed in this case, and the emission calculation, presented in Section 4, will be simplified.

A separate survey of recycling facilities should determine the type and amount of architectural coatings collected and recycled. Product types should match those used by the manufacturers or distributors surveyed.

If an emission factor method is used, the following data elements are needed: local and national population, local or national coating usage, and a VOC emission factor and speciation profiles. To develop a local or updated emission factor, usage and emission factors for the individual coating types at the national or state level, or for a representative subsection of the inventory area need to be collected. National, state or sample subsection population will also be needed to complete the calculation.

APPLICATION OF CONTROLS

Since most controls will affect the content of the coating itself, a survey of coating usage and VOC content or an emission factor developed from recent data will reflect controls that are in place. Because a reformulation or substitution represents an irreversible process change, and thus, a reduction in emissions from a coating type, rule effectiveness can be assumed to be 100 percent for that coating type.

Rule penetration will be based on the percent of sources within the category that are affected by the rule.

SPATIAL ALLOCATION

Spatial allocation may be needed in two possible cases during the preparation of an inventory: (1) allocation of state or regional activity to a county level, and (2) allocation of county level emission estimates to a modeling grid cell. In each case, a surrogate for activity should be found that can approximate spatial variation for this category.

Architectural surface coatings are almost always used in and on buildings where people live or work. Therefore, building square footage is the preferred method for spatial allocation in both cases. Tax assessor's offices typically have this information, and, if it has been compiled into a computerized database or geographical information system (GIS), it should be reasonably accessible for use in an inventory. This method should be particularly worthwhile for allocating emissions to a modeling grid cell.

A less detailed alternative spatial apportioning method uses land use data from county planning departments, or population distributions, available from the Census Bureau. Using population to allocate estimated emissions or activity by county or within a grid cell is fairly straight forward, and is discussed in this volume's, Chapter 1, *Introduction to Area Source Emission Inventory Development*. Land use data can be used to generalize building size and type.

TEMPORAL RESOLUTION

Seasonal Apportioning

Architectural surface coating use is influenced by the seasons, since spreading and drying characteristics for many paints are dependant on the temperature. Temperatures below 50°F are not suitable for painting, and limit activity. The seasonal factor for ozone season activity is 1.3 or 33% of annual activity (EPA, 1991). Bureau of the Census reports on paint and allied products^a can be used to calculate an alternative seasonal apportioning factor for a particular year. The second and third quarter usage figures cover the months of April through September. The first and fourth quarters are periods of low coating usage in most areas. Based on 1993 and 1992 Census data, the seasonal factor for ozone season architectural coating activity is 1.12, or 28 percent of annual activity for a 3-month period.

^a Bureau of the Census, Manufacturing and Construction Division, Report MA28F—Paint and Allied Products, available on the Census Bureau Bulletin Board, (301) 457-2310.

Daily Resolution

Coating use may take place 7 days a week during the active season.

PROJECTING EMISSIONS

A discussion about developing growth factors and projecting emission estimates can be found in Section 4 of this volume's Chapter 1, *Introduction to Area Source Emission Inventory Development*. Projected emission estimates may need to be calculated differently in the three following cases:

- Case 1) No controls and no change in emission factor;
- Case 2) Controls are reflected in the emission factor; and
- Case 3) Controls are expressed as a control efficiency factor, the emission factor stays the same.

Each case uses a different projection equation. If there are no controls and no changes in the emission factor, projected emissions are calculated using the following equation:

$$EMIS_{PY} = ORATE_{BY} * EMF * GF \quad (3-1)$$

where:

EMIS _{PY}	=	Projection year emissions
ORATE _{BY}	=	Base year activity rate
EMF	=	Emission factor
GF	=	Growth factor

For Case 2, where controls are reflected in the emission factor, the equation would be:

$$EMIS_{PY} = ORATE_{BY} * EMF_{PY} * GF \quad (3-2)$$

where:

EMF _{PY}	=	Projection year emission factor
-------------------	---	---------------------------------

When controls are expressed as an emission limit or a percent reduction, reductions are calculated using a control efficiency factor, which is Case 3. See Section 4 of this chapter for an example of how to develop and apply a control efficiency factor in a base year emission estimation equation. Projected emission estimates for Case 3 are calculated using the following equation:

$$\text{EMIS}_{\text{PY}} = \text{ORATE}_{\text{BY}} * \text{EMF} \left[1 - \left(\frac{\text{CE}_{\text{PY}}}{100} * \frac{\text{RE}_{\text{PY}}}{100} * \frac{\text{RP}_{\text{PY}}}{100} \right) \right] * \text{GF} \quad (3-3)$$

where:

CE_{PY}	=	Projection year control efficiency
RE_{PY}	=	Projection year rule effectiveness
RP_{PY}	=	Projection year rule penetration

Tools for the development and use of growth factors are discussed in Chapter 1 of this volume. Forecasts of real estate sales, available from local planning boards, can also be used to estimate future growth in architectural surface coating.

4

PREFERRED METHODS FOR ESTIMATING EMISSIONS

The preferred method for calculating emission estimates from architectural surface coating is a survey of coating manufacturers in the region, or distributors in the area. This section provides an outline for preparing and using an architectural surface coating survey, and calculating emission estimates from the information collected.

Survey methods are theoretically the most accurate approach for estimating emissions, but also are the most expensive. Advantages to using this method are that regional or area specific information about the amount and type of coatings used will be collected. Coatings surveyed will more precisely reflect the regulations for VOC that are in place in the inventory area. Emissions of HAPs can be calculated based on the specific types of coatings in use in the area. The level of detail that is possible to collect with a survey is not available when using the alternative methods.

The cost and labor effort is highest for the first time that a regional or local survey is performed. Subsequent updates to the survey may be done using fewer samples at much less cost. In the years following the baseline survey, updates on sales may be all that is needed. Periodically, changes in formulations, methods of application, and the percentages of different types of coatings used may be updated.

A specific discussion of surveys for area sources is provided in Volume I of the EIIP series and in Chapter 1 of this volume. An approach for a survey of suppliers or manufacturers of architectural coatings uses five steps: (1) survey planning, (2) survey preparation, (3) survey distribution, (4) survey compilation and scaling, and (5) emission estimation. These steps will be discussed below.

SURVEY PLANNING

During the planning phase for the survey, the following issues should be addressed:

- Identify survey data quality objectives (DQOs), information needed, and how the DQOs will be realistically reached.
- Identify the survey recipients, either suppliers or manufacturers, and the data needs, depending on either choice.

- If suppliers are chosen as the recipients, a subset of all area suppliers may be surveyed, but, the inventory DQOs should be taken into account when determining the sample size. Identify a scaling surrogate for scaling up the survey results (e.g., building square footage, number of burning units, or population).
 - If manufacturers are chosen as recipients, the resulting information will probably cover a larger region than the inventory area. The information collected will need to be scaled to the inventory area. Information about distribution patterns may need to be collected from the manufacturers in the survey.
- Decide whether to prescreen recipients.
 - Coordinate with other inventory areas, if necessary.
 - Identify data handling needs specific to this survey.
 - Identify and begin to implement survey QA/QC.

The survey package should include a cover letter explaining the program, the survey form, a list of definitions, a map defining the study area(s), and a postage-paid envelope.

Either architectural coating suppliers or manufacturers can be surveyed for the information needed for this category. Suppliers can be identified through the telephone Yellow Pages. Additional disposal information may be collected as part of a waste disposal or recycling category. The portion of emissions that correspond to recycled or discarded architectural surface coatings from the disposal or recycling category should be subtracted from the emission estimate for architectural surface coating. This is necessary to avoid double counting.

SURVEY PREPARATION

In the planning phase, the information that the survey will collect should have been identified. In this step, the survey should be put into its final form.

At a minimum, the survey should request the number of gallons of architectural surface coating distributed in the inventory area or the inventory county, listed by coating type and carrier (solvent or water), and the average VOC content of each coating. Alternatively, national averages of VOC for each coating type can be multiplied by the number of gallons of the coating type to estimate emissions. National averages of VOC content for types of coatings have been prepared by the National Paint and Coatings Association (EPA, 1993a). A more detailed survey will request:

- Product type;
- Product amount distributed by type (gallon);
- Product density (lb/gallon);
- Solvent content of each product type (weight percent);
- VOC content of product by type or of solvent by type (weight percent); and
- HAP content of product by type or of solvent by type (weight %) for all HAP in product.

The advantages of the more detailed approach are an inventory that is more specific to the locality, and information that can be more readily projected to inventories for subsequent years.

Instructions for the survey form are provided on the survey cover page, shown in Figure 4-1. As shown in Table 4-1, respondents must first estimate the annual amount of coatings and solvent used in coatings, less waste disposed of offsite. This information is then combined with the coating and solvent density to yield the pounds of product used in a given year. HAP weight-percent information is then derived from the material safety data sheets (MSDSs) provided with each coating.

Using this method for a HAP inventory would require HAP information collection. A representative sample of the HAP contents for each product type, applied to a more complete inventory of surface coating types and usage, will simplify data collection.

Since most coatings are not transported great distances from where they are manufactured, it is possible to characterize architectural surface coating use in an area by surveying regional manufacturers. These manufacturers can be identified through resources like the Paint Red Book (Commercial Channels, Inc., 1985), and the Rauch Guide (Rauch Associates, Inc., 1984), which are both commercial directories of the paint industry and should be available in university and technical libraries. A survey of manufacturers should include all manufacturers in a multi-state region surrounding the study area, as well as the major nationwide manufacturers. Before undertaking a regional manufacturers' survey, a state or local agency should consider coordinating the survey with neighboring states or localities, since repeated information requests from multiple agencies may be ignored. A regional manufacturer's survey may provide the most complete picture of coating use in an area.

Name of Manufacturer/Distributor: _____

Street Address: _____

City: _____

Contact Person/Phone Number: _____

1. On the attached table, list the amount of each individual product manufactured or distributed in 1994. Products include coatings and solvent manufactured to be used in preparing coatings for use.
2. Enter the amount of any coating disposed of offsite and not used in 1994. If only total amount of liquid disposed of offsite is known, allocate the total between the different products.
3. Subtract the amount of waste or unsold coatings from the amount purchased to yield the amount of each product used in gallons.
4. From the Material Safety Data Sheet (MSDS) for each product, enter the product density in pounds per gallon (lb/gal). If the MSDS only indicates the specific gravity, calculate the density by multiplying the specific gravity by 8.34 lb/gal (the density of water).
5. Multiply the gallons of product used by the density to yield the pounds of each product used.
6. From the Material Safety Data Sheet for each product, enter the hazardous air pollutant (HAP) or VOC weight percent listed.
7. Multiply the pounds of product used by the HAP/VOC weight percent to yield pounds of each HAP/VOC emitted.

FIGURE 4-1. SURVEY REQUEST FORM FOR ARCHITECTURAL SURFACE COATING SUPPLIERS AND MANUFACTURERS

TABLE 4-1

ARCHITECTURAL SURFACE COATING REQUEST FORM

Coating Type ^a	Amount Sold (gallon)	Amount Disposed of Offsite ^b (gallon)	Product Density (lb/gallon)	Amount Used (lb)

TABLE 4-1 (CONTINUED)

Coating Type ^a	Amount Sold (lb)	HAP Weight %	HAP Emitted (lb)

^aSee Figure 4-2 for list of example architectural coating types.

^bColumn not applicable to survey of manufacturers.

Anti-graffiti	Quick dry enamels
Below ground wood preservatives	Quick dry primers, sealers, undercoat
Bituminous coatings	Sanding sealers
Bond breakers	Sealers
Clear wood preservatives	Semi-transparent stains
Concrete curing compounds	Semi-transparent wood preservatives
Dry fog coatings	Shellacs
Fire retardant/resistive coatings	Swimming pool coatings
Form release compounds	Undercoaters
High performance architectural coatings	Varnishes
Lacquers	Waterproofing sealers
Magnesite cement coatings	Waterproofing sealers with pigment
Texture coatings	Interior flats
Opaque stains	Exterior flats
Opaque wood preservatives	Interior non-flats
Pretreatment wash primers	Exterior non-flats
Primers	

FIGURE 4-2. EXAMPLE ARCHITECTURAL COATING TYPES

SURVEY DISTRIBUTION

Survey distribution will be determined by the budget for this source category. Surveys can be distributed by a mailing, or the information can be collected through a telephone survey. Initial contacts and follow up contacts may also be undertaken as part of the survey, in order to answer any questions. Survey distribution issues are discussed in Chapter 1 of this volume.

SURVEY COMPILATION AND SCALING

Survey compilation and scaling issues are discussed in Volume I of this series. A survey of surface coating manufacturers or distributors will result in information that includes many types of paints and multiple pollutants, so compilation of this information will require planning for data transfer and data management. Efficient transfer to the data handling system will benefit from inventory planner's consideration of the transfer step during the design of the survey.

Quality control checks should be in place during this phase of the work (see Volume VI for QA/QC methods). Incoming surveys should be checked for errors such as potential unit conversion errors or misidentification of products or chemicals. Survey information should be checked for reasonableness. Compiled survey information should also be subject to similar checks. Survey recipients may need to be recontacted in order to correct any errors.

Depending on the recipients of the survey, results may need to be either scaled up for all counties in the inventory area or scaled down to the inventory area. In either case, a scaling factor should have been identified in the planning phase, and any necessary requests for information from the survey respondents included in the survey form.

EMISSION ESTIMATION

Emission estimation calculations involve the calculation of emissions of individual pollutants, and then the application of any necessary spatial or temporal adjustments. Because the application of architectural surface coating is generally defined as an area source, there should not be a need to subtract point source emission estimates from the total. However, there may be cases when emission estimates from this category may be estimated as one of many processes occurring at a point source for the purposes of permitting and emission tradeoffs. These emissions must be identified and then subtracted from the area source estimates.

The equation below can be used to estimate the total amount of pollutant (P) emitted in the inventory area from architectural surface coating operations.

$$ASE_P = \sum_{c=1}^C \sum_{s=1}^S TAC_{c,s} \cdot SC_{c,s} \cdot F_{P,s} \quad (4-1)$$

where:

ASE_P	=	Total emissions of pollutant (P) from architectural surface coating operations, for all coatings (C) with all solvents (S)
$TAC_{s,c}$	=	Total architectural surface coating consumed in the inventory area for each coating (c) with each solvent (s) containing pollutant (P)
$SC_{c,s}$	=	Amount of solvent (s) in each coating (c)
$F_{P,s}$	=	Fraction of pollutant (P) in each solvent (s)

Spatial allocation to individual counties or other inventory area units can be done using the methods described in Section 3. The methods that are available, in order of preference, are to use building square footage, land use data or population to allocate coating use.

Temporal allocation may be necessary if the inventory requires seasonal or daily emission estimates, and is discussed in Section 3 of this chapter.

Example 4-1:

Formaldehyde is reported in various weight percents for some formulations of primers, varnishes and waterproofing sealers. Reported weight percents for these coating types, and the amount delivered to the inventory area, in pounds, are presented below.

Formaldehyde Content by Weight Percent		
Coating Type	Weight %	Amount Distributed (lb)
Primers	1.60	304.50
	17.50	47.85
	0.55	52.20
	7.50	5.22
Varnishes	0.55	845.50
	0.65	1330.00
Waterproofing Sealers	0.55	8.96

Emissions are calculated for varnishes:

$$\begin{aligned}
 \text{Formaldehyde} \\
 \text{Emissions from Varnishes} &= [842.5 \text{ lb} * 0.55\%] + [1330 \text{ lb} * 0.65\%] \\
 &= 4.65 + 8.645 \\
 &= 13.295 \text{ lb Formaldehyde}
 \end{aligned}$$

Emissions are calculated for waterproofing and primers in the same manner, and all emission estimates are summed for the final estimate.

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5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

The alternative method for calculating emissions from architectural surface coating is to use population-based usage and emission factors. This section provides an outline for developing a per capita usage factor, and for using that usage factor and an emission factor to calculate a VOC emission estimate. Because the application of architectural surface coating is defined as an area source, there is no need to subtract point source emissions from the total, and all emissions estimated for this source are area source emissions. The procedure is as follows:

- Determine the per capita usage factor by dividing the national total architectural surface coating quantities^a for solvent and water based coatings by the U.S. population for that year.^b Example 5-1 shows how to sum gallons of water and solvent based paints for the year 1993.
- Determine the VOC emission factors for solvent- and water-based coatings. Emission factors based on weighted averages from a 1990 survey study are listed at the end of this section (EPA, 1993a). These emission factors are based on the weighted average VOC emission at maximum thinning. State or local emission limits also can be used to calculate an emission factor. If sufficient information is available, a more recent emission factor can be calculated. That information includes the amount used and percent VOC content of each of the architectural surface coatings.
 - When state or local emission limits are used to develop an emission factor, and those limits are a range of values for different types of coatings, a weighted average, based on real or estimated consumption of each coating type will need to be calculated.

^a Total national coating usage is compiled by the Bureau of the Census, Report MA28F—Paint and Allied Products, available on the Census Bureau Bulletin Board, (301) 457-2310.

^b U.S. Census Bureau, Department of Commerce, Washington, DC.

Example 5-1:

Table 5-1 shows a portion of Table 2 from the U.S. Bureau of Census MA28F - Paint and Allied Products. This section of the table summarizes the market information available on architectural coatings for the years of 1993 and 1992. In the table, types of paints are identified as being either solvent or water based paints, except for the two types listed as Architectural Lacquers and Architectural Coatings N.S.K. These latter types of paints can be assumed to be entirely solvent based coatings. The calculation to obtain the number of gallons of solvent based paints totals the gallons for Exterior Solvent Type, Interior Solvent Type, Architectural Lacquers and Architectural Coatings N.S.K.:

$$\begin{aligned}
 &\text{Solvent} \\
 &\text{Based} = 70,109 + 56,442 + 5,793 + 13,957 \\
 &\text{Paints} \\
 &= 146,301 \text{ thousand gallons of paints}
 \end{aligned}$$

The calculation to obtain the number of gallons of water based paints totals the gallons for Exterior Water Type and Interior Water Type:

$$\begin{aligned}
 &\text{Water} \\
 &\text{Based} = 154,777 + 297,729 \\
 &\text{Paints} \\
 &= 452,506 \text{ thousand gallons of paints}
 \end{aligned}$$

The per capita usage factor is calculated by dividing the total usage of solvent based paints by the U.S. population, and the total usage of water based paint by the U.S. population.

$$\begin{aligned}
 &\text{Per Capita Solvent} \\
 &\text{Based Usage Factor} = \text{Gallons of Solvent Based Paints/Population} \\
 &= 146,301,000/248,709,873 \\
 &= 0.59 \text{ gallons per person}
 \end{aligned}$$

For water based paints:

$$\begin{aligned}
 &\text{Per Capita Water} \\
 &\text{Based Usage Factor} = \text{Gallons of Water Based Paints/Population} \\
 &= 452,506,000/248,709,873 \\
 &= 1.82 \text{ gallons per person}
 \end{aligned}$$

TABLE 5-1
QUALITY AND VALUE OF SHIPMENTS OF PAINT AND ALLIED PRODUCTS: 1993 AND 1992

Product Code	Product Description	1993 Quantity	Value	1992 Quantity	Value
2851 --	Paint and allied products ^a	1,103,693	14,140,288	1,228,531	13,538,654
	Architectural coatings	598,807	5,504,636	571,022	5,252,250
	Exterior solvent type	70,109	779,207	71,238	799,293
28511 12	Solvent thinned paints and tinting bases, including barn and roof paints	15,058	166,880	15,787	183,423
28511 15	Solvent thinned enamels and tinting bases, including exterior-interior floor enamels				
28511 25	Solvent thinned undercoaters and primers	8,636	91,568	8,360	85,959
28511 35	Solvent thinned clear finishes and sealers	6,725	71,569	5,598	60,905
28511 37	Solvent thinned stains, including shingle and shake	14,086	138,787	16,183	159,863
28511 39	Other exterior solvent thinned coatings, including bituminous paints	11,884	136,797	11,576	140,629
	Exterior water-type	154,777	1,402,586	143,065	1,285,217
28511 41	Water thinned paints and tinting bases, including barn and roof paints	109,947	1,050,478	103,649	976,944
28511 42	Water thinned exterior-interior deck and floor enamels	1,674	17,755	1,633	17,011
28511 44	Water thinned undercoaters and primers	7,642	74,489	6,281	60,614
28511 49	Water thinned stains and sealers	7,724	66,570	6,520	53,907
28511 55	Other exterior water thinned coatings	27,790	193,294	24,982	176,741
	Interior solvent type	56,442	650,240	53,612	630,792
28511 63	Flat solvent thinned wall paints and tinting bases, including mill white paints	6,661	80,014	6,614	78,016
28511 65	Gloss and quick drying enamels and other gloss solvent thinned paints and enamels	4,330	59,199	3,842	52,274

TABLE 5-1

(CONTINUED)

Product Code	Product Description	1993 Quality	Value	1992 Quality	Value
28511 69	Semigloss, eggshell, satin solvent thinned paints and tinting bases	14,491	152,759	14,191	151,072
28511 71	Solvent thinned undercoaters and primers	9,558	84,326	8,240	77,790
28511 75	Solvent thinned clear finishes and sealers	9,426	124,693	9,334	133,820
28511 77	Solvent thinned stains	5,272	73,401	5,701	75,529
28511 79	Other interior solvent thinned coatings	6,704	75,848	5,690	62,291
	Interior water-type	297,729	2,451,662	284,098	2,328,621
28511 81	Flat water thinned paints and tinting bases	142,557	1,012,016	141,039	1,042,288
28511 83	Semigloss, eggshell, satin, and other water thinned paints and tinting bases				
28511 86	Water thinned undercoaters and primers	17,759	129,322	17,348	126,399
28511 88	Other interior water thinned coatings, stains, and sealers	26,434	232,847	24,232	213,271
28511 93	Architectural lacquers	5,793	56,856	5,879	56,817
28511 00	Architectural coatings N.S.K.	13,957	164,085	13,130	151,510

Source: Bureau of the Census Report MA 28F - Paint and Allied Products

N.S.K. = Not specified by kind.

^aRepresents total shipments for those establishments producing paint and allied product that have 20 or more employees. establishments represent approximately 95 percent of the total value of shipments for SIC industry 2851, paint, varnishes, enamels, and allied products based on relationships observed in the 1992 Census of Manufactures preliminary report.

These lacquers,

The following is a description of how emission factors for different coatings may be developed:

- Multiply the VOC content percentage times the amount used for each of the types of architectural surface coatings to produce an emission estimate for each of the types of coatings.
- Separately sum the VOC emission estimates for the solvent based coating types, and the water based coating types. Separately sum the amounts used of the solvent and the water based coatings.
- Divide the two VOC emission estimates by the total amounts of either solvent based or water based coating used. The result, in the form of emissions per gallon, is the emission factor for either solvent or water based coatings (see Example 5-2).

Example 5-2:

The equation to develop an emission factor for water-based architectural surface coatings is:

$$EF_w = \left[\sum_{c=1}^i ef_c * SC_c \right] \div \left[\sum_{c=1}^i SC_c \right]$$

where:

EF_w	=	Emission factor for all water based surface coatings
ef_c	=	Emission factor for each coating (c) in lb/gal
SC_c	=	Amount of coating (c) used in gal

- For solvent based paints, the equation to calculate emissions is:

$$\text{VOC Emissions From Solvent Based Coatings} = \text{Population} * \text{Solvent Usage Factor} * \text{Solvent VOC Emission Factor}$$

- For water based paints, the equation to calculate emissions is:

$$\text{VOC Emissions from Water Based Coatings} = \text{Population} * \text{Water Based Usage Factor} * \text{Water Based VOC Emission Factor}$$

- Add the two emission estimates to get the total VOC emissions from the category.
- When an emission factor is being calculated using regulatory limits, it is possible that the limits are expressed as a range rather than a single value. In that case, the upper bound of the limit should be used to calculate the emission factor. This is in keeping with the very conservative approach that this methodology represents.
- Use the speciation profiles at the end of this section to calculate HAP emissions from architectural surface coatings.
 - Multiply the percentage of the individual HAP for either solvent- or water-based paints with the amount of VOC calculated for that type of coating (see Example 5-3).

Example 5-3:

$$\text{Benzene Emissions from Water Based Coatings} = \text{VOC Emission Estimate for Water Based Coatings} * 0.003$$

Table 5-2 lists the emission factors for architectural surface coatings. Tables 5-3 and 5-4 list the VOC species profiles for water- and solvent-based architectural surface coating species, respectively.

TABLE 5-2**EMISSION FACTORS FOR ARCHITECTURAL SURFACE COATINGS (EPA, 1993A)**

Coating Type	VOC Content (lb/gal)
Water-based coatings	0.74
Solvent-based coatings	3.87

TABLE 5-3**VOC SPECIES PROFILE FOR WATER-BASED ARCHITECTURAL SURFACE COATING
(CARB, 1991)**

Species	Weight Fraction
Benzene ^a	0.0030
n-Butyl alcohol	0.2000
2-(2-Butoxyethoxy)-ethanol	0.0070
2-Butyltetrahydrofuran	0.0010
1-Chlorobutane	0.0220
3-(Chloromethyl)-heptane	0.0060
n-Decane	0.0020
Dibutyl ether	0.0020
Dichloromethane ^a (methylene chloride)	0.0550
Ethyl chloride ^a	0.0060
2-Ethyl-1-hexanol	0.0100
1-Ethoxy-2-propanol	0.0140
Ethylene glycol ^a	0.0050
1-Heptanol	0.0070

TABLE 5-3
(CONTINUED)

Species	Weight Fraction
Hexylene glycol	0.0140
Isoamyl isobutyrate	0.0030
Methyl chloride	0.0050
Methyl isobutyrate	0.0010
Propylcyclohexanone	.0100
Substituted C7 ester (C12)	.2690
Substituted C9 ester (C12)	.2850
n-Undecane	.0010
Undecane isomers	.0100

^aHazardous air pollutant listed in Clean Air Act Amendments of 1990.

TABLE 5-4

**VOC SPECIES PROFILE FOR SOLVENT-BASED ARCHITECTURAL
SURFACE COATING (CARB, 1991)**

Species	Weight Fraction
Acetone	0.0320
n-Butyl acetate	0.0250
n-Butyl alcohol	0.0160
Cyclohexane	0.2070
Dimethyl formamide ^a	0.0050
2-Ethoxyethyl acetate	0.0130
Ethyl alcohol	0.0060
Ethylbenzene ^a	0.0430
Ethylene glycol ^a	0.0060
n-Hexane	0.2070
Isobutyl acetate	0.0150
Isobutyl alcohol	0.0060
Isobutyl isobutyrate	0.0610
Isomers of xylene ^a	0.0260
Isopropyl alcohol	0.1640
Methyl alcohol	0.0390
Methyl ethyl ketone ^a	0.0560
Methyl isobutyl ketone ^a	0.0060
Methyl n-butyl ketone	0.0070
Propylene glycol	0.0080
Toluene	0.0520

^aHazardous air pollutant listed in Clean Air Act Amendments of 1990.

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6

QUALITY ASSURANCE/QUALITY CONTROL

When using the preferred method, the survey planning, sample design, and data handling should be planned and documented in the inventory QA/QC plan. Refer to the discussion of survey planning and survey QA/QC in Chapter 1 of the volume.

Data handling for the survey data and for data collected for the alternate methods should also be planned and documented in the inventory QA/QC plan and do not involve any category-specific issues. Please consult the EIIP volume on inventory QA/QC for more information.

EMISSION ESTIMATE QUALITY INDICATORS

The preferred method gives higher quality estimates than either of the alternative methods, but requires significantly more effort. The level of effort required to calculate emissions using either of the alternative methods ranges from 8-40 hours. Conducting a survey requires between 100 to 800 hours depending on the size of inventory region and the desired level of detail of the survey. However, the resultant increase in the quality may justify this expenditure of resources, especially if this category is believed to be a significant contributor to emissions. Emissions from architectural surface coatings are typically among the top ten area sources of VOCs and HAPs in urban areas.

DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The DARS scores for each method are summarized in Tables 6-1, 6-2, and 6-3. A range of scores is given for the preferred method because the scores are dependent on the representativeness, sample size, and other survey characteristics. All scores assume that good QA/QC measures are performed and that no significant deviations from the prescribed methods have been made. If these assumptions are not met, new DARS scores should be developed according to the guidance (Beck, et. al., 1994).

The preferred method gives higher DARS scores than either of the alternative methods. The two alternative methods have composite scores in the 0.3-0.4 range while the preferred method scores vary from 0.64 to 0.96. Furthermore, the scores on all attributes are higher compared to the alternatives. The alternative methods have similar composite scores, but the composite measurement and source specificity attribute scores are quite different.

TABLE 6-1

**PREFERRED METHOD DARS SCORES: SURVEY OF COATING USE
BY TYPES IN THE INVENTORY REGION**

Attribute	Scores			Comment
	Factor	Activity	Emissions	
Measurement	0.7-0.9	0.7-0.9	0.64-0.81	Sample size and representativeness of sample determine score.
Source Specificity	1.0	1.0	1.0	Assumes that survey is specific to source category and inventory region.
Spatial	0.8-1.0	0.8-1.0	0.64-1.0	A 1.0 is appropriate if survey is region specific; lower value given if factor or activity extrapolated from a larger or smaller region.
Temporal	0.7-1.0	0.7-1.0	0.49-1.0	High value applies if sample uses data from inventory target year; lower value if sample data are from a different year.
Composite Scores	0.80-0.98	0.80-0.98	0.69-0.95	

TABLE 6-2**ALTERNATIVE METHOD DARS SCORES: NATIONAL FACTORS APPLIED TO NATIONAL PER CAPITA USAGE**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.8*	0.7	0.56
Source specificity	0.7	0.5	0.35
Spatial	0.5	0.5	0.25
Temporal	0.7**	0.7**	0.49
Composite Scores	0.68	0.6	0.41

TABLE 6-3**ALTERNATIVE METHOD DARS SCORES: REGULATORY LIMITS APPLIED TO NATIONAL PER CAPITA USAGE**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.1*	0.7	0.07
Source specificity	0.6	0.5	0.3
Spatial	0.8	0.5	0.4
Temporal	0.7**	0.7**	0.49
Composite Scores	0.55	0.6	0.32

* Score assumes total VOC factor is used; if this is speciated to get HAPs, score should be lowered.

** Assumes factor/activity data year different than inventory year but not by much.

SOURCES OF UNCERTAINTY

The uncertainty of the emission estimates can be quantified if the preferred method is used (See QA Source Document, Chapter 4). However, the statistics needed to quantify the uncertainty of either alternative method are incomplete. The variability of paint use per capita is not well defined. Per capita usage may be lower than the national average in urban areas of high-density housing, in milder climates, or where wooden buildings are not common. For example, a survey of paint use in the New York City area resulted in per capita consumption 25 percent lower than the national average (Leone, et al., 1987), presumably due to the predominance of high-density housing in the city. Paint use may be higher in corrosive environments (such as near salt water) or in areas where wooden structures predominate.

The solvent content of paint is also variable. The VOC contents shown in Table 5-2 are weighted means for the two general categories shown. The unweighted mean and standard deviation for water-based coatings is 2.22 ± 1.9 lb/gal; for solvent-based coatings, the unweighted mean and standard deviation is 4.0 ± 1.07 lb/gal. The weighted means account for the proportions of primers, sealers, lacquers, and so forth used nationally, and if these proportions do not vary regionally, the national factor will be representative of local conditions. Therefore, the preferred method should be used wherever local conditions suggest that either the total quantity of paint used or the type of paints used are very different from the average.

The use of regulatory emission limits is likely to be biased because solvent content can be lower than the limit. The true emissions are likely to be lower than the limit. However, because the national factor is an average, it may either overestimate or underestimate emissions in a given area.

7

DATA CODING PROCEDURES

This section describes the codes available to characterize architectural surface coating emission estimates. Consistent categorization and coding will result in greater uniformity between inventories. Inventory planning for data collection calculations and inventory presentation should take the data formats presented in this section into account. Available codes and process definitions may impose constraints or requirements on the preparation of emission estimates for this category.

PROCESS AND CONTROL CODES

The source category process codes for architectural surface coating operations are shown in Table 7-1. These codes are derived from the EPA's Aerometric Information Retrieval System (AIRS) AMS source category codes (EPA, 1994). The control codes for use with AMS are shown in Table 7-2. The "099" control code can be used for miscellaneous control devices that do not have a unique identification code. The "999" code can be used for a combination of control devices where only the overall control efficiency is known.

Typically, the source category code for "total all solvent types, architectural surface coating" will be used. Low solvent or water-borne coatings will be the control method, so either control device code 101 or 103 will be used.

TABLE 7-1
AIRS AMS CODES FOR ARCHITECTURAL SURFACE COATING

Process Description	AMS Code
Total: All Solvent Types	24-01-001-000
Solvent — General	24-01-001-999
Acetone	24-01-001-030
Butyl Acetate	24-01-001-055
Butyl Alcohols: All Types	24-01-001-060
n-Butyl Alcohol	24-01-001-065
Isobutyl Alcohol	24-01-001-070
Diethylene Glycol Monobutyl Ether	24-01-001-125
Diethylene Glycol Monoethyl Ether	24-01-001-130
Diethylene Glycol Monomethyl Ether	24-01-001-135
Ethyl Acetate	24-01-001-170
Ethylene Glycol Monoethyl Ether (2-Ethoxyethanol)	24-01-001-200
Ethylene Glycol Monomethyl Ether (2-Methoxyethanol)	24-01-001-210
Ethylene Glycol Monobutyl Ether (2-Butoxyethanol)	24-01-001-215
Glycol Ether: All Types ^a	24-01-001-235
Isopropanol	24-01-001-250
Methyl Ethyl Ketone ^a	24-01-001-275
Methyl Isobutyl Ketone ^a	24-01-001-285
Special Naphthas	24-01-001-370
Xylenes ^a	N/A ^b

^aHazardous Air Pollutant listed in the Clean Air Act Amendments of 1990.

^bN/A = No AMS source code assigned.

TABLE 7-2
AIRS CONTROL DEVICE CODES

Control Device	Code
Process Modification — Low Solvent Coatings	101
Process Modification — Powder Coatings	102
Process Modification — Water-Borne Coatings	103
Miscellaneous Control Device	099
Combination Control Efficiency	999

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8

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DRY CLEANING

Final Report

May 1996



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Prepared for:
Area Sources Committee
Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

This chapter describes the procedures and recommended approaches for estimating emissions from dry cleaning. Section 2 of this chapter contains a general description of the dry cleaning category and an overview of available control technologies. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred method for emission estimation for dry cleaning, and Section 5 presents the alternative emission estimation techniques. Quality assurance issues and emission estimate quality indicators for the methods presented in this chapter are discussed in Section 6. Data coding procedures are discussed in Section 7, and Section 8 is the reference section.

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2

SOURCE CATEGORY DESCRIPTION

The dry cleaning industry is a service industry for the cleaning of garments, draperies, leather goods, and other fabric items. Dry cleaning operations do not use water that can swell textile fibers but typically use either synthetic halogenated or petroleum distillate organic solvents for cleaning purposes. Use of solvents rather than water prevents wrinkles and shrinkage of fabrics. The dry cleaning industry is the most significant emission source of perchloroethylene (PERC) in the United States.

The two major types of dry cleaning operations are coin-operated (coin-op) (Standard Industrial Classification [SIC] Code 7215) and commercial (SIC 7216). Industrial launderers (SIC 7218) are usually associated with soap and detergent cleaning, but also use large-capacity dry cleaning units. Coin-operated dry cleaning units are self-service machines that are usually found in laundromats. Commercial dry cleaners are independent small businesses that offer dry cleaning services to the public. Some commercial dry cleaning businesses provide numerous drop-off/pick-up outlet stores that are serviced by a single dry cleaning plant, and thus some sites identified as dry cleaners may not be emissions sources. Industrial launderers who use dry cleaning solvents are usually part of a business operation that generates soiled fabrics, where it is convenient or cost-effective to perform dry cleaning on site. Industrial launderers can also be large businesses that provide uniform and other rental services to business, industrial, and institutional customers.

The primary synthetic halogenated dry cleaning solvent is PERC; small quantities of 1,1,1-trichloroethane (TCA) and trichlorofluoroethane (CFC-113) are used in specialty cleaning operations. The petroleum solvents most used in dry cleaning are a mixture of paraffins and aromatic hydrocarbons. Stoddard solvent (mineral spirits) is the primary petroleum solvent used in dry cleaning. PERC is used for its aggressive solvent properties, whereas CFC-113 is well suited for cleaning delicate clothing. TCA is a more aggressive solvent than PERC, but may damage some clothing and must be used in stainless steel dry cleaning machines.

Dry cleaning facilities may be point or area sources. Most coin-op and commercial dry cleaners are expected to be area sources. Commercial dry cleaners are responsible for the greatest amount of emissions. Industrial launderers that do dry cleaning are expected to be point sources except for a few facilities. Point source emissions must be subtracted from total emissions to produce an estimate of dry cleaning area source emissions.

2.1 EMISSION SOURCES

Volatile organic solvents that are used as cleaning solvents are emitted during the dry cleaning process. The petroleum solvents most commonly used in dry cleaning are Stoddard solvent (mineral spirits) and 140-F (EPA, 1985). The synthetic solvents that are used in dry cleaning, PERC, TCA, and CFC-113, are not considered photochemically reactive and should not be included in an ozone (volatile organic compound [VOC]) inventory; PERC and TCA, however, are hazardous air pollutants (HAPs) that should be included in an air toxic inventory. TCA and CFC-113 are ozone-depleting substances (ODSs), and CFC-113 may be listed in some state regulations as a toxic air pollutant.

It is estimated that 82 percent of all dry cleaning facilities use PERC, 15 percent use petroleum solvents, 3 percent use CFC-113, and less than 1 percent use TCA (EPA, 1991a). However, based on a study of national solvent use, 57 percent of all dry cleaning solvents are petroleum solvents (primarily mineral spirits), 39 percent of the solvents are PERC, and 3 and 1 percent are TCA and CFC-113, respectively, with a minor amount of unspecified solvents (Frost & Sullivan, 1990). Small dry cleaning facilities, such as coin-operated sites use PERC exclusively, and larger facilities, such as commercial facilities use petroleum solvents, resulting in this disparity.

2.2 FACTORS INFLUENCING EMISSIONS

Emissions from dry cleaning operations are influenced by the type of dry cleaning machines used. Dry cleaning machines are either dry-to-dry or transfer machines. In the dry-to-dry process, both washing and drying takes place in one machine. Dry-to-dry machines are either vented during the drying cycle or are ventless, where emissions occur only during loading and unloading operations. With transfer machines, the material is washed in one machine and manually transferred to another machine to dry. Emissions occur during the transfer as well as from the washer and dryer vents. Facilities using petroleum solvents have typically used transfer machines. Transfer units are an older technology; all the demand for new equipment in the dry cleaning industry is for dry-to-dry machines. Some petroleum solvent dry-to-dry machines are now being produced in the United States and Europe, and may become more significant in the industry in the future.

Most facilities using PERC use dry-to-dry machines. CFC-113 is used exclusively in dry-to-dry systems. Because petroleum solvents are flammable and may form explosive mixtures, their use has been limited to transfer machines where the solvent concentration in vapors do not build up to high levels. However, commercial petroleum solvent dry-to-dry machines are now being manufactured. National Fire Protection Association codes may limit the locations, such as shopping centers, that petroleum solvents can be used.

In facilities that use PERC, solvents recovered during the dry cleaning process are usually filtered and distilled for recycling back to the process. Emissions occur from the equipment, such as filters, muck cookers, oil cookers, and other stills, that is used to filter and distill the dirty solvent. Filters may be reusable or the cartridge type that is drained, air dried, and discarded. With petroleum solvents, the residue (muck) is drained of excess solvent, air dried, and discarded. Because of the low cost of petroleum solvents, recycling is not emphasized at dry cleaning facilities using these solvents.

Industrial launderers usually have efficient recycling and recapture procedures. Most industrial and commercial cleaners use off-site solvent recycling businesses for solvent waste recovery and disposal services, whereas few coin-op dry cleaners utilize these services.

Solvent use is dependent upon the amount of material cleaned. Transfer machines can have a much larger capacity than dry-to-dry units, and therefore involve the use of more solvents. In general, industrial dry cleaning machines are larger than both commercial and coin-op machines, with commercial units larger than coin-op units. Coin-op units usually have a capacity of 8 to 25 pounds of clothes per load, with one or two machines per facility. The average capacity of commercial dry cleaning units is 35 pounds, with a range of 15 to 97 pounds per load. Most of these units are dry-to-dry. The average capacity of industrial dry cleaners is 140 pounds per load for dry-to-dry units and 250 pounds per load for transfer units. Most of the industrial units are transfer units, although their use is being phased out as new dry-to-dry units are purchased to replace the older transfer units.

2.3 CONTROL TECHNIQUES

Control strategies for dry cleaners include the use of add-on controls such as refrigerated condensers and carbon adsorbers to capture and reduce emissions from dry cleaning machine air vents. Emission control is also achieved through changes in operational practices to reduce fugitive emissions. Examples of changes in operational methods include prompt detection and repair of leaky valves, hose connections, and gaskets; storage of solvents and wastewater in tightly sealed containers; and minimization of the time the door of the dry cleaning machine is open.

The Occupational Safety and Health Administration requires that all equipment that uses PERC be enclosed to meet the permissible exposure level for PERC in the workplace. Under the National Emission Standards for Hazardous Air Pollutants (NESHAP) program, the EPA has passed regulations that require the control of emissions for dry cleaning units using PERC. The NESHAP requirements, shown in Table 4.2-1, include the use of refrigerated condensers, leak detection and seal inspection programs, and monitoring and reporting requirements. Coin-op dry cleaning units are exempt from all but the initial reporting NESHAP requirements. Dry cleaning with petroleum solvents will be regulated under

TABLE 4.2-1

NESHAP REQUIREMENTS FOR DRY CLEANING SOURCES OF PERC (58 FR 49354)

Source Size/ Machines	PERC Consumption Limits (gal/yr)	Process Vent Controls		Fugitive Controls	
		Existing	New	Existing	New
Small Area Source					
Dry-to-Dry Transfer Combination	Less than: 140 200 140	None	RC	LDR/SC	LDR/SC and NNT
Large Area Source					
Dry-to-Dry Transfer Combination	Between: 140 - 2,100 200 - 1,800 140 - 1,800	RC or CA ^a	RC	LDR/SC	LDR/SC and NNT
Major Source					
Dry-to-Dry Transfer Combination	More than: 2,100 1,800 1,800	RC or CA ^a	RC/CA	LDR/SC Room enclosure	LDR/SC Room enclosure

^a A carbon adsorber can be used if already in place.

CA = Carbon absorber.

LDR/SC = Leak detection and repair, and storage of PERC in sealed containers.

NNT = No new transfer units.

RC = Refrigerated condenser (or equivalent).

RC/CA = Refrigerated condenser followed by carbon adsorber.

NESHAP in 2000.

Many states also regulate emissions from dry cleaners. Inventory planning for this source category should include inquiries to the local air pollution control authorities about applicable regulations.

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3

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATION METHODOLOGIES

There are several methodologies available for calculating emissions from dry cleaning. The method used is dependent upon the degree of accuracy required in the estimate, available data, and available resources. Since dry cleaning has been one of the top ten largest area sources in area source ozone inventories, this category warrants time and effort in the calculation of emission estimates for it.

This section discusses the methods available for calculating emission estimates from dry cleaning and identifies the preferred method of calculation. A discussion of the data elements needed for each method is provided.

3.1.1 VOLATILE ORGANIC COMPOUNDS AND HAZARDOUS AIR POLLUTANTS

The VOCs emitted from dry cleaning operations are from the solvents used to clean in the dry cleaning process. These VOCs may be emitted from dry cleaning machines during operation of the units or during solvent reclamation processes. There are several approaches to estimating the amount of VOCs emitted from this category, depending on the information sought and the data available.

- Number of facilities or dry cleaning units:
 - Local per facility emission factors (using survey or permit information);
 - Emission factors based on type of machine;
 - National average per facility emission factors;
- Number of employees:
 - Local per employee emission factors (using survey or permit information);
 - National average per employee emission factors;

- Per capita: National average per capita emission factor.

Use caution when applying emission factors that are more than 3 years old, since emission factors can quickly become obsolete due to compliance efforts by the industry.

HAP emissions from this source are determined by the same approaches discussed for VOC emissions, in conjunction with a survey or estimate of the proportion of each solvent type used in the dry cleaning facilities in the inventory area. The emissions of each HAP are assumed to be proportional to the amount of each HAP used as solvent.

The preferred approach depends on the type of dry cleaning facilities for which emissions are being estimated. Table 4.3-1 summarizes these options.

3.1.2 AVAILABLE METHODOLOGIES

Coin-op

Please note that coin-op dry cleaners use PERC. For a VOC inventory, coin-op dry cleaners may not need to be inventoried. Also, all dry cleaners using PERC have been required under the dry cleaning NESHAP to report to their EPA Regional Office a description of each dry cleaning machine and the amount of PERC used. For a facility designated as a "small area source" (see Table 4.2-1), only PERC used in 1994 needs to be reported (58 FR 49354). Individual states may have more stringent rules requiring more detailed information.

For coin-op dry cleaners, development and use of a local per facility emission factor is the preferred method. Data collected under the dry cleaning NESHAP can be used if it reflects current local conditions. If a local per facility emission factor cannot be developed for coin-op dry cleaners, a locally developed per dry cleaning unit emission factor for commercial dry cleaners can be used as the first alternative method. If this approach is not practical, then the national per employee emission factor for dry cleaning is recommended. County employment data are the best source of the total number of employees. The third alternative method is a survey of the number of dry cleaning units in the inventory area, used with the corresponding appropriate emission factors. The effectiveness of any of these methods will depend on how well the activity and emission factors used or developed reflect all of the local conditions.

Commercial and Industrial Dry Cleaners

For commercial dry cleaners and industrial launderers, development of a per facility solvent consumption factor is the preferred approach. For this method, the number of facilities in the area must be obtained. NESHAP requirements promulgated in 1993 (58 FR 49354) require

TABLE 4.3-1

**PREFERRED AND ALTERNATE METHODS FOR ESTIMATING
EMISSIONS FROM DRY CLEANING FACILITIES**

Methods	Coin-op (SIC 7215)	Commercial (SIC 7216)	Industrial Laundries (SIC 7218)
Preferred Method	Survey a subset of facilities for the amount of solvent used, using data collected under the dry cleaning NESHAP, if it reflects current local conditions. Develop a per facility emission factor, based on either total solvent use by facility or solvent used by dry cleaning unit.	Survey a subset of facilities for the amount of solvent used, using data collected under the dry cleaning NESHAP. Develop a per facility emission factor, based on either total solvent use by facility or solvent used by dry cleaning unit.	Survey a subset of facilities for the amount of solvent used, using data collected under the dry cleaning NESHAP. Develop a per facility emission factor, based on either total solvent use by facility or solvent used by dry cleaning unit.
Alternative Method 1	Use the per dry cleaning unit emission factor developed for commercial laundries (see next column).	Survey a subset of facilities for the amount of solvent used and the number of employees. Develop a per employee emission factor.	Survey a subset of facilities for the amount of solvent used and the number of employees. Develop a per employee emission factor.
Alternative Method 2	Use the national average per employee emission factor.	Use the national average per employee emission factor.	None ^a
Alternative Method 3	Use the national average per facility emission factor.	None	None

^a There is no national average per employee emission factor for industrial laundries.

reporting of this information by commercial and industrial PERC dry cleaning facilities on an annual basis to the EPA Regional Office. The amount of solvent sent to off-site recycling should also be determined to estimate emissions. The first alternative method to estimate emissions for these categories is to use locally developed per employee emission factors. National emission factors can be used if local factors cannot be developed. A survey of the number of dry cleaning units can be used as another alternative method, as discussed above for coin-op dry cleaners. Industrial dry cleaners often use large dry cleaning units that may emit more than 10 tons/yr per unit. Inventory preparers should be careful that these industrial facilities and larger commercial facilities are treated as point sources.

All Cleaners

To determine the total emissions from dry cleaning in an inventory area, emissions from each of the types of dry cleaning are summed. All procedures discussed above must account for point source emissions.

3.2 DATA NEEDS

3.2.1 DATA ELEMENTS

The data elements needed to calculate emission estimates for dry cleaning sources will depend on the methodology used for data collection. The data elements that are needed for each emission estimation technique are presented in Table 4.3-2.

Some of the data elements in Table 4.3-2 are listed as "optional." Inventory preparers will need to consider current and future needs for the current and possibly other inventories. If the preferred methods are used, the extra work of collecting additional information will be small in comparison to repeating the survey effort later.

The number of employees and plants can be determined from local employment offices. The consumption data can be obtained from a limited survey of representative facilities.

3.2.2 ADJUSTMENTS TO EMISSION ESTIMATES

Data needs for adjustments to emission estimates are presented in Table 4.3-3. Any of these adjustments may be necessary, depending on the type of inventory being prepared. For instance, projections or temporal resolution may not be necessary for an annual inventory.

Point Source Corrections

The dry cleaning source category can include point and area sources. Because methods presented in this chapter may be used to estimate emissions from the entire source category,

TABLE 4.3-2
DATA ELEMENTS NEEDED FOR EACH METHOD

Data Element	Local Per Employee Emission Factor (from a survey)^a	Local Per Facility or Per Unit Emission Factor (from a survey)^a	National Average Emission Factors	Local Per Employee Emission Factor for Commercial and Industrial Dry Cleaners
Survey Information:				
Types of solvents used	X	X		
Amount of solvent used (purchased - shipped off-site)	X	X		
Amount of solvent shipped off-site	Optional ^b	Optional ^b		
Number of employees for each surveyed facility site	X	X		
Number of employees for inventory area for the SIC	X	X		
Number of dry cleaning units for a facility	Optional	X		
Type of dry cleaning units for a facility	Optional	X		
Control types and efficiencies for each equipment type	Optional	Optional		
Number of facilities in an inventory area for the SIC	Optional	X		
Emission Factor Methods:				
Local per employee factor				X
Number of employees or facilities for inventory area for the SIC			X	X
National average per employee or per facility factor			X	

^a If information collected under the NESHAP requirements is available, it should be the preferred and most accurate data source. If this is not available, survey a subset of facilities. See Volumes I and VI of this series and Chapter 1 of this volume for more information about surveys.

^b Collection of this information is optional, but it is needed for the most accurate results.

TABLE 4.3-3

DATA NEEDS FOR EMISSION ESTIMATE ADJUSTMENTS

Data Element	Local Per Employee Emission Factor (from a survey)	Local Per Facility or Per Unit Emission Factor (from a survey)	National Average Emission Factors	Local Per Employee Emission Factor for Commercial and Industrial Dry Cleaners
Point Source Corrections:				
Point source emissions	Alternate	Preferred	Alternate	Alternate
Point source employment for inventory area for the SIC	Preferred		Preferred	Preferred
Application of Controls:				
Control efficiency (CE)	X	X	X	X
Rule effectiveness (RE)	X	X	X	X
Rule penetration (RP)	X	X	X	X
Spatial Allocation:				
Employment	Preferred		Preferred	Preferred
Number of facilities	Alternate 1	Preferred	Alternate 1	Alternate 1
Population of inventory area	Alternate 2	Alternate 1	Alternate 2	Alternate 2
Temporal Resolution:				
Seasonal throughput	X	X	X	X
Operating days per week	X	X	X	X
Operating hours per day for representative facilities	Optional	Optional	Optional	Optional

TABLE 4.3-3

(CONTINUED)

Data Element	Local Per Employee Emission Factor (from a survey)	Local Per Facility or Per Unit Emission Factor (from a survey)	National Average Emission Factors	Local Per Employee Emission Factor for Commercial and Industrial Dry Cleaners
Projection:				
Projection year precontrol emission factors	X	X		
Projection year CE	X	X	X	X
Projection year RE	X	X	X	X
Projection year RP	X	X	X	X
Projection year growth factor	X	X	X	X

the total emission estimate should be corrected for the amount contributed by the point sources.

There are two ways to correct for point source contributions, and the choice of approach depends on the method used to estimate emissions and the data available. The two methods are either to correct the activity level, such as the number of employees used with an employee-based emission factor, or to subtract the point source emissions from the total calculated emissions. If the inventoried point source emissions are greater than the total estimated emissions, set the area source emissions to zero.

Table 4.3-3 lists the two point source correction methods and shows which is preferred and which is an alternative for each emission estimation method. The procedure for correcting the activity level, such as employment, is shown below.

The general equation to correct activity for point sources is:

$$\text{Total Employees at Area Sources} = \left[\text{Total Employees in Dry Cleaning} \right] - \left[\text{Total Employees at Point Sources} \right] \quad (4.3-1)$$

This information may be available from the point source inventory. Be sure to count employment by SIC Code. Match employees of point source commercial facilities (SIC Code 7216) to total commercial employment, and point source coin-op facilities (SIC Code 7215) with total coin-op employment.

If the number of employees at point sources is not known, an alternative method can be used to estimate this value, as follows:

- Use data from the state labor department or *County Business Patterns*^a to determine the total number of employees reported for SIC 7215 for each dry cleaning facility in each county in the inventory region.
- Use the region's point source files to obtain the number of point sources in the inventory region; if this is not available, then:
 - Use an inventory that lists dry cleaning facilities and their total emissions and determine the number of facilities above the emission

^a See the most recent publication, which can be obtained from the U.S. Bureau of Census, Department of Commerce, Washington, DC.

cutoff for point sources. This is dictated by the type of inventory; for ozone (VOC) State Implementation Plan (SIP) 1990 base year inventories, the cutoff was 10 tons of VOC per year.

- In the *County Business Patterns*, the number of employees can be determined from information presented as the number of facilities with a total number of employees in a specified range. The total number of employees for all the facilities listed in each range can be estimated by the midpoint of the indicated size range. The following example illustrates this technique:

Example 4.5-1:

If an inventory for the region contains five dry cleaning point sources, and the top five dry cleaning facilities by total employment in the *County Business Patterns* for dry cleaning in the region are distributed as follows: three facilities in the 100 to 149 employees per facility size range and two facilities in the 50 to 99 employee per facility size range, then the total number of employees for point sources can be calculated using the midpoint of the employee size ranges, as in the equation below:

$$\begin{array}{l} \text{Total Employees} \\ \text{at Point Sources} \end{array} = \left[3 \frac{(100 + 149)}{2} + 2 \frac{(50 + 99)}{2} \right] = 3(124.5) + 2(74.5) = 523$$

Assume that point sources correspond to the facilities with the highest number of employees. Start with the facilities with the largest number of employees and sum the number of employees at the largest facilities for as many facilities as there are point sources of dry cleaning in the county for the desired SIC.

Application of Controls

Since the level of control required by regulation is usually determined by factors of individual facility size, type of solvent, and/or machine type, it will be difficult to determine the exact reduction in emissions with controls unless a survey is performed and information on the type of machine is gathered. Information on the age of the units, type and amount of solvent used, and current controls in place may also be needed to estimate the level of control in place. See the section below on projecting emissions to see the calculation for the application of controls.

Spatial Allocation

The spatial allocation of dry cleaning emissions by county can be performed using local population data. If a detailed survey is performed to estimate emissions, the spatial allocation of emissions can be performed according to facility location, as with the point source inventory, or with local employment data. If urban versus rural population is known, urban population should be used to allocate dry cleaning emissions. Urban and rural population information can be found in *Population and Housing Unit Counts*^b from the U.S. Census Bureau.

Temporal Resolution

Seasonal Apportioning. Dry cleaning emissions do not demonstrate differences in activity from season to season (EPA, 1991a). The seasonal activity factor that should be used for this category is 1.0; activity takes place 52 weeks in the year.

Daily Resolution. Commercial and industrial dry cleaning businesses are open 5 to 6 days a week. Commercial cleaners are usually open 12 hours a day (starting from 6 or 7 a.m.) but may only actually do cleaning from 6 to 11 a.m. Industrial dry cleaners may run two shifts, i.e., 16 hours a day. Coin-op cleaners are open 6 to 7 days a week and may operate anywhere from 12 to 24 hours a day (Agyei, 1994; EPA, 1991b). The preferred method for daily resolution is to collect representative information from industrial, commercial, and coin-op facilities. The alternative method is to assume that activity takes place during a 5-day week (EPA, 1991a).

3.3 PROJECTING EMISSIONS

The number of employees or facilities can be adjusted to project future emissions, assuming that there is no change in the basic processes or chemicals that are used. These data may be obtained from information on projected revenue growth in the industry and correlation of revenue to number of employees or facilities.

The equation for projecting emissions in this case is:

^b See the most recent publication, which can be obtained from the U.S. Bureau of Census, Department of Commerce, Washington, DC.

$$\text{EMIS}_{\text{PY}} = \text{ORATE}_{\text{BY,O}} * \text{EMF}_{\text{PY,pc}} * \left[1 - \left(\frac{\text{CE}_{\text{PY}}}{100} \right) \left(\frac{\text{RP}_{\text{PY}}}{100} \right) \left(\frac{\text{RE}_{\text{PY}}}{100} \right) \right] * \text{GF} \quad (4.3-2)$$

where:

EMIS_{PY}	=	Projection year emissions
$\text{ORATE}_{\text{BY,O}}$	=	Base year operating rate for each production unit
$\text{EMF}_{\text{PY,pc}}$	=	Projection year precontrol emissions factor (mass of pollutant/ production unit)
CE_{PY}	=	Projection year control efficiency (percent)
RP_{PY}	=	Projection year rule penetration (RP) (percent)
RE_{PY}	=	Projection year rule effectiveness (RE) (percent)
GF	=	Growth factor (dimensionless)

The precontrol emission factor ($\text{EMF}_{\text{PY,pc}}$) reflects the mass of pollutant per production unit emitted before control (EPA, 1993). Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development*, discusses inventory projections in more detail.

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4

PREFERRED METHODS FOR ESTIMATING EMISSIONS

The preferred method to estimate emissions for coin-op dry cleaners is the development of local per facility or per dry cleaning unit emission factors. For commercial dry cleaners and industrial launderers, a per facility emission factor method is the preferred approach. Unless permit information with actual emission values is available, developing local emission factors requires a survey of a subset of dry cleaning facilities. Please refer to Volume I of this series, Chapter 5, *Inventory Development*, Chapter 1 of this volume, and Volume VI of this series, *Quality Assurance*, for more detailed information about using surveys.

4.1 SURVEY PLANNING

A sample survey cover sheet and form is included in Figures 4.4-1 and 4.4-2. Recommended data elements to be requested on the forms are:

- Solvent types used;
- Amounts of each type of solvent purchased for inventory year;
- Listing of equipment types at the facility;
- Controls in place at the facility;
- Operating days per week, hours per day;
- Facility employment; and
- Estimated amount of solvent sent for off-site disposal or recycling.

The remainder of this section describes the preferred method of estimating emissions from all types of dry cleaning sources. Note that total emission estimates for dry cleaners must be adjusted for point sources to estimate area source emissions.

4.2 PER DRY CLEANING UNIT EMISSION FACTOR METHOD

Name of Facility: _____

Street Address: _____

City/State: _____

Contact Person: _____

Telephone Number: _____

Please check the appropriate box describing your operation.

1. Solvent Used	Amount Purchased Annually (gallons)
<input type="checkbox"/> PERC (Perchloroethylene)	_____
<input type="checkbox"/> Petroleum (Stoddard Solvent)	_____
<input type="checkbox"/> Other Petroleum Solvents	_____
<input type="checkbox"/> CFC-113 (Trichlorofluoroethane)	_____
<input type="checkbox"/> TCA (1,1,1-Trichloroethane)	_____
<input type="checkbox"/> Other	_____

FIGURE 4.4-1. SAMPLE SURVEY COVER SHEET

For each machine at your facility, please provide the following information:

Machine Type	Load Capacity (pounds of garments)	Estimated Solvent Use Per Load (gallons of solvent)	Controls in Place
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

For your entire facility, please estimate the amount of solvent sent for off-site disposal or recycling:

Solvent Type	Estimated (gallons/year)
PERC (Perchloroethylene)	_____
Petroleum Solvents:	_____
_____	_____
_____	_____
TCA (1,1,1-Trichloroethane)	_____
CFC-113 (Trichlorofluoroethane)	_____
Other (please specify):	_____
_____	_____
_____	_____

For your facility, please estimate the average days per week and hours per day that dry cleaning equipment is operating:

_____ days per week _____ hours per day

Please list the number of employees at this facility:

_____ employees

FIGURE 4.4-2. SAMPLE SURVEY FORM

The following list identifies the steps involved in developing a local per unit emission factor.

- Identify facilities that would be suitable survey recipients, noting those that are point sources. Facilities can be identified from the local employment office or tax office records; because many of these facilities are small, they do not usually belong to dry cleaning associations. However, as more rules come into place affecting the dry cleaning industry, local information should be easier to collect.
- Conduct a survey of the total number of dry cleaning units and solvent consumed for a representative sample of facilities and develop a per unit emission factor for coin-op dry cleaners. Emission factors that can include the type of dry cleaning machine as well as the method of control will produce a more accurate estimate of emissions, and provide a good basis for projections.
- Determine the total number of coin-op dry cleaning facilities in the inventory region in SIC 7215 from data acquired by state or local labor departments, or *County Business Patterns*. If county figures are not available for 4-digit SICs, state data (which are given in both 2-digit and 4-digit levels) can be used to break county 2-digit levels into 4-digits.
- Scale up the number of dry cleaning units reported in the survey for all of the coin-op facilities in the area.
- Correct for point source facilities by subtracting the number of units at the point source facility sites for this SIC from the estimated total number of area source dry cleaning units.
- Multiply the per unit emission factor obtained by the procedures described above by the estimated number of dry cleaning units in area source facilities of SIC 7215 to obtain an estimate of emissions at dry cleaning area sources.

4.3 PER PLANT CONSUMPTION FACTOR METHOD (COMMERCIAL DRY CLEANERS AND INDUSTRIAL LAUNDERERS)

- Determine the number of facilities in the SIC from local employment offices or dry cleaning trade association.
- Determine average solvent consumption per facility through a survey of a representative number of facilities in the SIC.
- Total solvent consumption is estimated by multiplying the number of facilities times the average solvent consumed per facility.
- For commercial dry cleaners, total emissions are estimated by reducing the total estimated solvent consumption by the average percent of solvent sent off-site for recycling. This amount can either be collected by the survey of facilities, or be obtained from local waste processing and solvent recovery companies that can be identified from the Yellow Pages. A typical plant produces approximately one 55-pound bucket of solvent-laden wastes every 2 months.
- For industrial launderers, total emissions are estimated as a percentage of solvent purchased that cannot be accounted for in its off-site disposal or recycling manifests. If this information is not available, it can be assumed to be 5 percent (Agyei, 1994).
- To obtain area source emissions for commercial or industrial dry cleaners, subtract point source emissions from the total emissions estimated above.

As a gauge of the information returned by the surveys, average annual consumption for commercial dry cleaning facilities with dry-to-dry units is approximately 40 gallons PERC per facility (± 10 percent). Fewer facilities use transfer machines, since these units are being phased out. For transfer machines, the annual PERC consumption rate can be assumed to be in the range of 80 gallons per facility (± 10 percent) for facilities with controls, up to 200 gallons per facility for facilities without controls (Agyei, 1994). Please keep in mind that any projections from this information should reflect this change in equipment type.

In 1993, NESHAP regulations were put into place that require reporting from commercial and industrial PERC dry cleaners (58 FR 49354). Reports include information about the dry cleaning machines used at a facility, and the PERC consumption at that facility. The EPA has distributed this information to their ten Regional Offices. Inventory preparers should contact the Air Toxics Coordinator in the Air Division of their Regional Office for more information.

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5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

The alternative methods for estimating dry cleaning emissions are described below, by industry type.

5.1 METHODS FOR COIN-OP DRY CLEANERS (SIC 7215)

The three alternative methods are, in order of preference:

- Use the per dry cleaning unit factor developed as the first alternate method for commercial dry cleaners (SIC 7216).
- Use the national per employee emission factor.
- Use the national per facility emission factor.

5.1.1 ALTERNATIVE ONE

The first alternative, using the per unit factor that has been developed for commercial dry cleaners, is described in Section 4.2 of this chapter for the commercial dry cleaning category.

5.1.2 ALTERNATIVE TWO

The steps needed to use the second alternative method are as follows:

- Subtract the number of employees at dry cleaning point sources using information acquired from the point source inventory, or use the method for point source correction described in Section 3.2.2 of this chapter. Be sure to match only those employees working at coin-op facilities.
- Multiply the per employee emission factor, either the local commercial per employee factor, or the national per employee factor (listed in Table 4.5-1), by the number of employees in area sources of SIC 7215 to obtain an estimate of emissions at dry cleaning area sources.

TABLE 4.5-1**NATIONAL PER EMPLOYEE EMISSION FACTORS FOR
DRY CLEANING OPERATIONS FROM (EPA, 1991A)**

Subcategory	Reactive VOC (lb/year/employee)	Applicable SIC	Total Organics (lb/year/employee)	Applicable SIC
All solvents (total)	1,800 ^a	7216	2,300 ^b	7215, 7216
Halogenated Solvents (total PERC, TCA and CFC 113)			980 ^c	7215 & 7216
Coin Operated			52 ^c	7215
Commercial/Industrial			1,200 ^c	7216
Mineral Spirits & Other Unspecified Solvents	1,800	7216	1,800	7216

^a Emission factor excludes emissions of PERC, TCA, and CFC 113, and represents only emissions of mineral spirits and other solvents. Thus, this factor is not applicable for coin-operated facilities (SIC 7215) that use exclusively PERC.

^b Total organics are the sum of the PERC, TCA, CFC 113, mineral spirits, and unspecified other solvents.

^c These emission factors would not be used in a VOC inventory, but could be used for an inventory of HAPs. Readers are encouraged to review the source document for more information about these factors (EPA, 1991a).

5.1.3 ALTERNATIVE THREE

The third alternative method is the use of a national average per facility emission factor of 0.8 tons/facility-year (EPA, 1988). Please note that this number is based on the following assumptions:

- The average coin-op facility has two dry cleaning units; and
- Each unit emits 0.4 tons of PERC per year.

The total number of coin-op facilities can be determined using the same method as the one described in Section 4 for the coin-op preferred method. Point source facilities should be subtracted from this total amount of facilities to determine the number of area source facilities. This number is applied to the emission factor to calculate the emission estimate.

5.2 METHODS FOR COMMERCIAL AND INDUSTRIAL DRY CLEANERS (SIC 7216 AND 7218)

For commercial dry cleaners and industrial launderers, the alternative methods are the same for the two industry types, except that the national per employee factor should not be used to estimate emissions from industrial launderers. The two alternative methods are, in order of preference:

- Use a local per employee emission factor developed by surveying a subset of facilities.
- Use a national per employee emission factor (only for commercial dry cleaners).

5.2.1 ALTERNATIVE ONE

The first alternative method, developing a local per employee emission factor, involves sending out a survey to a subset of commercial or industrial laundry facilities in the area. Note that per employee emissions will be significantly different between commercial and industrial laundries, and separate factors for the two should be developed. Survey forms should request solvent use, employment numbers, operating days and hours, equipment types and solvent use, off-site waste disposal, and controls. Emission factors that can incorporate the type of dry cleaning machine as well as the method of control will produce a more accurate estimate of emissions. Be certain that point source emissions are not included in the estimate of area source emissions estimates. See the point source correction discussion in Section 3.2.2.

5.2.2 ALTERNATIVE TWO

The steps needed to use the second alternative method for commercial dry cleaners, using a national per employee emission factor (listed in Table 4.5-1), are similar to the steps required in the first alternative method for commercial dry cleaners and industrial launderers. These steps are:

- Subtract the number of employees at dry cleaning point sources using information acquired from the point source inventory, or using the method described in Section 3.2.2, for point source corrections. Be sure to match only those employees working at commercial facilities to the commercial dry cleaning employment and industrial laundries to industrial laundry employment.

- Multiply the per employee emission factor, either the local per employee factor, or the national per employee factor, by the number of employees in area sources of SIC 7216 to obtain an estimate of emissions at dry cleaning area sources for commercial dry cleaners.
- Multiply the local per employee emission factor by the number of employees in area sources of SIC 7218 to obtain an estimate of emissions at dry cleaning area sources for industrial launderers.

6

QUALITY ASSURANCE/QUALITY CONTROL

When using the preferred method, or alternative survey methods, the survey planning, sample design, and data handling should be undertaken according to the inventory work plan and Quality Assurance/Quality Control (QA/QC) plans. Refer to the discussion of survey planning, QA/QC, and the Data Attribute Rating System (DARS) in Volume I of this series and in the QA volume of this series. No category-specific issues need to be considered.

Data handling for the survey data and for data collected for the other methods should also be undertaken according to the inventory QA/QC plan. Since facilities may use different acronyms or trade names for solvents, and may use different measurement units in describing their operations, care should be taken in the review and collation of the information gathered from the surveys. No other category-specific issues need to be addressed.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

The preferred method and the alternative survey methods give higher quality estimates than the alternative national emission factor method, but require significantly more effort. The level of effort required to calculate emissions using any of the national emission factor methods ranges from 8-40 hours. Conducting a survey requires between 100 to 800 hours depending on the size of inventory region and the desired level of detail of the survey. However, the resultant increase in the quality may justify this expenditure of resources, especially if this category is believed to be a significant contributor to emissions. Emissions from dry cleaning operations, when calculated using national emission factors, are typically among the top ten area sources of VOCs and HAPs in urban areas.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The DARS scores for each method are summarized in Tables 4.6-1 through 4.6-6. A range of scores is given for several of the survey methods because the scores are dependent on the representativeness, sample size, and other survey characteristics.

For example, in Table 4.6-1 the score for the activity data will be at the lower end of the ranges shown if the sample size is small or does not adequately sample facilities of different sizes because the variability in emissions between facilities can be high. Source

TABLE 4.6-1

**PREFERRED METHOD DARS SCORES: SURVEY SIC 7215, 7216,
AND 7218: DEVELOP A LOCAL PER UNIT OR
PER FACILITY EMISSION FACTOR**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.7 - 0.9	0.4 - 0.7	0.28 - 0.54
Source Specificity	1.0	1.0	1.0
Pollutant	0.6 - 1.0	1.0	0.6 - 1.0
Spatial	0.8 - 1.0	0.8 - 1.0	0.64 - 1.0
Temporal	0.7 - 1.0	0.7 - 1.0	0.49 - 1.0
Composite Scores	0.76 - 0.98	0.78 - 0.94	0.60 - 0.92

TABLE 4.6-2

**ALTERNATIVE METHOD 1 FOR SIC 7215 (COIN-OP): USING A LOCAL
COMMERCIAL (SIC 7216) PER DRY CLEANING UNIT EMISSION FACTOR**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.7 - 0.9 ^a	0.5	0.35 - 0.45
Source Specificity	0.5	0.8	0.40
Pollutant	1.0	1.0	1.0
Spatial	0.8	0.9	0.72
Temporal	0.8	0.7	0.56
Composite Scores	0.76 - 0.8	0.78	0.60 - 0.62

^aAssumes a factor developed by the preferred method.

TABLE 4.6-3

ALTERNATIVE METHOD 1 FOR SIC 7216 AND 7218 (COMMERCIAL AND INDUSTRIAL CLEANERS): SURVEY TO DEVELOP A LOCAL PER EMPLOYEE FACTOR

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.7 - 0.9	0.3 - 0.5	0.21 - 0.45
Source Specificity	0.9	0.8	0.72
Pollutant	0.6 - 1.0	1.0	0.6 - 1.0
Spatial	0.8	0.8	0.64
Temporal	0.7 - 1.0	0.7 - 1.0	0.49 - 1.0
Composite Scores	0.74 - 0.92	0.72 - 0.82	0.53 - 0.75

TABLE 4.6-4

ALTERNATIVE METHOD 2 FOR SIC 7215 AND 7216 (COIN-OP AND COMMERCIAL CLEANERS): USING A NATIONAL PER EMPLOYEE FACTOR

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.4	0.4	0.16
Source Specificity	0.5	0.9	0.45
Pollutant	1.0 ^a	1.0	1.0
Spatial	0.4	0.9	0.36
Temporal	0.7 ^b	0.7 ^b	0.49
Composite Scores	0.6	0.78	0.47

^a Lower for speciated emissions.

^b Assumes factor/activity data year is different than inventory year, but not by much.

TABLE 4.6-5

**ALTERNATIVE METHOD 3 FOR SIC 7215 CLEANERS:
USING A NATIONAL PER FACILITY FACTOR**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.3	0.3	0.09
Source Specificity	0.4	0.9	0.16
Pollutant	0.6 - 1.0	1.0	0.6 - 1.0
Spatial	0.3	0.9	0.27
Temporal	0.6	0.7	0.42
Composite Scores	0.44 - 0.52	0.76	0.33 - 0.40

TABLE 4.6-6

**COMPOSITE EMISSIONS DARS SCORES:
SUMMARY FOR ALL INDUSTRIES, ALL METHODS**

Method	Coin-op (SIC 7215)	Commercial (SIC 7216)	Industrial (SIC 7218)
Preferred Method	0.60 - 0.92	0.60 - 0.92	0.60 - 0.92
Alternate Method 1	0.60 - 0.62	0.53 - 0.75	0.53 - 0.75
Alternate Method 2	0.47	0.47	--
Alternate Method 3	0.33 - 0.40	--	--

specificity is set to 1.0 assuming that the specific inventory region is surveyed; if the survey region is different, then this score should be lowered.

In the summary tables, scores may be presented as a range for a particular method because of variability in the survey sample size, the region covered, or the applicability of the emission factor to individual sources. For each attribute, issues that would influence scores would be:

- Measurement--sample size and representativeness of the sample determine the score. The score will also be affected by the correlation between emissions and the choice of a surrogate activity.
- Source Specificity--is based on whether the emission factor and activity factor, particularly a surrogate activity factor, are specific to the source being inventoried or is based on a subset, superset, or category that has been judged similar.
- Pollutant--a high score is given if the emission factor is developed specifically for the intended pollutant, and a lower score if less specific methods, such as speciation profiles are used.
- Spatial--a high score is given if the method was developed for the inventory region. A lower score is given if the emission factor or activity factor is extrapolated from a larger or smaller region.
- Temporal--scores will vary based on how specific the emission factor or activity factor is to the inventory year.

All scores assume that good QA/QC measures are performed and that no significant deviations from the prescribed methods have been made. If these assumptions are not met, new DARS scores should be developed according to the guidance [refer to Source Document (Beck et al., 1994)].

The preferred method gives higher DARS scores than any of the alternative methods. The alternative methods have composite scores ranging between 0.33 and 0.75, while the scores for the preferred method vary from 0.6 to 0.92. Furthermore, the scores on all attributes for the preferred method are higher compared to the alternatives. The highest possible scores for alternative methods are for well-run surveys of solvent used per employee or amount of clothes cleaned. The lowest score is for a national average per facility emission factor for coin-op dry cleaners. The measurement and spatial attribute scores have the greatest variations amongst the different types of attributes. National level emission factors, because they represent top-down methods and will not reflect spatial variations, are the methods most strongly affected by the measurement and spatial attributes.

The uncertainty of the emission estimates can be quantified if any of the survey methods is used. [See QA Source Document, Chapter 4]. However, the statistics needed to quantify the uncertainty of the national emission factor methods and the national solvent use method are incomplete. Factors that affect the uncertainty for these methods are:

- Regional variability of activity;
- Spatial variability of locations of facilities;
- The number of employees that actually are involved with operations; and
- The amount of true activity that takes place relative to that implied by a surrogate activity.

7

DATA CODING PROCEDURES

This section describes the codes available to characterize dry cleaning emission estimates. Consistent categorization and coding will result in greater uniformity between inventories.

7.1 PROCESS AND CONTROL CODES

The process codes for dry cleaning operations are shown in Table 4.7-1. These codes are compatible with the Aerometric Information Retrieval System (AIRS) Area and Mobile Source (AMS) source category codes (EPA, 1994). The control codes for use with AMS are shown in Table 4.7-2. Federal, state, and local regulations can be used as guides to estimate the type of control used and the level of efficiency that can be achieved. Be careful to apply only the regulations that specifically include area sources. If the regulation is applicable only to point sources, it should not be assumed that similar controls exist at area sources without a survey. The "099" control code can be used for miscellaneous control devices that do not have a unique identification code. The "999" code can be used for a combination of control devices where only the overall control efficiency is known.

TABLE 4.7-1**AIRS AMS CODES FOR THE DRY CLEANING CATEGORY**

Category Description	Process Description	AMS Code
Commercial/Industrial Cleaners (SIC 7216 and SIC 7218)	Perchloroethylene	24-20-010-055
	Special Naphthas	24-20-010-370
	Solvent - Other	24-20-010-999
	Total: All Solvent Types	24-20-010-000
Coin-Operated Cleaners (SIC 7215)	Perchloroethylene	24-20-020-055
	Special Naphthas	24-20-020-370
	Solvent - Other	24-20-020-999
	Total: All Solvent Types	24-20-020-000
All Processes	Perchloroethylene	24-20-000-055
	Special Naphthas	24-20-000-370
	Total: All Solvent Types	24-20-000-000

TABLE 4.7-2**AIRS CONTROL DEVICE CODES**

Control Device	Code
Carbon Adsorption	048
Refrigeration System	073
Miscellaneous Control Device	099
Combined Control Efficiency	999

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VOLUME III: CHAPTER 5

CONSUMER AND COMMERCIAL SOLVENT USE

Final Report

August 1996



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Prepared for:
Area Sources Committee
Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

This chapter describes the procedures and recommended approaches for estimating emissions from consumer and commercial solvent use. Section 2 of this chapter contains a general description of the consumer and commercial solvents category and an overview of available control technologies. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation methods for consumer and commercial solvents, and Section 5 presents alternative emission estimation techniques. Quality assurance and quality control procedures are described in Section 6. Data coding procedures are discussed in Section 7, and Section 8 is the reference section. Appendix A presents a compilation of the U.S. Environmental Protection Agency's (EPA's) 1992 consumer product survey, as presented in Table 5-1 of the March 1995 Report to Congress (EPA-453/R-94-066-A). This information was used to develop the volatile organic compound (VOC) emission factors presented in this chapter. Information derived from the survey was also used to develop hazardous air pollutant (HAP) emission factors for consumer and commercial solvent use. Appendix B presents the survey form developed by the EPA to obtain information on these products.

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2

SOURCE CATEGORY DESCRIPTION

Products containing solvents are used in a variety of industrial, commercial, and domestic applications. Solvent compounds are used as cleaning agents, as intermediate compounds in the application of another product, or as a component in the formulation of many products. Section 183(e) of the 1990 Clean Air Act Amendments required the EPA to prepare a Report to Congress to assess the impact of VOC emissions from the use of consumer and commercial products. As explained in the EPA's Report to Congress *Study of Volatile Organic Compound Emissions from Consumer and Commercial Products* (EPA, 1995), the 1990 Clean Air Act's statutory definition of consumer and commercial products is much broader than just traditional personal care and household cleaning products. It includes all VOC-emitting products used in the home, by businesses and institutions, and in industrial manufacturing operations. Therefore, this broad definition of products includes surface coatings, metal cleaning solvents, graphic arts inks, industrial adhesives, and asphalt paving materials.

In the Report to Congress, the terminology is clarified by defining "consumer products" as those products used around the home, office, institution, or similar settings. The commercial and institutional use of these products is included under "consumer products." This definition is consistent with the EPA's definition of "commercial/consumer solvent use" discussed in the procedures document (EPA, 1991). The other solvent-containing products included in the broad statutory definition of consumer and commercial products are covered in individual inventory source categories, particularly under stationary source solvent evaporation source categories such as graphic arts, dry cleaning, surface cleaning, and asphalt paving. Industrial solvent applications should also be accounted for as point sources, or included in industrial area source solvent categories.

This chapter discusses only nonindustrial solvents that are used in commercial or consumer applications. The solvent-containing products in this category include personal care products, household products, automotive aftermarket products, adhesives and sealants, pesticides, some coatings, and other commercial and consumer products that may emit VOCs. The product subcategories will be discussed in more detail below. The information and emissions data presented in this section remain consistent with previous area source emission inventory definitions of consumer products, while at the same time allowing the inventory agency to be consistent with regulatory and compliance requirements, provided all terminology is clearly defined. Products *not* included in this category are products used as non-aerosol traffic markings, architectural and industrial maintenance coatings, autobody refinishing coatings, and products used in industrial processes.

2.1 EMISSION SOURCES

Volatile organic compounds are ingredients of consumer and commercial products that serve as propellants, aid in product drying (through evaporation), act as co-solvents and cleaning agents, and are emitted during product use. Typically these VOC sources are large in number, highly dispersed, and individually emit relatively small amounts of VOC. It is important to note here that not all organic compounds contained in consumer and commercial products are considered reactive VOCs by the EPA due to their negligible photochemical reactivity. Care must be taken to identify the individual VOC species in consumer and commercial products and exclude nonreactive compounds in a State Implementation Plan (SIP) emissions inventory or similar inventory. The VOC emission factors presented in this chapter have been adjusted to remove compounds such as acetone listed as nonreactive by the EPA as of April 1996.

Solvents contained in consumer and commercial products are primarily released during product use. Residual amounts of solvent may also remain in discarded product packaging, enter the municipal solid waste stream, and be disposed of in landfills. Solvents from these products may also enter the wastewater treatment system through use and disposal. The assumption in previous SIP inventories has been that all VOCs in consumer and commercial products will volatilize to the air. However, recent studies prepared by the EPA have identified several substances that are known to be biodegradable in wastewater, which allows for more accurate assessments of the fate of these compounds when they are ingredients of products that are used with water (detergents, soaps, etc.). The EPA concluded, however, that there was not enough information available on the fate of VOCs in consumer products in landfills to make any adjustments for VOC-release mechanisms at this time. Therefore, as noted in Appendix A, the VOC emission factors presented in this chapter have been adjusted to account for biodegradation of VOCs that enter the wastewater stream, but not those that enter a landfill. Detailed information on the fate of solvents in consumer and commercial products in landfills and wastewater treatment systems is presented in two EPA Reports to Congress (EPA, 1994a, 1994b).

The EPA is in the process of developing regulations for this source category. Seven major consumer and commercial product groups and their respective categories have been established by the EPA. These are:

- Personal care products;
- Household products;
- Automotive aftermarket products;
- Adhesives and sealants;
- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)-regulated products;

- Coatings and related products; and
- Miscellaneous products.

Table 5.2-1 provides the categories assigned to these major product groups. These product categories are also categories of household hazardous waste and are discussed in more detail below.

2.1.1 PERSONAL CARE PRODUCTS

Personal care products, as shown in Table 5.2-1, include hair care products, deodorants and antiperspirants, perfumes and colognes, and nail care products. According to surveys of the industry, ethanol and isopropanol are the primary solvents used in the formulation of these products (Frost & Sullivan, Inc., 1989).

As shown in Appendix A, hair care products alone consist of over 20 different subcategories of product types. Most hair care products are regulated by the Food and Drug Administration (FDA) as cosmetics. Hair care product types differ by the function they perform. Frequency of use depends on the product's function and determines the quantity of the product type consumed annually. Virtually every hair care product contains some amount of VOCs; the amount of VOC can range from 0 to 100 percent of total formulation.

Several factors affect the amount of VOC emitted by hair care products, primarily market share and VOC content. These factors are influenced by product type, product form, and variation in consumer use.

The product market for deodorants and antiperspirants offers a variety of high- to low-VOC content products. The ingredients in deodorants and antiperspirants are classified as active or nonactive (inert), depending on the function they perform. The active ingredients in most deodorants on the market are Triclosan®, zinc phenolsulfonate, or Hyamine®. Aluminum salts are the active ingredient in most antiperspirants. Unlike active ingredients, nonactive ingredients vary greatly from product to product. Like hair care products, virtually all underarm products contain VOCs that are generally nonactive ingredients. Aerosol propellants account for the largest VOC weight percentage of an ingredient in underarm products. Deodorant aerosols contain

TABLE 5.2-1

CONSUMER PRODUCT GROUPS AND CATEGORIES

Personal Care Products	Adhesives and Sealants
------------------------	------------------------

Hair Care Products ^a	Consumer Adhesives
Deodorants and Antiperspirants	Sealants
Fragrance Products	FIFRA-Regulated Products^b
Powders	Insecticides
Nail Care Products	Fungicides and Nematicides
Facial and Body Treatments	Herbicides
Oral Care Products	Antimicrobial Agents
Health Use Products	Other FIFRA-Regulated Products
Miscellaneous Personal Care Products	Coatings and Related Products
Household Products	Aerosol Spray Paints
Hard Surface Cleaners	Coating-Related Products
Laundry Products	Miscellaneous Products (not otherwise covered)
Fabric and Carpet Care Products	Arts and Crafts Supplies
Dishwashing Products	Nonpesticidal Veterinary and Pet Products
Waxes and Polishes	Pressurized Food Products
Air Fresheners	Office Supplies
Shoe and Leather Care Products	
Miscellaneous Household Products	
Automotive Aftermarket Products	
Detailing Products	
Maintenance and Repair Products	

^a Consists of over 20 different subcategories of product types. Most products are regulated by the Food and Drug Administration as cosmetics.

^b Federal Insecticide, Fungicide, and Rodenticide Act.

95 percent VOCs by weight, 30 percent propellant and 65 percent solvent. Antiperspirant aerosols contain an average of 75 percent VOCs by weight. The most commonly used propellants are n-butane, isobutane, and propane.

2.1.2 HOUSEHOLD PRODUCTS

Household products primarily consist of cleaning products for hard surfaces, clothing, carpet, and dishes, and waxes and polishes. Other products include air fresheners and charcoal lighter fluids.

Each subcategory of cleaning products is made up of a variety of product types and formulations. Cleaning products are categorized based on their cleaning function. The frequency of use and quantity of a product used depends on the product's cleaning function and the amount of product required to meet that function. Like the other products discussed here, cleaning products can contain from 0 to 100 percent VOCs. The amount of VOCs emitted primarily depends on the VOC content of the product and the amount of product used. The VOC content of a product formulation depends on the product type and form, as well as the VOC function requirements. The VOCs in a product may be an essential component of the cleaning function, or serve to maintain interactions among other ingredients.

Product types differ by their function to mask or remove odors from the air. Air fresheners (room deodorizers) are designed principally to treat indoor environments. Most products are air fresheners that mask odors with a pleasant scent. Other products are marketed to remove the odors through chemical reactions. The VOC content of air fresheners ranges from 3.5 to 100 percent, depending on the form of the product. Aerosol and liquid sprays typically contain ethanol and isopropanol as solvents. Aerosols also contain propane, butane, and isobutane as propellants. Gels and powders have a relatively low VOC content.

2.1.3 AUTOMOTIVE AFTERMARKET PRODUCTS

The EPA has divided automotive consumer products into two major categories: (1) detailing products, and (2) maintenance and repair products. Table 5.2-2 delineates the subcategories of products in these two groups. It is often difficult to distinguish the automotive aftermarket product subcategories because product category descriptions and designations may overlap. It can also be difficult to distinguish between formulations for distinct product types and different formulations for products intended for the same use. In some cases, varying formulations may be due to the product form. There are a large number of individual VOCs in these products, including HAPs.

TABLE 5.2-2

AUTOMOTIVE CONSUMER PRODUCT SUBCATEGORIES

Product Type	
Detailing Products	Maintenance and Repair Products
Body cleaning compounds	Antifreeze/coolant
Bug and tar removers	Belt dressings
Car washing products	Engine cleaners/degreasers/parts cleaners
Fiberglass polish	Engine starting fluids
Glass or plexiglass/plastic window cleaner/treatment	Fuel system antifreeze
Metal polish/chrome cleaner	Lubricants
Polishes	Motor flush/crankcase cleaner
Rubber/vinyl/leather protectants/dressing (and vinyl top cleaners/waxes)	Transmission sealer/conditioner/additive/leak-stop
Rustproofing/treatment compounds (exterior)	Tire cement/sealant/inflators
Soaps	Windshield deicer
Tire coating/paints	Windshield washer fluid
Upholstery cleaners/interior cleaners	
Waxes	
Wheel/tire/mat cleaners	

Detailing products are used for cosmetic purposes for cleaning, polishing, and waxing. This category does not include products used for restoring or repainting operations, but does include windshield washer fluids. VOCs contained in detailing products are emitted during their use or over time after application.

Maintenance and repair products include engine and parts cleaners, carburetor/fuel injection cleaners, lubricants, antifreeze, radiator cleaners, and brake fluids, among others. VOC emissions from the use of these products occur during application, removal (for replacement), leakage, and from disposal of unused portions.

Automotive "touch-up" paints, sanding primers, engine enamels and other aerosol coatings that would not be included in the autobody refinishing area source category are in the coatings group of the consumer and commercial solvent use area source category.

2.1.4 ADHESIVES AND SEALANTS

Adhesives are formulated organic polymer compounds that adhere to, or form a bond between, one or more substrates. They are commonly referred to as cements, glues, and pastes. Adhesives can be classified as water-based, solvent-based, hot melts, or radiation curable. Sealants and caulking compounds are organic polymers used to fill or seal gaps between surfaces. The primary solvents used in formulating adhesives and sealants are aliphatic hydrocarbons and ketones.

2.1.5 FIFRA-REGULATED PRODUCTS

Pesticides defined by FIFRA include substances or mixtures that are used to prevent, destroy, repel, or mitigate pests, as well as substances used as plant regulators, defoliators, and desiccants. The pesticide industry can be divided into consumer and agricultural categories. Agricultural products are applied to crops to prevent the growth of weeds and insect infestations.

Consumer pesticides are used in the home and garden, as well as in commercial and governmental applications. Disinfectants and antimicrobial products are included. Household uses include pet care products, disinfectants, and insecticides. All consumer and commercial pesticide products contain VOCs. Aerosol and liquid sprays contain VOCs as solvents, usually ethanol and isopropanol. Aerosol propellants are primarily propane, butane, and isobutane. Products such as baits, powders, and granules have relatively low VOC content due to their solid form. Pesticide products can be grouped according to their target pest, but should also be grouped according to their form (solid, liquid, or aerosol) when considering control measures.

The FIFRA emission factors presented in this chapter are for consumer and commercial product use. Emission estimation methods for FIFRA-regulated products are also discussed in detail in Chapter 9, Pesticide Applications, of this volume. Care should be taken to avoid double counting emissions calculated with Chapter 9 methods and those presented in this chapter. Depending on the methods used, it may not be practical to use the FIFRA data in Appendix A (Consumer Product Survey).

2.1.6 COATINGS AND RELATED PRODUCTS

Aerosol spray paints and related products such as paint removers make up this consumer and commercial solvent product group. Other forms of coatings (besides aerosols) are not included in this group, but are included under architectural or industrial coatings, or autobody refinishing. Aerosol spray paints contain VOCs that function as both solvents and propellants. The most commonly used propellants in aerosol paints are propane, butane, and isobutane. Synthetic propellants such as chlorofluorocarbons are no longer used in significant

amounts as propellants nor are they regulated as VOCs.

Paint removers are classified as either application removers or immersion removers. Paint removers typically contain methylene chloride (a nonreactive VOC) as the principal ingredient. Other solvents such as methanol, ethanol, and isopropanol are also used to enhance the action of the paint remover. Methylene chloride (53 percent) and methanol (41 percent) account for the majority of paint-removing solvents consumed (Frost & Sullivan, Inc., 1990).

2.1.7 MISCELLANEOUS PRODUCTS

Miscellaneous consumer products not covered in the other product groups include arts and crafts supplies, nonpesticidal veterinary and pet products, and pressurized food products. These products are not significant contributors to VOC emissions relative to the other source categories.

2.2 FACTORS INFLUENCING EMISSIONS

2.2.1 PROCESS OPERATING FACTORS

Consumer purchasing practices directly influence VOC emissions by controlling total product consumption on a long-term basis. In any evaluation of emissions and potential control strategies, consumer acceptability and product safety must be considered. The method used to dispose of unused products also affects overall VOC emissions from consumer and commercial products.

2.2.2 CONTROL TECHNIQUES

Potential control strategies for VOC emissions from consumer and commercial products typically involve:

- A change in the application method (repackaging);
- Product substitution;
- Product reformulation; and
- Directions for use, storage, and disposal.

Requiring a change in the application method generally means that liquid and aerosol products are replaced with solid products. As discussed above, products in solid form typically have lower VOC content because solvent is not required to aid in drying and

propellants are not needed.

Product substitution is a control measure that consists of replacing an existing product with a substitute product that achieves the desired goal, but results in reduced VOC emissions (EPA, 1995).

The EPA also acknowledges the innovative product concept, which involves the use of higher VOC-containing products that result in reduced VOC emissions over time or per application. For example, the use of some types of products results in less frequent reapplications, or less of the product is needed, thereby reducing overall VOC emissions.

Product reformulation typically consists of developing low-VOC products by modifying the chemical composition. Reformulation may involve substitution of VOCs with less photochemically reactive compounds while maintaining the product's integrity (SAIC, 1987; EPA, 1995). An example of a compound used to replace VOCs in consumer and commercial products is the use of carbon dioxide as a propellant.

Providing consumers with directions for the proper use, storage, and disposal of products can also result in reduced emissions. Product labeling and consumer education are typically used.

In a March 23, 1995, Federal Register (FR) notice, the EPA identified 24 consumer product subcategories scheduled for development of federal regulations (60 FR 15264). These subcategories are shown in Table 5.2-3. The EPA notes in the Federal Register notice that these products are currently regulated in one state or more. As individual products and categories are further assessed, the EPA reserves the right to remove categories from or add categories to the list.

Seven states--California, Connecticut, Massachusetts, New Jersey, New York, Rhode Island, and Texas--have or are proposing regulations that affect consumer and commercial product VOC emissions. Table 5.2-4 summarizes the existing and proposed state regulations for consumer and commercial products that limit the percentage of VOCs the products can contain. The regulations listed in Table 5.2-4 may not be all inclusive and are subject to change.

TABLE 5.2-3
PRODUCT SUBCATEGORIES LISTED FOR DEVELOPMENT OF
FEDERAL REGULATIONS BY 1997

Aerosol Cooking Sprays
Aerosol Underarm Antiperspirants and Deodorants
Air Fresheners
Auto Windshield Washer Fluids
Bathroom and Tile Cleaners
Carburetor and Choke Cleaners
Charcoal Lighter Materials
Dusting Aids
Engine Degreasers
Fabric Protectants
Floor Waxes and Polishes
Furniture Maintenance Products
General Purpose Cleaners
Glass Cleaners
Hair Sprays
Hair Mousses
Hair Styling Gels
Household Adhesives
Nonagricultural Insecticides
Laundry Prewash Treatments
Laundry Starch Products
Nail Polish Removers
Oven Cleaners
Shaving Creams

TABLE 5.2-4

**EXISTING AND PROPOSED STATE REGULATIONS FOR CONSUMER
AND COMMERCIAL PRODUCTS (AS OF 12/94)**

Product Subcategory	Percent VOCs by Weight										
	California ^a		Proposed Connecticut ^b		Mass ^c	Proposed New Jersey ^f		New York ^l		Proposed Rhode Island ^l	Texas ^{m,n}
	Phase I	Phase II	Phase I ^c	Phase II ^d		Phase I ^e	Phase II ^h	Phase I ⁱ	Phase II ^k		
Aerosol Cooking Sprays	18					18					18
Air Freshener											
Single-phase	70	30	70	30	70	70	30	70	30	70	70
Double-phase	30		30		30	30		30		30	30
Liquids/Pump Sprays	18		18		18	18		18		18	18
Solids/Gels	3				3	3		3		3	3
Dual Purpose Air Freshener/ Disinfectant Aerosol		60								60	
Automotive Windshield Washer Fluids											23.5
Cold Climate Areas	35										
All Other Areas	10										
Bathroom and Tile Cleaners											
Aerosols	7					35				7	7
All Other Forms	5					10				5	5
Charcoal Lighter Material											
Carburetor/Choke Cleaners	75					75					75

TABLE 5.2-4

(CONTINUED)

Product Subcategory	Percent VOCs by Weight										
	California ^a		Proposed Connecticut ^b		Mass ^e	Proposed New Jersey ^f		New York ⁱ		Proposed Rhode Island ^l	Texas ^{m,n}
	Phase I	Phase II	Phase I ^c	Phase II ^d		Phase I ^g	Phase II ^h	Phase I ^j	Phase II ^k		
Disinfectants	60	30								60	
Dusting Aids											
Aerosol	35	25				35	25				35
All Other Forms	7					7					7
Engine Degreasers	75	50	75	50	75	75	50			75	75
Fabric Protectants	75	60				75					75
Floor Polishes/Waxes											
Products for Flexible Flooring Materials	7				7	7				7	7
Products for Nonresilient Flooring	10				10	10				10	10
Wood Floor Wax	90				90	90				90	90
Furniture Maintenance Products											
Aerosols	25				25	25				25	25
All Other Forms (except solid or paste)	7				7					7	
General Purpose Cleaners	10		10		10	10		10		10	10
Glass Cleaners											
Aerosols	12				12	12				12	12

TABLE 5.2-4

(CONTINUED)

Product Subcategory	Percent VOCs by Weight										
	California ^a		Proposed Connecticut ^b		Mass ^e	Proposed New Jersey ^f		New York ⁱ		Proposed Rhode Island ^l	Texas ^{m,n}
	Phase I	Phase II	Phase I ^c	Phase II ^d		Phase I ^g	Phase II ^h	Phase I ^j	Phase II ^k		
All Other Forms	8	6			8	8	6			8	6
Hair Mousses	16				16					16	16
Hair Sprays	80	55	80	55	80	80	55	80	55	80	80
Hair Styling Gels	6				6					6	6
Household Adhesives											
Aerosols	75	25				75	25				75
Construction and Panel	40					40					40
Contact	80					80					80
General Purpose	10					10					10
Insecticides											
Crawling Bug	40	20	40	20	40	40	20			40	40
Flea and Tick	25		25		25	25				20	25
Flying Bug	35		35		35	35				30	35
Foggers	45		45		45	45				40	45

TABLE 5.2-4

(CONTINUED)

Product Subcategory	Percent VOCs by Weight										
	California ^a		Proposed Connecticut ^b		Mass ^e	Proposed New Jersey ^f		New York ^l		Proposed Rhode Island ^l	Texas ^{m,n}
	Phase I	Phase II	Phase I ^c	Phase II ^d		Phase I ^g	Phase II ^h	Phase I ^j	Phase II ^k		
Lawn and Garden	20		20		20	20				20	20
Aerosol Insect Repellents				65							-- ^o
Wasp and Hornet	40									40	
All Other Forms	25									20	
Laundry Prewash											
Aerosols/Solids	22				22	22					22
All Other Forms	5				5	5					5
Laundry Starch Products	5					5					5
Nail Polish Removers	85	75				85	75			85	75
Oven Cleaners											
Aerosols/Pump Sprays	8					8				8	8
All Other Forms	5					5				5	5
Shaving Creams	5					5					5
Underarm Antiperspirants											
Aerosol	60/20 ^p	0/10 ^p	60		60 ^q	60 ^q	0 ^q	60/20 ^p	0/10 ^p	0/10 ^p	60 ^q
Nonaerosol	0/0 ^p	0/0 ^p				0 ^q	0 ^q	0/0 ^p	0/0 ^p	0/0 ^p	0 ^q

TABLE 5.2-4

(CONTINUED)

Product Subcategory	Percent VOCs by Weight										
	California ^a		Proposed Connecticut ^b		Mass ^e	Proposed New Jersey ^f		New York ⁱ		Proposed Rhode Island ^l	Texas ^{m,n}
	Phase I	Phase II	Phase I ^c	Phase II ^d		Phase I ^g	Phase II ^h	Phase I ^j	Phase II ^k		
Underarm Deodorant											
Aerosol	20/20 ^p	0/10 ^p	20		20 ^q	60 ^q	0 ^q	20/20 ^p	0/10 ^p	0/10 ^p	20 ^q
Nonaerosol	0/0 ^p	0/0 ^p				0 ^q	0 ^q	0/0 ^p	0/0 ^p	0/0 ^p	0 ^q

^a California Code of Regulations, Title 17 - Public Health, Division 3 - Air Resources, Chapter 1 - Air Resources Board, Subchapter 8.5 - Consumer Products; adopted January 28, 1991; amended September 19, 1991; December 7, 1992.

^b "Sprays Under Pressure," *Spray Technology & Marketing*, 4:18. October 1994.

^c Effective 1/1/96 (if adopted).

^d Effective 1/1/98 (if adopted).

^e "Sprays Under Pressure/Regulatory Affairs," *Spray Technology and Marketing*, 5:23. January 1995.

^f "Regulatory: Sprays Under Pressure," *Spray Technology and Marketing*, 5:14. February 1995.

^g Expected to become effective in December 1995.

^h Effective at some yet undetermined date.

ⁱ Regulatory Affairs/Aerosols Under Pressure," *Spray Technology and Marketing*, 1:10. December 1991.

^j Effective 1/1/94.

^k Effective 1/1/96 for air fresheners and hair sprays and 1/1/97 for deodorants and antiperspirants.

^l "Sprays Under Pressure," *Spray Technology and Marketing*, 4:10. January 1994.

^m "Sprays Under Pressure/Regulatory," *Spray Technology and Marketing*, 4:39. September 1994.

ⁿ Effective 1/1/95 for everything but nail polish removers and 1/1/96 for nail polish removers.

^o In response to a petition from a manufacturer, Texas is in the process of deleting Aerosol Insect Repellents from the Table of Standards (65%).

^p HVOC/MVOC limits (MVOC = organic compounds with vapor pressure greater than 2 mm of Hg at 20°C).

^q Limit is for HVOCs (organic compounds with vapor pressure greater than 20 mm of Hg at 20°C).

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3

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATION METHODOLOGIES

Two methodologies are available for calculating emissions from consumer and commercial solvent use. The method used depends upon the degree of accuracy required in the estimate, available data, and available resources.

This section discusses the methods available for calculating emissions estimates from consumer and commercial products and identifies the preferred calculation method. A discussion of the data elements needed for each method is also provided.

3.2 AVAILABLE METHODOLOGIES

3.2.1 VOLATILE ORGANIC COMPOUNDS

As discussed previously, most VOCs released into the air from the use of consumer and commercial products are from the evaporation of the solvent contained in the product or from the propellant. Determining the amount of VOCs in the products, making adjustments for the biodegradation of VOCs in wastewater, and determining the volume of products sold (or used) should provide a good estimate of the VOCs emitted by this source category. There are two approaches for estimating the amount of VOCs emitted from this source category:

- National average per capita emission factors adjusted for state or local emission limits; or
- Surveying consumer and commercial product use or sales in the inventory area.

The population-based method is preferred for emission estimation. This method can be used to estimate VOC emissions from consumer and commercial products in the inventory area, and can be adjusted to reflect applicable controls (see discussion in Section 4.1).

While surveying consumer and commercial product use may be a more accurate method for

emission estimation, it will be very expensive if done correctly. Most consumer and commercial solvent use cannot be easily identified by questionnaires, surveys, or other inventory procedures yielding local emission estimates because of variations in product formulations and wholesale/retail distribution. Product surveys of distributors and retailers may still be useful in determining local trends in product use, however. It may also be useful to conduct surveys of product use by the general public. The survey results can be used to make adjustments to the population-based emission estimates if it is determined that they are needed.

3.2.2 HAZARDOUS AIR POLLUTANTS

HAP emissions from this source can also be estimated using two methods:

- Using national average per capita emission factors (population-based method); or
- Developing speciation profiles based on the information provided in this chapter and applying them to the VOC emission estimate developed using the alternative method.

The population-based method is the preferred method, with adjustments for state and local regulations on this industry.

3.3 DATA NEEDS

3.3.1 DATA ELEMENTS

The data elements used to calculate emission estimates for the consumer and commercial products category depend on the methodology used to estimate emissions. The data elements that are necessary for using the national average per capita VOC or HAP emission factors are:

- Population in the inventory area;
- Per capita emission factors (shown in Section 4 and in Appendix A); and
- Information on state and local regulations.

If the survey method is used to estimate emissions or to make local adjustments to the estimates made using the national average per capita emission factors, the data elements necessary in a survey include:

- Product type;
- Product amount distributed or used by type (weight or volume); and
- Product density, if distributors or retailers are surveyed rather than consumers.

The survey may also request information on seasonal variability and other factors that may affect product use.

3.3.2 APPLICATION OF CONTROLS

Because most controls will affect the content of the products themselves (requiring reformulation or a change in the application method) or require product substitution, an evaluation of applicable state or local regulations will give an indication of the adjustments that should be made to the emission estimates derived using the population-based method. Since a reformulation or substitution represents an irreversible process change, and thus a reduction in emissions from a product category, rule effectiveness can be assumed to be 100 percent for that product type.

Rule penetration will be based on the percentage of sources within the category that are affected by the rule and consumer purchasing practices. Factors that will affect rule penetration include: (1) sales of older products that may be grandfathered in the regulation because they were manufactured or distributed before the regulation was enacted, (2) the ease with which consumers can purchase unregulated products, and (3) the desire on the part of consumers to purchase unregulated products.

A discussion of how controls affect emission estimates when emissions are calculated using emission factors is in Section 4. This section also provides examples of calculations for controlled emissions.

3.3.3 SPATIAL ALLOCATION

Spatial allocation may be needed during the preparation of an inventory to allocate: (1) state or regional activity to a county level, and (2) county-level emission estimates to a modeling grid cell. In each case, a surrogate for activity should be found that can approximate spatial variation for this category.

The preferred method, per capita emission factors, uses activity which is available at the county level. The alternative method, a survey, can also use population as a scaling method. However, it should be assumed that usage is constant over the inventory area for consumer and commercial products. If estimated emissions from consumer and commercial products

are to be allocated on a refined level within the study area, residential population, households, or number of commercial establishments should be used with the allocation depending on the category.

3.3.4 TEMPORAL RESOLUTION

Seasonal Apportioning

For the most part, consumer and commercial product use is not influenced by the seasons. An exception is pesticides, which are discussed in this chapter as well as in Chapter 9 of this volume. In colder climates and seasons, windshield washer fluids typically have higher VOC content, which would mean that the emission factor for windshield washer fluids for that time period will be higher. There should not be a significant difference in the use between different seasons.

Daily Resolution

The use of consumer and commercial products is generally assumed to occur 7 days a week throughout the year. Thus, the annual emissions estimate is divided by 365 in order to calculate a daily emission estimate.

3.3.5 PROJECTING EMISSIONS

Projected emission estimates may need to be calculated differently in the three following cases:

- Case 1: No controls and no change in the emission factor;
- Case 2: Controls are reflected in the emission factor; and
- Case 3: Controls are expressed as a control efficiency factor and the emission factor stays the same.

Each case uses a different projection equation (EPA, 1993). If there are no controls and no changes in the emission factor, projected emissions are calculated using the following equation:

$$EMIS_{PY} = ORATE_{BY} * EMF * GF \quad (5.3-1)$$

where:

EMIS _{PY}	=	Projection year emissions
ORATE _{BY}	=	Base year activity rate
EMF	=	Emission factor
GF	=	Growth factor

For Case 2, where controls are reflected in the emission factor, the equation would be:

$$EMIS_{PY} = ORATE_{BY} * EMF_{PY} * \left[\frac{200 - RP_{PY}}{100} \right] * GF \quad (5.3-2)$$

where:

EMF _{PY}	=	Projection year emission factor
RP _{PY}	=	Projection year rule penetration (%)

When controls are expressed as an emission limit or a percent reduction, reductions are calculated using a control efficiency factor, as in Case 3. See Section 4 of this chapter for an example of how to develop and apply a control efficiency factor in a base year emission estimation equation. Projected emission estimates for Case 3 are calculated using the following equation:

$$EMIS_{PY} = ORATE_{BY} * EMF \left[1 - \left(\frac{CE_{PY}}{100} * \frac{RE_{PY}}{100} * \frac{RP_{PY}}{100} \right) \right] * GF \quad (5.3-3)$$

where:

CE _{PY}	=	Projection year control efficiency
RE _{PY}	=	Projection year rule effectiveness (%)

A discussion about developing growth factors and projecting emission estimates can be found

in Section 4 of this volume's Chapter 1, *Introduction to Area Source Emission Inventory Development*.

4

PREFERRED METHODS FOR ESTIMATING EMISSIONS

The preferred method for calculating emissions from consumer and commercial products uses the nationally based per capita emission factors for the product categories of interest. This section provides an outline for using these emission factors and makes recommendations on how to make adjustments to the estimated emissions based on applicable regulations. Because the use of consumer and commercial products is defined as an area source, there is no need to subtract point source emissions from the total. All of the emissions estimated for this source are area source emissions. The procedure recommended for estimating emissions is as follows:

- Identify applicable state and local regulations;
- Create a database or spreadsheet with per capita emission factors for the source categories of interest (making sure they can be matched to regulated categories);
- Obtain population data for the base year of interest and allocate it to geographic areas as needed (including consideration of areas affected by regulations);
- Multiply per capita emission factors by population to obtain overall emissions estimates; and
- Adjust estimated emissions for applicable regulations as needed.

An example calculation (5.4-1) is shown on the following page.

Table 5.4-1 and Appendix A present the per capita VOC emission factors recommended for estimating emissions from consumer and commercial solvents (EPA, 1995). These emission factors were developed by the EPA in conjunction with product manufacturers and trade associations. Information on product sales and baseline VOC content were gathered by the EPA for base year 1990 through an extensive survey of manufacturers and distributors. Table 5.4-2 presents the per capita HAP emission factors.

Example 5.4-1

The equation to estimate VOC emissions from personal care products is:

$$\text{Population} * \text{Per Capita Emission Factor} = \text{Emissions}$$

If the population of the area is 1 million persons, the VOC emissions from personal care products are:

$$\begin{aligned} 1,000,000 \text{ persons} * 2.32 \text{ lb VOCs/person/yr} &= 2,320,000 \text{ lb VOC/yr} \\ &= 1,160 \text{ tons VOCs/yr} \end{aligned}$$

The VOC and HAP emission factors developed from the survey results were adjusted for estimated market coverage of respondents based on a review of the survey data by manufacturing and trade association members. As discussed in Section 2, some of the VOCs in products that come in contact with water during use may not be emitted to the air, and thus should be excluded from an emissions inventory. The percent VOCs emitted (as opposed to biodegraded in wastewater) was therefore used to further adjust the per capita emission factors. These adjustments were also developed based on the trade association members, review of the survey data. The adjustments take into consideration the likelihood of VOC-containing products entering the wastewater stream at significant levels (because they are detergents, soaps, shampoos, etc.) and the fate of individual VOC compounds in the water (likelihood of biodegradation).

4.1 APPLICATION OF CONTROLS

If there are applicable state or local regulations, estimated emissions must be adjusted. The existing and proposed regulations limit the VOC content of products. The information presented in Appendix A can be used to calculate the baseline VOC content (by weight) of the products surveyed. These values can be calculated by dividing the adjusted VOC content (tons) by the adjusted product sales (tons) shown in Appendix A.

As an example (5.4-2), the average VOC content for finishing hair sprays is 90 percent. The California Phase I regulation limits the VOC content of hair sprays to 80 percent by weight. In this example, product usage of the regulated hairspray is assumed to be the same as product usage of the unregulated hairspray. If information on consumer practices is available that indicates product usage would change, adjustments would be needed to account for additional (or lower) VOC reductions. Note that this example assumes that RE and RP are both 100 percent. Section 3.3.2 discusses some factors that should be considered about these assumptions.

TABLE 5.4-1
PER CAPITA CONSUMER AND COMMERCIAL SOLVENT VOC
EMISSION FACTORS^{a,b}

Product Category	Per Capita Emission Factor (lb VOC/person)^c
Personal Care Products	2.32
Household Products	0.79
Automotive Aftermarket Products	1.36
Adhesives and Sealants	0.57
FIFRA-Regulated Products ^d	1.78
Coatings and Related Products	0.95
Miscellaneous Products	0.07
Total for All Consumer and Commercial Products	7.84

^a Source: Adapted from EPA, 1995.

^b Emission factors are based on usage and population data for 1990.

^c Compounds listed as nonreactive by the EPA as of April 1996 have been excluded. Significant changes to earlier definitions are the removal of acetone from the list of reactive VOCs.

^d Care should be taken to avoid double counting in applying this VOC emission factor if the alternative estimation method given in Chapter 9 of this volume for consumer and commercial pesticide use is used.

TABLE 5.4-2

PER CAPITA CONSUMER AND COMMERCIAL SOLVENT HAP EMISSION FACTORS (LB/YR/PERSON)^a

Pollutant	Personal Care Products	Household Products	Automotive Aftermarket Products	Adhesives & Sealants	FIFRA-Regulated Products ^b	Coatings & Related Products	Misc.	Overall Emission Factor (lb HAP/yr/person)
Acetamide	1.38E-07							1.38E-07
Acetophenone						8.53E-06		8.53E-06
Acrylic acid				3.94E-09				3.94E-09
Benzene			4.72E-06					4.72E-06
Carbon tetrachloride						4.10E-10		4.10E-10
Chlorobenzene					7.16E-02	1.51E-05		7.16E-02
Chloroform			3.60E-05			9.55E-04		9.91E-04
Dibenzofurans				8.07E-06				8.07E-06
1,4-Dichlorobenzene		4.79E-02			3.52E-02			3.52E-02
1,2-Dichloroethane	4.62E-06	3.52E-08						4.65E-06
1,3-Dichloropropene					1.60E-01			1.60E-01
Dimethyl formamide	2.71E-05		2.78E-08	2.29E-07			7.43E-06	3.49E-05
1,4-Dioxane				1.09E-05				1.09E-05
Ethyl benzene		2.56E-06	7.51E-05	1.36E-05	1.30E-03	6.86E-04		2.07E-03
Ethylene oxide					1.51E-02			1.51E-02
Formaldehyde		6.74E-06		2.51E-05	3.81E-04	8.55E-04		1.26E-03

TABLE 5.4-2

(CONTINUED)

Pollutant	Personal Care Products	Household Products	Automotive Aftermarket Products	Adhesives & Sealants	FIFRA-Regulated Products ^b	Coatings & Related Products	Misc. (Not Covered)	Overall Emission Factor (lb HAP/yr/person)
Glycol ethers	1.52E-05	5.31E-03	2.69E-02	1.28E-04	5.65E-03	2.24E-03	2.42E-04	4.04E-02
Hexane		2.09E-03	3.53E-03	7.83E-02		2.39E-03		8.63E-02
Hydrochloric acid		1.75E-06						1.75E-06
Hydrogen fluoride		8.75E-08	1.41E-05					1.41E-05
Isophorone					9.47E-04			9.47E-04
Methanol	5.67E-07	6.66E-04	6.61E-01	6.82E-04	9.48E-04	1.60E-02	1.84E-02	6.97E-01
Methyl bromide					2.22E-01			2.22E-01
Methyl ethyl ketone	1.75E-05	4.49E-04	3.04E-03	3.91E-02	2.01E-05	7.94E-03	1.01E-05	5.06E-02
Methyl isobutyl ketone		1.08E-04	8.73E-04	1.24E-03	9.01E-05	5.26E-03		7.57E-03
Methyl-tert-butyl ether			2.36E-05					2.36E-05
Methylene chloride		2.39E-03	4.83E-03	8.78E-03	6.81E-04	1.97E-02	2.38E-05	3.64E-02
Naphthalene		5.52E-07	2.26E-06	1.07E-04	4.60E-02	5.75E-06		4.61E-02
2-Nitropropane				2.12E-06				2.12E-06
Perchloroethylene		2.96E-03	2.35E-02	6.75E-04	1.92E-04	1.48E-04	7.53E-04	2.82E-02
Toluene	3.41E-03	5.82E-04	2.49E-02	8.43E-02		3.16E-01	2.46E-06	4.29E-01
1,1,1-Trichloroethane	7.45E-04	2.85E-02	7.63E-02	2.14E-01	5.99E-02	7.69E-03	2.46E-04	3.87E-01
Trichloroethylene		4.34E-05	2.67E-04	3.88E-05		1.37E-04		4.86E-04

TABLE 5.4-2

(CONTINUED)

Pollutant	Personal Care Products	Household Products	Automotive Aftermarket Products	Adhesives & Sealants	FIFRA-Regulated Products ^b	Coatings & Related Products	Misc. (Not Covered)	Overall Emission Factor (lb HAP/yr/person)
Triethylamine					3.13E-04	5.26E-04		8.39E-04
Vinyl acetate				4.94E-08				4.94E-08
Xylenes		3.28E-03	1.20E-02	9.76E-03	1.37E-01	4.05E-02	4.31E-04	2.03E-01

^a Factors are from the Consumer Products Database (adjusting for content emitted and market coverage). Some HAP emission factors may not be shown here because they were not considered reportable VOCs. Additional HAPs may be emitted from consumer and commercial products.

^b Before using these factors, refer to the discussion in Section 2 of this chapter.

Example 5.4-2

To estimate VOC emissions from finishing hair sprays affected by the California Phase I regulation, CE must first be calculated.

$$\text{Uncontrolled Emissions} * [1 - (\text{CE}) * (\text{RE}) * (\text{RP})] = \text{Controlled Emissions}$$

CE is calculated as:

$$(\text{Uncontrolled VOC content} - \text{Controlled VOC content}) / \text{Uncontrolled VOC} = \text{Control Efficiency}$$

$$(90 - 80.0) / 90 = 0.11$$

The uncontrolled emissions from finishing hair sprays are calculated from the information in Appendix A using the per capita VOC emission factor of 1.3 lbs/person.

The controlled emissions from finishing hair sprays in a city with a population of 1 million persons will be:

$$\text{Uncontrolled Emissions} * [1 - (\text{CE}) * (\text{RE}) * (\text{RP})] = \text{Controlled Emissions}$$

$$650 \text{ tons VOC} * [1 - (0.11 * 1.00 * 1.00)] = 578.5 \text{ tons VOC}$$

4.2 OTHER ADJUSTMENTS

Finally, adjustments may be made to the estimated emissions from consumer and commercial products based on local survey data. If a survey is conducted for a product category and the results are sufficient to provide an indication of local product usage (i.e., delineate types of products that are not used or sold in the inventory area, provide information on a different formulation), some products can be excluded from the emissions inventory, or adjustments can be made to the per capita emission factors.

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5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

The alternative method for calculating VOC emissions from consumer and commercial solvent use is to conduct a survey of product usage or sales, and combine the information obtained with the VOC and HAP content of the products. This section provides an outline for preparing and using a consumer and commercial products survey if distributors and retailers or consumers are surveyed, and calculating emissions from the information collected. As discussed previously, the survey method is not recommended for this source category unless the agency has reason to believe that local product usage differs greatly from national average usage, and the agency has adequate resources to survey this diverse and widespread source category. Please refer to Chapter 1 of this volume; Volume I of this series, Chapter 5, *Inventory Development*; and Volume VI of this series, *Quality Assurance Procedures*, for more detailed information about using surveys.

5.1 PROCEDURE

The survey procedure is as follows:

- Perform a survey of distributors and retailers or consumers of consumer and commercial products use in the inventory region;
- Obtain data on the amounts of products sold or used in the inventory region; and
- Estimate the total amount of VOCs (or HAPs) emitted in the inventory region from consumer and commercial products.

5.2 DATA ELEMENTS

A survey should request the following information:

- Product type;
- Product amount distributed by type (weight or volume); and
- Product density, if manufacturers and distributors are surveyed, and product

amount is recorded in volume units.

The Consumer and Commercial Products Survey sent out by the EPA to manufacturers and distributors is shown in Appendix B (EPA, 1995). Instructions for the survey form are provided on the survey cover page. Respondents must estimate the annual amount of products sold. This information is then combined with the product density to yield the pounds of product used in a given year. A smaller survey of local usage would use a simplified version of this questionnaire, limiting questions to a smaller group of products and to just usage amounts. The survey package should include a cover letter explaining the program, the survey form, a list of definitions, a map of the study area, and a postage-paid return envelope.

Returned information from the questionnaires should be compiled and stored using procedures defined in the inventory quality assurance plan. Because the survey recommended as an alternative method for this source category collects information about local usage, emissions are calculated by multiplying the usage amounts by the product VOC content (calculated by dividing the adjusted VOC content by the adjusted product sales) and VOC emitted percents developed from the EPA 1995 report and listed in Appendix A. Product usage amounts collected in volume units will need to be converted to weight units using the product density information collected from manufacturers or distributors.

To estimate HAP emissions from consumer and commercial products using the local usage data, use the per capita emission factors in Table 5.4-2 and the VOC per capita emission factors in Table 5.4-1 to develop weight percent factors for the HAP of interest. The weight percent factors are developed based on a ratio of individual HAPs to product VOC content. This method assumes that only product usage has changed (based on the survey results), not the HAP/VOC content ratio. An example calculation is shown below.

Example 5.5-1

The estimate glycol ethers emitted from personal care products (all types), the weight percent of glycol ethers emitted per pound of VOC is calculated by:

$$\begin{aligned}\text{glycol ethers} \\ \text{weight percent} &= [(0.0000152 \text{ lb/yr/person}) / (2.32 \text{ lb/yr/person})] * 100 \\ &= 0.0006551\end{aligned}$$

The weight percent factor is applied to the local VOC emission estimate:

$$\begin{aligned}\text{glycol ethers} \\ \text{emissions} &= (0.0006551/100) * \text{VOC emissions}\end{aligned}$$

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6

QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

When using the preferred method, data handling for all activity and emission factor data collected should be planned and documented in the Quality Assurance Plan. When using the alternative survey method, the survey planning, sample design, and data handling should be planned and documented in the Quality Assurance Plan. Refer to the discussion of survey planning and survey QA/QC in Chapter 1 of this volume, and the QA volume (VI) of the EIIP series.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

The role of emission estimate quality indicators in the inventory planning and development process is discussed in the QA volume of the EIIP series. This volume also provides information about the Data Attribute Rating System (DARS).

The preferred method gives high-quality estimates with relatively little effort. The level of effort required to calculate VOC emissions from consumer and commercial solvent use can range from 8 to 40 hours, depending on the level of detail needed within each product category, and whether or not there are applicable regulations that must be considered. It is impossible to estimate the resources needed if a survey is undertaken for all or some of the product categories to evaluate local use patterns. In fact, it is not recommended that a survey be undertaken for this source category unless the agency has reason to believe adjustments in the activity data (and product formulations if distributors and retailers are surveyed) are justified.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The DARS scores for each method are summarized in Tables 5.6-1 and 5.6-2. All scores assume that satisfactory QA/QC measures are performed and no significant deviations from good inventory practice have been made. If these assumptions are not met, new DARS scores should be developed according to the guidance provided in the QA volume.

TABLE 5.6-1**PREFERRED METHOD DARS SCORES: NATIONAL PER CAPITA EMISSION FACTORS
WITH ADJUSTMENTS FOR REGULATIONS**

Attribute	Scores		
	Emission Factor	Activity Factor	Emissions
Measurement	3	4	0.12
Source specificity	9	3	0.27
Spatial	6	9	0.54
Temporal ^a	9	10	0.90
Composite scores	0.675	0.65	0.457

^a Temporal scores will go down for the factors as time increases (i.e., the more time elapsed from survey date).

TABLE 5.6-2**ALTERNATIVE METHOD DARS SCORES: LOCAL SURVEY OF
DISTRIBUTORS/RETAILERS**

Attribute	Scores ^a		
	Emission Factor	Activity Factor	Emissions
Measurement	3	6	0.18
Source specificity	10	7	0.70
Spatial	10	10	1.0
Temporal ^b	10	10	1.0
Composite scores	0.825	0.825	0.72

^a Assumes that the survey is well designed and carried out. Flaws or limitations in the survey coverage will lower the scores.

^b Assumes this survey is for year of inventory.

6.1.2 SOURCES OF UNCERTAINTY

The statistics needed to quantify the uncertainty of the preferred method are incomplete. The variability of consumer and commercial product use is not well defined. Per capita usage may be lower or higher than the national average in different parts of the country and in different seasons. The product formulations are also variable. The VOC and HAP contents are national averages adjusted only for estimated market coverage of the manufacturer/distributor survey respondents and do not reflect local variations in product formulation. The uncertainty of the emission estimates can be quantified if the alternative method is used, as discussed in the QA volume.

The greatest source of variability pertinent to emissions is the regional variation in product usage. Climate, lifestyle, and behavioral factors will affect the amounts and types of products used in a locality. Furthermore, demographics (i.e., proportion of population in different age groups) need to be considered. Preteen children are not likely to use many of these products. Other age, gender, and ethnic differences will affect the type and amount of product used. Because the emission factor is based on the national population, local variations from national demographics patterns contribute to emission estimate uncertainty.

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7

DATA CODING PROCEDURES

This section describes the codes available to characterize consumer and commercial solvent emission estimates. Consistent categorization and coding will result in greater uniformity between inventories. Inventory planning for data collection calculations and inventory presentation should take the data formats presented in this section into account. Available codes and process definitions may impose constraints or requirements on the preparation of emission estimates for this category.

7.1 PROCESS CODES

The source category process codes for consumer and commercial products are shown in Table 5.7-1. These codes are derived from the EPA's Aerometric Information Retrieval System (AIRS) Area and Mobile Source (AMS) category codes (EPA, 1994c). There are no appropriate control codes for use with AMS for this source category.

TABLE 5.7-1

AIRS AMS CODES FOR CONSUMER AND COMMERCIAL PRODUCTS

Process Description	AMS Code
Miscellaneous Nonindustrial: All Classes	
All processes	24-60-000
Total: All solvent types	24-60-000-000
Acetone	24-60-000-030
Butyl acetate	24-60-000-055
Butyl alcohols: All types	24-60-000-060
n-Butyl alcohol	24-60-000-065
Isobutyl alcohol	24-60-000-070
Ethanol	24-60-000-165
Ethyl acetate	24-60-000-170
Ethylbenzene	24-60-000-185
Isopropanol	24-60-000-250
Methanol	24-60-000-260
Methyl isobutyl ketone	24-60-000-285
Monochlorobenzene	24-60-000-300
o-Dichlorobenzene	24-60-000-330
p-Dichlorobenzene	24-60-000-340
Perchloroethylene	24-60-000-345
Propylene glycol	24-60-000-350
Special naphthas	24-60-000-370
Trichloroethylene	24-60-000-385
Solvents: NEC ^a	24-60-000-999

TABLE 5.7-1

(CONTINUED)

Process Description	AMS Code
Miscellaneous Nonindustrial: Commercial	
All Processes	24-61-000
Total: All solvent types	24-61-000-000
Adhesives and Sealants	24-61-200
Total: All solvent types	24-61-200-000
Pesticide Application: All Processes	24-61-800
Total: All solvent types	24-61-800-000
Solvents: NEC	24-61-800-999
Miscellaneous Nonindustrial: Consumer	
All Products/Processes	24-65-000
Total: All solvent types	24-65-000-000
Acetone	24-65-000-030
Butyl acetate	24-65-000-055
Butyl alcohols: All types	24-65-000-060
n-Butyl alcohol	24-65-000-065
Isobutyl alcohol	24-65-000-070
Ethanol	24-65-000-165
Ethyl acetate	24-65-000-170
Ethylbenzene	24-65-000-185
Isopropanol	24-65-000-250
Methanol	24-65-000-260
Methyl isobutyl ketone	24-65-000-285

TABLE 5.7-1

(CONTINUED)

Process Description	AMS Code
Monochlorobenzene	24-65-000-300
o-Dichlorobenzene	24-65-000-330
p-Dichlorobenzene	24-65-000-340
Perchloroethylene	24-65-000-345
Propylene glycol	24-65-000-350
Special naphthas	24-65-000-370
Trichloroethylene	24-65-000-385
Solvents: NEC	24-65-000-999
Personal Care Products	24-65-100
Total: All solvent types	24-65-100-000
Household Products	24-65-200
Total: All solvent types	24-65-200-000
Automotive Aftermarket Products	24-65-400
Total: All solvent types	24-65-400-000
Adhesives and Sealants	24-65-600
Total: All solvent types	24-65-600-000
Pesticide Application	24-65-800
Total: All solvent types	24-65-800-000
Miscellaneous Products: NEC	24-65-900
Total: All solvent types	24-65-900-000

Source: EPA, 1994c.

8

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APPENDIX A

RESULTS OF THE EPA'S CONSUMER PRODUCT SURVEY (VOC)

[Adapted from Table 5-1 of EPA, 1995]

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APPENDIX A

Notes on Results of the Consumer Products Survey

1. Reportable volatile organic compounds (RVOCs) are a subset of VOCs (EPA's definition of VOC can be found in 57 FR 3941, February 3, 1992). RVOCs are those VOCs that have a vapor pressure greater than 0.1 mm Hg at 20°C or which, if the vapor pressure is unknown, contain 12 or less carbon atoms. Those VOCs that exist as solids at 20°C and readily sublime or become vapors at the temperature at which they are used are also RVOCs.
2. Information on product sales reported, and RVOC content were obtained directly from the survey responses.
3. Estimated market coverage information was obtained from Chemical Specialties Manufacturers Association (CSMA), Cosmetics, Toiletries, and Fragrance Association (CTFA), and Soap and Detergent Association (SDA).
4. Adjusted RVOC content was obtained by dividing RVOC content reported by estimated market coverage.
5. Percent RVOC content emitted is based on information submitted by CSMA, CTFA, and SDA. This factor accounts for biodegradation or other fates (other than being emitted to the air) of consumer product RVOCs that enter the wastewater stream.
6. RVOC emitted in U.S. was obtained by multiplying Adjusted RVOC content by percent RVOC content emitted and reflects actual RVOC emissions to the air.
7. Emissions per person were obtained by dividing RVOC emitted in U.S. by the U.S. population (284 million).
8. Before using the pesticide data, refer to the discussion in Section 2 of this chapter.

The remainder of this Appendix is a table of emission factors, and is attached to this document as a spreadsheet, named EIIPRES.WK1. (Note: Worksheet has been converted to a pdf file. ALI 6/24/97)

Product Category Description	RVOC Content Reported (tons per year)	Estimated Market Coverage (percent)	Adjusted Product Sales (tons)	Adjusted RVOC Content (tons per year)	RVOC Content Emitted (percent)	RVOC Emitted in U.S. (tons per year)	Per Capita Emissions (lb/yr/person)
PERSONAL CARE PRODUCTS							
Hair Care Products							
Bleaches and lightners	101.97	95	3,090.13	107.34	10	10.73	8.66E-05
Brilliantines	0.18	95	5.83	0.19	100	0.19	1.53E-06
Conditioners	843.35	95	130,813.90	887.74	5	44.39	3.58E-04
Conditioning sprays	12.62	95	1,398.02	13.29	100	13.29	1.07E-04
Curl activators	2.33	95	1,220.80	2.46	100	2.46	1.98E-05
Curl revitalizers	172.02	95	833.59	181.07	100	181.07	1.46E-03
Dyes - Permanent	1,455.34	95	15,662.70	1,531.93	10	153.19	1.24E-03
Dyes - Semipermanent	72.25	95	3,327.25	76.06	10	7.61	6.13E-05
Dyes - Temporary	739.12	95	6,649.97	778.02	10	77.80	6.27E-04
Finishing hair sprays	152,229.77	94	179,512.87	161,946.56	100	161,946.56	1.31E+00
Finishing spritzes	6,115.34	95	7,422.48	6,437.20	100	6,437.20	5.19E-02
Grooming creams	4.17	95	1,408.68	4.39	100	4.39	3.54E-05
Mousses	2,312.69	95	19,471.63	2,434.41	100	2,434.41	1.96E-02
Permanent wave treatments	251.36	95	52,933.83	264.59	10	26.46	2.13E-04
Pomades	3.78	95	1,945.92	3.98	100	3.98	3.21E-05
Rinses	9.21	95	975.96	9.69	5	0.48	3.91E-06
Setting lotions	237.34	95	1,357.55	249.83	100	249.83	2.01E-03
Shampoos	1,895.11	95	291,199.33	1,994.85	5	99.74	8.04E-04
Spray shines	469.51	95	917.98	494.22	100	494.22	3.99E-03
Straighteners	0.00	95	5.48	0.00	10	0.00	2.86E-09
Styling gels	603.24	95	12,647.41	634.99	100	634.99	5.12E-03
Styling sprays	3,637.18	95	6,322.15	3,828.61	100	3,828.61	3.09E-02
Styling spritzes	7,101.12	95	9,469.20	7,474.86	100	7,474.86	6.03E-02
Thickeners	0.06	95	29.82	0.06	100	0.06	5.13E-07
Tonics	367.56	95	1,455.58	386.90	100	386.90	3.12E-03
Other hair care products	48.91	95	2,723.76	51.49	100	51.49	4.15E-04
All Hair Care Products	178,685.53		752,801.82	189,794.74		184,564.91	1.49E+00
Deodorants and Antiperspirants							
Underarm deodorants and antiperspirants	8,961.29	100	24,363.66	8,961.29	100	8,961.29	7.23E-02
Underarm antiperspirants	21,817.84	100	37,755.10	21,817.84	100	21,817.84	1.76E-01
Foot deodorant sprays	167.74	95	184.94	176.57	100	176.57	1.42E-03
Feminine hygiene deodorants	32.31	95	69.72	34.01	100	34.01	2.74E-04
Other deodorants and antiperspirant products	81.91	95	363.20	86.22	100	86.22	6.95E-04
All Deodorants and Antiperspirants	31,061.10		62,736.62	31,075.94		31,075.94	2.51E-01
Fragrance Products							
Colognes	8,460.98	95	10,755.10	8,906.29	100	8,906.29	7.18E-02
Perfumes	152.50	95	183.02	160.53	100	160.53	1.29E-03
Toilet waters	807.21	95	949.20	849.70	100	849.70	6.85E-03
After shave treatments	5,988.03	95	11,177.61	6,303.19	100	6,303.19	5.08E-02
Body fragrance sprays	1,562.69	95	1,818.60	1,644.94	100	1,644.94	1.33E-02
Bath oils, beads and capsules	156.36	95	10,156.94	164.59	5	8.23	6.64E-05
Other fragrance products	753.20	95	3,770.56	792.84	100	792.84	6.39E-03
All Fragrance Products	17,880.98		38,811.03	18,822.08		18,665.72	1.51E-01
Powders							
Baby powders	10.15	95	92,141.87	10.69	100	10.69	8.62E-05
Body powders	19.45	95	3,598.28	20.47	100	20.47	1.65E-04

Foot powders	2,497.19	95	4,448.12	2,628.63	100	2,628.63	2.12E-02
Other powder products	847.84	95	2,515.23	892.47	100	892.47	7.20E-03
All Powders	3,374.64		102,703.50	3,552.25		3,552.25	2.86E-02
Nail Care Products							
Polishes	1,448.30	95	2,780.68	1,524.53	100	1,524.53	1.23E-02
Base coats, undercoats	417.25	95	580.68	439.21	100	439.21	3.54E-03
Polish removers	1,804.10	95	8,072.25	1,899.05	100	1,899.05	1.53E-02
Nail extenders	0.00	95	11.52	0.00	100	0.00	0.00E+00
Cuticle softeners	0.37	95	109.91	0.39	10	0.04	3.11E-07
Manicure preparations	0.19	95	55.36	0.20	100	0.20	1.61E-06
Other nail care products	819.77	95	1,133.93	862.91	100	862.91	6.96E-03
All Nail Care Products	4,489.98		12,744.33	4,726.29		4,725.94	3.81E-02
Facial and Body Treatments							
Astringents	5,442.72	95	15,563.60	5,729.18	100	5,729.18	4.62E-02
Creams, scrubs, cleaners	311.29	95	24,919.04	327.68	10	32.77	2.64E-04
Rouges and blushes	10.28	95	1,203.92	10.82	100	10.82	8.72E-05
Makeup bases, foundations and fixatives	128.29	95	4,181.73	135.04	100	135.04	1.09E-03
Lipsticks	3.00	95	952.80	3.15	100	3.15	2.54E-05
Moisturizers	152.72	95	14,399.23	160.75	100	160.75	1.30E-03
Skin lighteners	17.24	95	268.63	18.14	100	18.14	1.46E-04
Facial masques	8.77	95	1,554.50	9.23	100	9.23	7.44E-05
Mascara	175.05	95	954.41	184.27	100	184.27	1.49E-03
Eyeliners	11.58	95	135.51	12.19	100	12.19	9.83E-05
Eye shadow	6.55	95	420.08	6.89	100	6.89	5.56E-05
Eye makeup remover	8.31	95	509.67	8.74	100	8.74	7.05E-05
Eyebrow pencil	0.51	95	57.52	0.53	100	0.53	4.31E-06
Hand and body lotions	361.31	95	57,966.63	380.32	100	380.32	3.07E-03
Skin protectants	136.40	95	12,325.90	143.58	100	143.58	1.16E-03
Depilatories	6.56	95	1,566.48	6.91	10	0.69	5.57E-06
Self-tanning preparations	30.42	95	885.02	32.03	100	32.03	2.58E-04
Suntan oils and lotions	52.60	95	1,579.12	55.36	100	55.36	4.46E-04
Sunscreens	132.82	95	4,343.37	139.81	100	139.81	1.13E-03
Other facial and body makeup and treatments	248.79	95	3,097.84	261.89	100	261.89	2.11E-03
All Facial and Body Treatments	7,245.20		146,885.00	7,626.52		7,325.39	5.91E-02
Oral Care Products							
Mouthwashes	23,932.53	77	159,846.68	31,081.21	5	1,554.06	1.25E-02
Breath fresheners	386.42	95	619.34	406.76	5	20.34	1.64E-04
Toothpastes, gels and powders	1,083.21	95	89,532.10	1,140.23	5	57.01	4.60E-04
Plaque removal solutions	2,111.43	95	32,925.46	2,222.55	5	111.13	8.96E-04
Fluoride rinses	562.81	95	9,203.84	592.43	5	29.62	2.39E-04
Dental care products	33.34	95	3,868.67	35.10	5	1.75	1.42E-05
Other oral care products	24.91	95	1,084.85	26.22	5	1.31	1.06E-05
All Oral Care Products	28,134.66		297,080.94	35,504.50		1,775.22	1.43E-02
Health Use Products (External Only)							
Over-the-counter (OTC) drugs (external only)	3,877.13	95	43,373.96	4,081.19	100	4,081.19	3.29E-02
Prescription pharmaceuticals (external only)	438.58	95	2,523.03	461.67	100	461.67	3.72E-03
Other health use products	1,539.26	95	10,484.45	1,620.27	100	1,620.27	1.31E-02
All Health Use Products (External Only)	5,854.98		56,381.44	6,163.13		6,163.13	4.97E-02
Miscellaneous Personal Care Products							

Hand cleaners and soaps	13,594.20	72	636,887.19	18,880.83	5	944.04	7.61E-03
Rubbing alcohol	23,027.28	95	37,084.21	24,239.24	100	24,239.24	1.95E-01
Shaving creams, gels, and soaps	1,857.50	97	47,990.06	1,914.95	5	95.75	7.72E-04
Other miscellaneous personal care products	3,979.46	95	119,394.84	4,188.91	100	4,188.91	3.38E-02
All Miscellaneous Personal Care Products	42,458.44		841,356.30	49,223.93		29,467.94	2.38E-01
ALL PERSONAL CARE PRODUCTS	319,185.49		2,311,500.98	346,489.38		287,316.45	2.32E+00

HOUSEHOLD PRODUCTS

Hard Surface Cleaners							
General purpose cleaners	27,741.06	90	529,617.81	30,823.39	5	1,541.17	1.24E-02
Glass cleaners	14,604.73	95	217,180.86	15,373.40	100	15,373.40	1.24E-01
Oven cleaners	1,806.96	95	28,607.45	1,902.06	100	1,902.06	1.53E-02
Tub, tile, and sink cleaners	2,634.83	95	57,011.15	2,773.50	50	1,386.75	1.12E-02
Mildew removers	291.00	100	18,805.17	291.00	100	291.00	2.35E-03
Toilet bowl cleaners	606.46	100	55,364.27	606.46	5	30.32	2.45E-04
Hard surface rust stain removers	1.17	100	3,336.53	1.17	100	1.17	9.42E-06
Metal cleansers	1,525.42	100	20,302.87	1,525.42	100	1,525.42	1.23E-02
Soap scouring pads	93.24	100	12,233.37	93.24	100	93.24	7.52E-04
Other hard surface cleaners	6,145.07	100	226,340.20	6,145.07	5	307.25	2.48E-03
All Hard Surface Cleaners	55,449.94		1,168,799.68	59,534.72		22,451.79	1.81E-01

Laundry Products							
Detergents	41,476.16	81	2,826,470.93	51,205.14	1	512.05	4.13E-03
Soaps	1.81	73	28,130.75	2.47	1	0.02	1.99E-07
Presoaks	18.67	73	4,470.05	25.58	1	0.26	2.06E-06
Prewash spot and stain removers	3,795.64	73	86,965.05	5,199.50	25	1,299.88	1.05E-02
Bleaches	714.10	58	1,395,927.74	1,231.20	1	12.31	9.93E-05
Whiteners/brighteners	15.63	73	22,231.11	21.41	1	0.21	1.73E-06
Bluing	0.16	73	220.17	0.22	1	0.00	1.78E-08
Fabric softeners	6,279.65	75	581,862.56	8,372.87	1	83.73	6.75E-04
Water softeners and conditioners	14.67	73	54,326.31	20.10	1	0.20	1.62E-06
Starches, sizings, and fabric finishes	4,423.94	73	127,141.62	6,060.20	100	6,060.20	4.89E-02
Other laundry products	1,463.84	73	31,284.10	2,005.26	1	20.05	1.62E-04
All Laundry Products	58,204.28		5,159,030.39	74,143.96		7,988.92	6.44E-02

Fabric and Carpet Care Products							
Carpet cleaners	1,820.25	100	42842.87	1,820.25	50	910.13	7.34E-03
Carpet deodorizers and fresheners	245.26	100	21457.70	245.26	100	245.26	1.98E-03
Upholstery cleaners	208.27	100	2064.63	208.27	100	208.27	1.68E-03
Spot removers	996.28	100	5102.85	996.28	100	996.28	8.03E-03
Fabric stain repellants	1,043.52	95	5142.87	1,098.45	100	1,098.45	8.86E-03
Water repellants	10.91	50	409.56	21.82	100	21.82	1.76E-04
Fabric dyes	0.01	100	33.14	0.01	5	0.00	2.66E-09
Antistatic sprays	22.24	50	212.60	44.47	100	44.47	3.59E-04
Dry cleaning fluids	1,629.65	100	1689.68	1,629.65	100	1,629.65	1.31E-02
Other fabric, carpet, and upholstery care products	172.15	100	2998.74	172.15	100	172.15	1.39E-03
All Fabric and Carpet Care Products	6,148.55		81,954.64	6,236.63		5,326.49	4.30E-02

Dishwashing Products							
Dish detergents (manual)	23,198.00	78	637,692.42	29,741.02	5	1,487.05	1.20E-02
Dish detergents (machine)	3,377.83	79	384,802.25	4,275.74	2	85.51	6.90E-04
Rinse aids	99.98	73	8,978.14	136.96	1	1.37	1.10E-05
Film and spot removers	1.05	73	494.50	1.43	1	0.01	1.16E-07

Other dishwashing products	13.59	73	2,452.49	18.62	1	0.19	1.50E-06
All Dishwashing Products	26,690.45		1,034,419.80	34,173.77		1,574.14	1.27E-02
Waxes and Polishes							
Furniture waxes and polishes	3,856.47	95	31,909.86	4,059.44	100	4,059.44	3.27E-02
Floor waxes and polishes	6,275.82	95	163,125.16	6,606.13	100	6,606.13	5.33E-02
Dusting aids	720.58	90	4,030.50	800.64	100	800.64	6.46E-03
Other household waxes and polishes	1,271.03	90	21,546.06	1,412.25	100	1,412.25	1.14E-02
All Waxes and Polishes	12,123.90		220,611.58	12,878.47		12,878.47	1.04E-01
Air Fresheners							
Room air fresheners	25,647.83	95	120,722.48	26,997.72	100	26,997.72	2.18E-01
Toilet deodorant blocks	6,648.37	75	9,661.94	8,864.49	50	4,432.25	3.57E-02
Other air fresheners	2,064.23	90	10,915.68	2,293.59	100	2,293.59	1.85E-02
All Air Fresheners	34,360.44		141,300.10	38,155.80		33,723.56	2.72E-01
Shoe and Leather Care Products							
Leather preservative treatments	101.84	100	286.63	101.84	100	101.84	8.21E-04
Shoe polishes	43.50	50	486.82	87.00	100	87.00	7.02E-04
Other shoe and leather care products	85.58	75	313.47	114.11	100	114.11	9.20E-04
All Shoe and Leather Care Products	230.92		1,086.92	302.95		302.95	2.44E-03
Miscellaneous Household Products							
Lubricants	1,735.72	50	13,000.28	3,471.44	100	3,471.44	2.80E-02
Drain openers	385.20	100	18,277.87	385.20	1	3.85	3.11E-05
Charcoal lighters	35,653.66	90	95,932.98	39,615.18	10	3,961.52	3.19E-02
Wick lamp fuels	5,962.97	90	8,573.40	6,625.52	10	662.55	5.34E-03
Plant leaf cleaners and waxes	6.24	100	52.57	6.24	100	6.24	5.04E-05
Driveway cleaners	2.94	90	239.70	3.27	100	3.27	2.64E-05
Other miscellaneous household products	5,122.62	90	23,665.43	5,691.80	100	5,691.80	4.59E-02
All Miscellaneous Household Products	48,869.35		159,742.23	55,798.64		13,800.67	1.11E-01
ALL HOUSEHOLD PRODUCTS	242,077.83		7,966,945.34	281,224.94		98,046.98	7.91E-01

AUTOMOTIVE AFTERMARKET PRODUCTS

Detailing Products							
Waxes, polishes and finish sealers	4,107.63	95	16,793.88	4,323.83	100	4,323.83	3.49E-02
Vinyl and leather cleaners	157.76	95	1,224.34	166.07	100	166.07	1.34E-03
Upholstery fabric cleaners	262.89	95	2,849.90	276.73	100	276.73	2.23E-03
Tire cleaners	385.13	90	5,653.91	427.92	100	427.92	3.45E-03
Wheel cleaners	145.25	90	3,003.06	161.39	100	161.39	1.30E-03
Bug and tar removers	857.68	95	1,397.16	902.82	100	902.82	7.28E-03
Chrome cleaners and polishes	103.15	95	555.86	108.57	100	108.57	8.76E-04
Rubber and vinyl protectants	1,101.17	95	3,001.27	1,159.12	100	1,159.12	9.35E-03
Other automotive detailing products	1,606.04	90	18,717.36	1,784.49	100	1,784.49	1.44E-02
All Detailing Products	8,726.70		53,196.74	9,310.94		9,310.94	7.51E-02
Maintenance and Repair Products							
Engine degreasers	6,551.91	98	17,875.50	6,685.62	25	1,671.40	1.35E-02
Carburetor and choke cleaners	10,858.42	95	13,372.35	11,429.92	50	5,714.96	4.61E-02
Brake cleaners	3,750.73	95	16,020.42	3,948.13	100	3,948.13	3.18E-02
Brake anti-squeal compounds	14.52	95	295.56	15.28	100	15.28	1.23E-04
Tire sealants and inflators	3,293.63	100	10,955.59	3,293.63	100	3,293.63	2.66E-02
Belt dressings	46.09	100	336.56	46.09	100	46.09	3.72E-04

Engine starting fluids	4,099.05	90	5,102.64	4,554.50	50	2,277.25	1.84E-02
Lubricants (other than engine oil)	17,371.06	100	70,324.77	17,371.06	100	17,371.06	1.40E-01
Antifreezes	2,843.42	90	241,697.15	3,159.36	100	3,159.36	2.55E-02
Brake fluids	2,553.71	90	30,036.85	2,837.45	100	2,837.45	2.29E-02
Body repair products (other than coatings)	312.54	90	12,412.39	347.26	100	347.26	2.80E-03
Windshield deicers	2,030.61	100	3,943.82	2,030.61	100	2,030.61	1.64E-02
Windshield washer fluids	45,476.18	60	214,854.52	75,793.64	100	75,793.64	6.11E-01
Other automotive maintenance and repair products	36,736.64	90	65,403.43	40,818.49	100	40,818.49	3.29E-01
All Maintenance and Repair Products	135,938.50		702,631.55	172,331.04		159,324.62	1.28E+00
ALL AUTOMOTIVE AFTERMARKET PRODUCTS	144,665.20		755,828.29	181,641.98		168,635.56	1.36E+00

ADHESIVES AND SEALANTS

Consumer Adhesives							
Household glues and pastes	276.23	90	13,680.39	306.92	100	306.92	2.48E-03
Arts and crafts adhesives	479.60	90	3,088.70	532.89	100	532.89	4.30E-03
Carpet and tile adhesives	5,152.04	90	80,383.57	5,724.49	100	5,724.49	4.62E-02
Wallpaper adhesives	22.96	90	2,336.56	25.51	100	25.51	2.06E-04
Woodworking glues	570.64	90	24,160.91	634.05	100	634.05	5.11E-03
Plastic pipe cements and primers	4,114.23	90	6,551.56	4,571.37	100	4,571.37	3.69E-02
Thread locking compounds	6.36	90	2,769.59	7.06	100	7.06	5.70E-05
Specialty automotive adhesives	1,662.34	90	57,844.11	1,847.05	100	1,847.05	1.49E-02
Construction adhesives	26,048.42	90	154,405.11	28,942.69	100	28,942.69	2.33E-01
Other adhesives	16,958.14	90	113,610.19	18,842.37	100	18,842.37	1.52E-01
All Consumer Adhesives	55,290.96		458,830.69	61,434.40		61,434.40	4.95E-01

Sealants							
Spackling compounds	76.15	90	22,834.94	84.61	100	84.61	6.82E-04
Caulking compounds	3,119.17	90	84,098.71	3,465.74	100	3,465.74	2.79E-02
Window glazing compounds	446.62	90	18,082.99	496.24	100	496.24	4.00E-03
Pipe thread sealants	16.34	90	1,375.18	18.16	100	18.16	1.46E-04
Plumber's putties	0.00	90	492.09	0.00	100	0.00	0.00E+00
Painter's putties	0.03	90	1.98	0.03	100	0.03	2.39E-07
Wood fillers	356.11	90	2,661.23	395.67	100	395.67	3.19E-03
Insulating and sealing foams	8.03	90	5,751.61	8.93	100	8.93	7.20E-05
Driveway patching compounds	173.47	90	3,453.59	192.75	100	192.75	1.55E-03
Cold process roof cements	1,086.57	90	4,036.37	1,207.30	100	1,207.30	9.74E-03
Other sealants	2,825.91	90	57,176.98	3,139.90	100	3,139.90	2.53E-02
All Sealants	8,108.40		199,965.67	9,009.33		9,009.33	7.27E-02
ALL ADHESIVES AND SEALANTS	63,399.36		658,796.36	70,443.73		70,443.73	5.68E-01

FIFRA-REGULATED PRODUCTS

Insecticides							
Lawn and garden insecticides	6,627.42	75	77,260.81	8,836.56	100	8,836.56	7.13E-02
Space insecticides and room foggers	4,120.99	95	24,508.89	4,337.89	100	4,337.89	3.50E-02
Flying insect sprays	5,908.45	95	16,758.28	6,219.42	100	6,219.42	5.02E-02
Residual insecticides	16,417.44	95	46,263.01	17,281.52	100	17,281.52	1.39E-01
Hornet and wasp sprays	1,319.84	95	4,615.46	1,389.31	100	1,389.31	1.12E-02
Flea and tick soaps, sprays, and dips	3,070.47	95	11,900.53	3,232.07	100	3,232.07	2.61E-02
Other insecticides	16,127.67	90	104,977.41	17,919.64	100	17,919.64	1.45E-01
All Insecticides	53,592.29		286,284.39	59,216.41		59,216.41	4.78E-01

Fungicides and Nematicides

Lawn and garden treatments	221.24	90	4,259.13	245.83	100	245.83	1.98E-03
Wood preservatives	15,562.75	100	93,048.64	15,562.75	100	15,562.75	1.26E-01
Mold and mildew retardants	22.97	100	439.81	22.97	100	22.97	1.85E-04
Other fungicides and nematicides	23,538.86	90	71,774.82	26,154.29	100	26,154.29	2.11E-01
All Fungicides and Nematicides	39,345.83		169,522.40	41,985.84		41,985.84	3.39E-01
Herbicides							
Aquatic herbicides	2.44	90	15,348.99	2.71	5	0.14	1.09E-06
Swimming pool algicides	336.38	90	10,390.77	373.76	5	18.69	1.51E-04
Terrestrial herbicides, defoliants, desiccants	43,195.79	100	328,635.53	43,195.79	100	43,195.79	3.48E-01
Other herbicides	20,195.67	100	86,289.05	20,195.67	100	20,195.67	1.63E-01
All Herbicides	63,730.28		440,664.34	63,767.92		63,410.28	5.11E-01
Antimicrobial Agents							
Sanitizers	1,757.65	100	65,584.93	1,757.65	50	878.83	7.09E-03
Disinfectants	29,094.86	99	367,780.51	29,388.75	50	14,694.37	1.19E-01
Sterilants	2,494.15	90	15,108.13	2,771.27	75	2,078.46	1.68E-02
Other antimicrobial agents	353.44	100	8,875.93	353.44	75	265.08	2.14E-03
All Antimicrobial Agents	33,700.10		457,349.50	34,271.11		17,916.74	1.44E-01
Other FIFRA-Regulated Products							
Insect repellants	7,951.05	99	10,286.23	8,031.36	100	8,031.36	6.48E-02
Domestic cat and dog repellants	169.30	100	1,323.19	169.30	100	169.30	1.37E-03
Rodent poisons and baits	12.42	100	3,148.36	12.42	100	12.42	1.00E-04
Other miscellaneous FIFRA-controlled products	29,677.70	100	43,053.89	29,677.70	100	29,677.70	2.39E-01
All Other FIFRA-Regulated Products	37,810.47		57,811.67	37,890.79		37,890.79	3.06E-01
ALL FIFRA-REGULATED PRODUCTS	228,178.97		1,411,632.30	237,132.07		220,420.05	1.78E+00
COATINGS AND RELATED PRODUCTS (Except Architectural and Industrial Maintenance Coatings)							
Aerosol Spray Paints							
Nonflat enamels	27,520.66	100	54,693.77	27,520.66	100	27,520.66	2.22E-01
Flat enamels	5,884.67	100	15,432.01	5,884.67	100	5,884.67	4.75E-02
Nonflat lacquers	5,172.12	100	9,918.92	5,172.12	100	5,172.12	4.17E-02
Flat lacquers	999.29	100	2,091.84	999.29	100	999.29	8.06E-03
Metallic pigmented coatings	4,163.64	100	6,039.44	4,163.64	100	4,163.64	3.36E-02
Clear coatings	2,650.33	100	4,250.81	2,650.33	100	2,650.33	2.14E-02
Ground/traffic marking coatings	3,153.50	100	5,348.38	3,153.50	100	3,153.50	2.54E-02
Exact match automotive paints	905.52	100	1,955.83	905.52	100	905.52	7.30E-03
Vinyl/fabric coatings	144.26	100	255.07	144.26	100	144.26	1.16E-03
Glass coatings	13.30	100	680.53	13.30	100	13.30	1.07E-04
Automotive sanding primers	1,703.57	100	3,586.64	1,703.57	100	1,703.57	1.37E-02
Rust-inhibitive primers	2,865.97	100	5,074.98	2,865.97	100	2,865.97	2.31E-02
Spatter finishes	525.52	100	1,013.80	525.52	100	525.52	4.24E-03
Wood stains	221.34	100	1,659.26	221.34	100	221.34	1.79E-03
Engine enamels	2,046.38	100	3,618.87	2,046.38	100	2,046.38	1.65E-02
High temperature coatings	1,475.44	100	2,273.24	1,475.44	100	1,475.44	1.19E-02
Other aerosol spray paints and coatings	3,181.10	100	13,446.85	3,181.10	100	3,181.10	2.57E-02
All Aerosol Spray Paints	62,626.62		131,340.24	62,626.62		62,626.62	5.05E-01
Coating-Related Products							
Paint thinners	14,061.00	90	15,659.00	15,659.00	100	15,623.00	1.26E-01
Paint removers	4,499.78	90	15,928.21	4,999.76	100	4,999.76	4.03E-02
Brush cleaners and reconditioners	331.73	90	482.29	368.59	100	368.59	2.97E-03

Solvents	28,407.76	90	46,338.53	31,564.18	100	31,564.18	2.55E-01
Other coatings related products	3,081.06	90	24,563.35	3,423.40	100	3,423.40	2.76E-02
All Coating-Related Products	50,381.34		102,971.38	56,014.94		55,978.94	4.51E-01
ALL COATINGS AND RELATED PRODUCTS	113,007.96		234,311.62	118,641.55		118,605.55	9.56E-01
MISCELLANEOUS PRODUCTS (Not Otherwise Covered)							
Arts and Crafts Supplies							
Artists paints, pigments and thinners	577.28	90	1,129.61	641.42	100	641.42	5.17E-03
Fixative sprays	29.74	90	158.68	33.05	100	33.05	2.67E-04
Specialty cleaning products	642.84	90	1,313.02	714.27	100	714.27	5.76E-03
Ceramic finishing products	19.48	90	436.37	21.64	100	21.64	1.75E-04
Other arts and crafts supplies	501.55	90	2,454.20	557.27	100	557.27	4.49E-03
All Arts and Crafts Supplies	1,770.89		5,491.88	1,967.65		1,967.65	1.59E-02
Animal drugs (external only)	176.51	100	15,398.93	176.51	100	176.51	1.42E-03
Livestock and pet grooming products	126.30	100	1,620.76	126.30	100	126.30	1.02E-03
Cat litters	262.50	60	319,601.89	437.50	100	437.50	3.53E-03
Other non-pesticidal veterinary and pet products	72.05	100	5,809.78	72.05	100	72.05	5.81E-04
All Non-Pesticidal Veterinary and Pet Products	637.36		342,431.36	812.36		812.36	6.55E-03
Pressurized Food Products							
Pan sprays	2,583.89	95	9,902.98	2,719.88	100	2,719.88	2.19E-02
Whipped dessert toppings	107.85	90	7,596.50	119.83	100	119.83	9.66E-04
Other pressurized food products	0.04	90	157.76	0.04	100	0.04	3.29E-07
All Pressurized Food Products	2,691.77		17,657.24	2,839.75		2,839.75	2.29E-02
Office Supplies							
Pens	16.58	25	23,725.04	66.32	100	66.32	5.35E-04
Ink	1.93	25	128.78	7.73	100	7.73	6.23E-05
Permanent markers	14.21	25	2,412.22	56.84	100	56.84	4.58E-04
Dry erasable markers	0.01	25	305.76	0.04	100	0.04	3.04E-07
Highlighters	2.48	25	1,910.13	9.90	100	9.90	7.98E-05
Correction fluids	0.01	25	0.03	0.03	100	0.03	2.42E-07
Inked ribbons (for typewriters, printers, etc.)	0.00	25	1,226.75	0.00	100	0.00	0.00E+00
Other office supplies	702.18	25	5,703.84	2,808.72	100	2,808.72	2.27E-02
All Office Supplies	737.39		35,412.55	2,949.58		2,949.58	2.38E-02
ALL MISCELLANEOUS PRODUCTS	5,837.41		400,993.03	8,569.34		8,569.34	6.91E-02
All Surveyed Categories	1,116,352.23		13,740,007.92	1,244,143.00		972,037.67	7.84E+00

APPENDIX B

EPA CONSUMER/COMMERCIAL PRODUCTS SURVEY

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**U.S. ENVIRONMENTAL PROTECTION AGENCY
CONSUMER AND COMMERCIAL PRODUCTS SURVEY**

**EPA CONSUMER/COMMERCIAL PRODUCTS SURVEY
P.O. Box 14847
RESEARCH TRIANGLE PARK, NC 27709-4847
(919) 493-6263**

GENERAL INSTRUCTIONS FOR THE CONSUMER AND COMMERCIAL PRODUCTS VOC SURVEY FORM

THE **CONSUMER AND COMMERCIAL PRODUCTS VOC SURVEY FORM** (SURVEY FORM) IS COMPOSED OF TWO SHEETS; A **COMPANY SHEET** AND A TWO-PAGE **PRODUCT SHEET**. EACH COMPANY RECEIVING THIS FORM NEEDS TO COMPLETE AND RETURN A COMPANY SHEET. THE PRODUCT SHEET (OR THE COMPUTER DATABASE EQUIVALENT) NEEDS TO BE COMPLETED BY ALL COMPANIES THAT PRODUCE OR MARKET A PRODUCT LISTED IN ATTACHMENT A AND THAT ARE NOT EXEMPT, AS DESCRIBED BELOW. THE FOLLOWING STEPS SHOULD BE FOLLOWED BEFORE COMPLETING EITHER THE **COMPANY SHEET** OR **PRODUCT SHEET**:

- 1) DETERMINE IF ANY OF THE PRODUCT CATEGORIES LISTED IN ATTACHMENT A INCLUDE PRODUCTS DISTRIBUTED OR SOLD BY THE COMPANY.
- 2) DETERMINE IF ANY OF THE PRODUCTS IDENTIFIED IN ITEM 1 ABOVE ARE SOLD UNDER THE COMPANY'S LABEL (SEE **EXEMPTIONS FROM SUBMITTING PRODUCT SHEETS** BELOW).
- 3) GATHER FORMULATION DATA (LIST OF INGREDIENTS), DISTRIBUTION DATA, 1990 SALES DATA, AND OTHER INFORMATION REQUIRED FOR COMPLETING THE **PRODUCT SHEET** FOR EACH PRODUCT MEETING THE ABOVE REQUIREMENTS. TREAT EACH PRODUCT FORM (AEROSOL, LIQUID, ETC.) AS A SEPARATE PRODUCT.

GROUPING OF PRODUCTS. PRODUCTS MAY BE GROUPED AND REPORTED ON ONE PRODUCT SHEET IF ALL OF THE FOLLOWING CONDITIONS ARE MET:

- A) ALL PRODUCTS IN THE GROUP ARE IN THE SAME PRODUCT CATEGORY (I.E., HAVE THE SAME PRODUCT

- CATEGORY CODE IN ITEM 2 ON THE **PRODUCT SHEET**).
- B) ALL PRODUCTS HAVE THE SAME PRODUCT FORM (ITEM 3 ON THE **PRODUCT SHEET**).
 - C) EACH PRODUCT IN THE GROUP HAS A TOTAL REPORTABLE VOLATILE ORGANIC COMPOUND (**RVOC**) CONTENT THAT DOES NOT DIFFER BY MORE THAN 5% FROM ANY OTHER PRODUCTS IN THE GROUP. SEE

ATTACHMENT B FOR A DESCRIPTION OF RVOC AND THE **INSTRUCTIONS FOR COMPLETING PRODUCT SHEETS**, ITEM 9 ON PAGE 11 FOR FURTHER CLARIFICATION.

IF PRODUCTS ARE BEING GROUPED, THE NET PRODUCT WEIGHT SOLD IN 1990 (ITEM 8) SHOULD BE A SUM OF THE TOTAL WEIGHT FOR ALL PRODUCTS IN THE GROUP. THE TOTAL RVOC (ITEM 9) AND ENTRIES FOR INDIVIDUAL RVOC'S (ITEM 11A) SHOULD BE BASED ON AVERAGES OF ALL PRODUCTS INCLUDED IN THE GROUP.

- 4) DETERMINE WHICH INGREDIENTS FIT THE DESCRIPTION OF AN RVOC AS OUTLINED IN ATTACHMENT B.
- 5) FILL OUT THE **COMPANY SHEET** APPROPRIATELY, USING THE INSTRUCTIONS PROVIDED.
- 6) FILL OUT THE **PRODUCT SHEETS** USING EITHER OPTION A OR B.
 - A) AN OPTION FOR THE TRANSFER OF INFORMATION BY ELECTRONIC MEDIA (COMPUTER DISKS) IS AVAILABLE FOR **PRODUCT SHEETS**, AND IS HIGHLY ENCOURAGED. THIS IS A MENU-DRIVEN, PC-BASED PROGRAM THAT WILL OPERATE INDEPENDENTLY. HELP SCREENS EXPLAINING EACH ITEM IN THE COMPUTERIZED SURVEY FORM ARE AVAILABLE WITH ONE KEYSTROKE. REQUIREMENTS TO RUN THE PROGRAM INCLUDE: A

FLOPPY DISK DRIVE (5.25 OR 3.5 INCH, DOUBLE SIDED, DOUBLE DENSITY); 640 KILOBYTES OR MORE OF RAM; AND DOS 3.0 OR HIGHER. A COPY OF THE PROGRAM FILES ARE PROVIDED ON THE ENCLOSED 5.25 INCH DISKETTE. ARRANGEMENTS CAN BE MADE TO ACQUIRE THE PROGRAM ON A 3.5 INCH DISKETTE BY CALLING (919) 493-6263. IF YOU HAVE QUESTIONS REGARDING THE PROGRAM, PLEASE CALL (919) 493-6263.

- B) IF YOU PREFER TO SEND HARD COPY INFORMATION FOR **PRODUCT SHEETS**, PLEASE FOLLOW THE INSTRUCTIONS PROVIDED. BE SURE TO COPY THE BLANK FORM (2 PAGES) AND COMPLETE A SEPARATE COPY FOR EACH PRODUCT OR GROUP OF PRODUCTS.

EXEMPTIONS FROM SUBMITTING PRODUCT SHEETS

- 1) IF A COMPANY PRODUCES A PRODUCT THAT DOES NOT FALL INTO ONE OF THE CATEGORIES LISTED IN ATTACHMENT A, THEY ARE EXEMPT FROM SUBMITTING A **PRODUCT SHEET** FOR THAT PRODUCT. IF THE PRODUCT FALLS WITHIN ONE OF THE CATEGORIES ON THE LIST IN ATTACHMENT A, A **PRODUCT SHEET** MUST BE SUBMITTED FOR THAT PRODUCT REGARDLESS OF RVOC CONTENT.
- 2) ONLY THOSE COMPANIES LISTED ON THE PRODUCT LABEL ARE REQUIRED TO SUBMIT PRODUCT SHEETS. IF MORE THAN ONE COMPANY IS IDENTIFIED ON THE PRODUCT LABEL, THE COMPANY THAT THE PRODUCT WAS *MANUFACTURED FOR* OR *DISTRIBUTED BY* IS REQUIRED TO SUBMIT A PRODUCT SHEET.
- 3) ALL COMPANIES NOT REQUIRED TO SUBMIT PRODUCT SHEETS **ARE STILL REQUIRED** TO COMPLETE AND SUBMIT A **COMPANY SHEET**.

INSTRUCTIONS FOR USING THE COMPUTERIZED SURVEY FORM

THE COMPUTERIZED SURVEY FORM IS DESIGNED TO WORK ON IBM-COMPATIBLE PERSONAL COMPUTERS USING DOS VERSION 3.0 OR HIGHER. VERSIONS FOR OTHER OPERATING PLATFORMS (MACINTOSH, VAX, ETC.) ARE NOT AVAILABLE. THE COMPUTERIZED FORM CONSISTS OF THREE DATABASE FILES (**PRODUCT.DBF**, **RVOC.DBF** AND **ALT.DBF**) AND AN EXECUTABLE FILE (**SURVEY.EXE**) DESIGNED TO REQUEST INFORMATION IN A FORMAT THAT RESEMBLES THE HARD COPY FORM. SUPPORT DATABASE FILES FOR PROVIDING CATEGORY CODE CHOICES (**CATCODES.DBF**) AND HELP SCREENS (**SURVHELP.DBF**) ARE ALSO PROVIDED. HELP SCREENS ARE AVAILABLE BY PRESSING THE <F1> KEY IN MOST INSTANCES. IF A "HELP" SCREEN IS NOT AVAILABLE, INSTRUCTIONS PROVIDED FOR THE HARD-COPY SURVEY FORM ALSO APPLY TO THE COMPUTERIZED FORM AND SHOULD HELP TO PROVIDE GUIDANCE.

IT IS HIGHLY RECOMMENDED THAT THE PROGRAM AND DATABASE FILES BE COPIED TO A HARD-DRIVE IN A SEPARATE SUBDIRECTORY. THE **INSTALL** BATCH FILE ON THE ENCLOSED DISK WILL DO THIS JOB FOR YOU. FOLLOW THE INSTRUCTIONS GIVEN BELOW FOR **INSTALLING SOFTWARE ON A HARD DRIVE**. IF YOU PLAN ON ENTERING DATA USING A FLOPPY DRIVE, PLEASE COPY ALL FILES ON THE DISK PROVIDED TO ANOTHER DISK (PREFERABLY HIGH-DENSITY, 1.2 OR 1.44 MEGABYTES) AND KEEP THE ORIGINAL DISK SEPARATE.

THE SOFTWARE WAS DESIGNED TO ALLOW SURVEY RESPONDENTS TO ENTER THE SURVEY INFORMATION INTO APPROPRIATE DATABASE FORMATS FROM A KEYBOARD. IF MOST OF THE INFORMATION BEING REQUESTED IS ALREADY IN A DATABASE FORMAT, IT MAY BE ADVANTAGEOUS TO **APPEND** THAT INFORMATION INTO THE SURVEY DATABASES BEFORE PERFORMING ANY KEYBOARD ENTRY. IF TRANSFER OF INFORMATION IN THIS MANNER IS POSSIBLE FOR YOUR ORGANIZATION, PLEASE CALL **(919) 493-6263** AND REQUEST A COPY OF THE DATABASE STRUCTURES AND FIELD DEFINITIONS. ANY QUESTIONS REGARDING THIS PROCEDURE CAN ALSO BE ADDRESSED BY CALLING THE NUMBER LISTED ABOVE.

ALTHOUGH THE COMPUTERIZED SURVEY FORM IS DESIGNED TO REPLACE THE NEED FOR SUBMITTING **PRODUCT SHEETS**, A SIGNED **COMPANY SHEET** NEEDS TO BE SUBMITTED IN HARD COPY FORM. IF SEPARATE DIVISIONS WITHIN A COMPANY ARE SUBMITTING INDIVIDUALLY, EACH DIVISION MUST ALSO SUBMIT SEPARATE **COMPANY SHEETS**.

INSTALLING SOFTWARE ON A HARD DRIVE

1. PLACE THE DISK PROVIDED INTO AN APPROPRIATE FLOPPY DRIVE. ENTER THE LETTER OF THAT DISK PLUS A COLON (:) AT THE DOS PROMPT (E.G., **A:**), AND FOLLOW BY PRESSING THE <ENTER> KEY. THIS MAKES THAT DRIVE THE CURRENT DRIVE.
2. TYPE **INSTALL**, LEAVE A SPACE, THEN TYPE THE LETTER OF THE HARD-DRIVE (OR HIGH-DENSITY FLOPPY) TO WHICH YOU WANT THE PROGRAM COPIED (E.G., **INSTALL C:**), FOLLOWED BY PRESSING THE <ENTER> KEY. IF YOU DO NOT DESIGNATE A DRIVE AFTER YOU TYPE **INSTALL**, THE FILES WILL AUTOMATICALLY BE COPIED TO THE C DRIVE.
3. THE PROGRAM CAN BE INVOKED BY TYPING **CDISURVEY** FOLLOWED BY PRESSING <ENTER>, THEN TYPING **SURVEY** FOLLOWED BY THE <ENTER> KEY.

USING THE SURVEY SOFTWARE (FOR TECHNICAL ASSISTANCE, CALL (919) 493-6263)

STARTING SURVEY

BEFORE THE **SURVEY** SOFTWARE CAN BE INVOKED, THE PROPER DRIVE AND DIRECTORY MUST BE MADE CURRENT USING DOS. IF THE **INSTALL** BATCH FILE WAS USED, THE DIRECTORY IS CALLED **SURVEY**. THE DEFAULT DRIVE IS **C:** UNLESS OTHERWISE INDICATED DURING INSTALLATION. FIRST MAKE THE APPROPRIATE DRIVE CURRENT BY TYPING THE DRIVE LETTER, PLUS A COLON(:) AT THE DOS PROMPT (E.G., **C:**), THEN PRESS THE **<ENTER>** KEY. NEXT, MAKE THE **SURVEY** DIRECTORY CURRENT BY TYPING **CDISURVEY** AND PRESSING THE **<ENTER>** KEY.

START THE PROGRAM BY TYPING **SURVEY** FOLLOWED BY THE **<ENTER>** KEY. IF THE PROGRAM DOES NOT OPERATE, CALL THE TECHNICAL ASSISTANCE NUMBER LISTED ABOVE. OTHERWISE, A SCREEN ASKING FOR THE APPROPRIATE DIRECTORY FOR DATABASE FILES WILL APPEAR. SIMPLY PRESS THE **<ENTER>** KEY TO ACCEPT THE DEFAULT. IF YOUR ORGANIZATION HAS MANY DIVISIONS, EACH WITH A LARGE NUMBER OF PRODUCTS THAT WILL BE INCLUDED IN THE SURVEY, IT MAY BE ADVANTAGEOUS TO COPY A SEPARATE VERSION OF THE EMPTY DATABASES TO A DIFFERENT SUBDIRECTORY FOR EACH DIVISION BEFORE DATA ENTRY. IF YOU HAVE QUESTIONS REGARDING HOW THIS CAN BE DONE, CALL THE NUMBER LISTED ABOVE.

ENTERING DATA INTO THE COMPUTERIZED FORM

THERE ARE TWO SCREENS OF INFORMATION REQUESTS ASSOCIATED WITH THE COMPUTERIZED SURVEY FORM. THESE SCREENS ARE ROUGHLY EQUIVALENT TO THE TWO-PAGE **PRODUCT FORM** INCLUDED IN THE HARD COPY OF THE SURVEY FORM. MOST OF THE **INSTRUCTIONS FOR COMPLETING PRODUCT SHEETS** ALSO APPLY TO THE COMPUTERIZED FORM. ADDITIONAL HELP INFORMATION IS ALSO AVAILABLE THROUGH **HELP** SCREENS IN THE SOFTWARE BY PRESSING THE **<F1>** KEY. PLEASE ALSO NOTE THAT INSTRUCTIONS ARE GIVEN AT THE BOTTOM OF THE SCREEN. THESE INSTRUCTIONS WILL CHANGE BASED ON THE INFORMATION BEING REQUESTED.

OTHER UTILITIES ARE AVAILABLE THROUGH OTHER "F" KEYS: **<F2>** SEARCH, **<F5>** DELETE, **<F8>** PRINT, AND THE CONTROL KEY (DESIGNATED **^**) PLUS PAGE UP (**PgUp**) OR PAGE DOWN (**PgDn**) TO GO TO THE TOP OF THE FILE **<^PgUp>** OR THE BOTTOM OF THE FILE **<^PgDn>**. PLEASE NOTE THAT THE AVAILABILITY OF THESE FUNCTIONS DURING VARIOUS POINTS IN THE PROGRAM EXECUTION WILL BE SUSPENDED AND THAT THE INSTRUCTIONS AT THE BOTTOM OF THE SCREEN WILL REFLECT THIS STATUS. EACH OF THESE FUNCTIONS IS DESCRIBED IN GREATER DETAIL BELOW.

MANY OF THE DATA ELEMENTS REQUESTED IN THE SURVEY FORM ARE REQUIRED. IF A REQUIRED ELEMENT IS LEFT BLANK, THE PROGRAM CONTINUOUSLY LOOPS BACK UNTIL A VALID ENTRY IS MADE.

ITEM 1. THE INFORMATION ENTERED IN **ITEM 1** (COMPANY NAME AND DIVISION NAME) FOR THE FIRST RECORD WILL ALSO BE ENTERED IN EACH SUBSEQUENT NEW RECORD, UNTIL CHANGED THROUGH THE KEYBOARD. ALL SUBSEQUENT RECORDS WILL THEN HAVE THE "NEW" **ITEM 1** INFORMATION ADDED AUTOMATICALLY.

ITEM 2. A SERIES OF THREE MENUS ARE AVAILABLE TO ASSIST YOU IN ENTERING THE CATEGORY CODES. THESE ARE INVOKED BY PRESSING **<ENTER>** WITH THE **ITEM 3** INFORMATION LEFT BLANK. THESE MENUS ARE SIMILAR IN STRUCTURE TO **ATTACHMENT A** OF THE **SURVEY FORM**. TO CHANGE AN ENTRY IN **ITEM 3**, USE THE **<DELETE>** KEY TO BLANK OUT THE FIELD AND PRESS **<ENTER>** TO INVOKE THE MENUS. AN INVALID ENTRY WILL ALSO INVOKE THE MENUS.

ITEM 4. THE **PRODUCT NAME** IS A REQUIRED PIECE OF INFORMATION. PLEASE CONSULT THE **INSTRUCTIONS FOR COMPLETING PRODUCT SHEETS** FOR A DISCUSSION OF GROUPING PRODUCTS.

ITEM 8. THE AMOUNT OF PRODUCT SOLD IN 1990 IS ALSO A REQUIRED PIECE OF INFORMATION. THE PROGRAM WILL NOT CONTINUE TO THE NEXT SCREEN UNLESS THIS INFORMATION IS FILLED OUT.

ITEM 11. THE DEFAULT ASSUMPTION IS THAT YOU WILL BE PROVIDING PRODUCT **RVOC** INFORMATION. THE SCREEN WILL

ACCOMMODATE RVOC INFORMATION BASED ON ENTRIES TO ITEM 9 AND ITEM 10 FOR UP TO 20 RVOC INGREDIENTS. UPON FIRST ENTERING THE SECOND SCREEN (PAGE 2) OF THE COMPUTERIZED FORM FOR A NEW RECORD, YOU WILL BE ASKED WHETHER OR NOT YOU HAVE PRODUCT FORMULATION INFORMATION. IF YOU ANSWER <Y>EL, YOU WILL NOT BE ASKED AGAIN UNLESS YOU ENTER A ZERO FOR ITEMS 9 AND 10. IF YOU ANSWER <N>O, YOU WILL BE ASKED TO VERIFY YOUR ANSWER EVERY TIME YOU ENTER PAGE 2 FOR THAT RECORD. BASED ON YOUR ANSWER TO THAT FIRST INQUIRY, YOU WILL EITHER BE ASKED TO PROVIDE RVOC INGREDIENT INFORMATION, OR THE NAME AND ADDRESS OF SOMEONE WHO DOES HAVE THAT INFORMATION.

PLEASE CONSULT THE **INSTRUCTIONS FOR COMPLETING PRODUCT SHEETS** FOR ADDITIONAL GUIDANCE.

DESCRIPTIONS OF FUNCTIONS

SEARCH <F2>

THE SEARCH UTILITY ALLOWS YOU TO QUICKLY GO TO A RECORD MEETING THE GIVEN CRITERIA. THE CRITERIA CHOICES ARE **RECORD NUMBER**, **PRODUCT NAME**, OR **CATEGORY CODE**. FOR THE FIRST TWO CRITERIA, ONLY ONE RECORD WILL APPLY. FOR CATEGORY CODE, IT IS POSSIBLE FOR MANY RECORDS (PRODUCTS OR GROUPS OF PRODUCTS) TO HAVE THE SAME CATEGORY CODE. THE CATEGORY CODE SEARCH WILL ONLY LOCATE THE FIRST RECORD MEETING THE CRITERIA.

DELETE <F5>

DELETE WILL MARK THE CURRENT RECORD FOR DELETION. THE DELETION STATUS WILL THEN BE DISPLAYED AT THE TOP RIGHT CORNER OF THE SCREEN. **DELETE** CAN BE TOGGLED OFF BY PRESSING THE <F5> KEY AGAIN. RECORDS ARE NOT PERMANENTLY DELETED UNTIL THE PROGRAM IS EXITED BY PRESSING THE <Esc> KEY.

PRINT <F8>

THE PRINT FUNCTION ALLOWS EITHER A HARD COPY OR DISK FILE IN ASCII FORMAT TO BE PRODUCED FROM INFORMATION IN THE DATABASES. THE PURPOSE OF SUCH A UTILITY IS TO ALLOW FOR BETTER QUALITY CONTROL OF DATA ENTRIES.

TECHNICAL ASSISTANCE

IF YOU HAVE ANY REMAINING QUESTIONS OR NEED ADDITIONAL GUIDANCE, PLEASE CALL THE FOLLOWING NUMBER AND DESCRIBE YOUR NEED:

(919) 493-6263

INSTRUCTIONS FOR COMPLETING COMPANY SHEET

ALL COMPANIES RECEIVING THIS INFORMATION COLLECTION REQUEST MUST RESPOND BY SUBMITTING A COMPLETED **COMPANY SHEET**, EVEN IF NO COVERED PRODUCTS ARE MANUFACTURED OR SOLD. (SEE **EXEMPTIONS FROM SUBMITTING PRODUCT SHEETS** IN **GENERAL INSTRUCTIONS**). ONE **COMPANY SHEET** CAN BE SUBMITTED FOR AN ENTIRE COMPANY, UNLESS THE COMPANY HAS DELEGATED RESPONSIBILITY FOR SUBMITTING THE **PRODUCT SHEETS** TO SEPARATE DIVISIONS. IN THIS CASE, PLEASE SUBMIT A **COMPANY SHEET** FOR EACH DIVISION SUBMITTING **PRODUCT SHEETS**, INDICATING BOTH COMPANY AND DIVISION NAMES ON EACH

SHEET.

1. **COMPANY NAME.** ENTER THE COMPANY NAME, OR COMPANY AND DIVISION NAMES.
2. **PERSON TO CONTACT.** ENTER THE NAME OF THE PERSON TO BE CONTACTED BY EPA IF CLARIFICATIONS ARE NEEDED.
3. **ADDRESS.** ENTER THE MAILING ADDRESS OF THE PERSON TO CONTACT.
4. **PHONE.** ENTER THE PHONE NUMBER OF THE PERSON TO CONTACT.
5. **TYPE OF BUSINESS.** PLACE AN "X" IN ONE OR MORE OF THE BOXES TO INDICATE THE PRIMARY ASPECTS OF THE BUSINESS CONDUCTED BY THE COMPANY OR DIVISION. THIS INFORMATION WILL BE USED TO ASSIST EPA IN DETERMINING COVERAGE OF PRODUCT CATEGORIES IN THE SURVEY. MARKING A PARTICULAR BOX DOES NOT DETERMINE IF YOUR COMPANY IS THE COMPANY RESPONSIBLE FOR REPORTING ON A PARTICULAR PRODUCT. THE COMPANY RESPONSIBLE FOR REPORTING IS THE COMPANY WHICH IS IDENTIFIED ON THE PRODUCT LABEL.

MANUFACTURER MEANS A COMPANY THAT MANUFACTURES PRODUCTS WITH ITS COMPANY OR DIVISION NAME ON THE LABEL PER FTC, EPA, CPSC, OSHA, OR FDA LABELING REQUIREMENTS. THE COMPANY THAT OWNS THE PRODUCT LABEL AND INITIATES MANUFACTURE IS CONSIDERED TO BE THE **MANUFACTURER**, EVEN IF SOME OR ALL OF THE FORMULATION AND PACKAGING OF THAT PRODUCT OCCURS AT A CONTRACT PACKAGER SITE.

RETAILER MEANS A COMPANY THAT SELLS PRODUCTS TO INDIVIDUAL CONSUMERS OR HOUSEHOLDS. **RETAILER** ALSO INCLUDES RETAIL OUTLETS AND COMPANIES WHO SELL DIRECTLY TO THE CONSUMER THROUGH SALES REPRESENTATIVES OR THROUGH MAIL-ORDER.

DISTRIBUTOR MEANS A COMPANY THAT SELLS PRODUCTS TO RETAIL BUSINESSES OR TO INSTITUTIONAL OR INDUSTRIAL CUSTOMERS.

PRIVATE LABEL CONTRACT PACKAGER MEANS A COMPANY THAT MANUFACTURES PRODUCTS BASED ON ITS OWN FORMULATION BUT PLACES ANOTHER COMPANY'S NAME ON THE PRODUCT LABEL.

CUSTOM CONTRACT PACKAGER MEANS A COMPANY THAT MANUFACTURES PRODUCTS BASED ON FORMULATION SPECIFICATION OF ANOTHER COMPANY AND PLACES THE OTHER COMPANY'S NAME ON THE PRODUCT LABEL PER FTC, EPA, CPSC, OSHA, OR FDA LABELING REQUIREMENTS.

6. **INDICATE NUMBER OF PRODUCT SHEETS ATTACHED.** ENTER THE NUMBER OF **PRODUCT SHEETS** ATTACHED FOR THE COMPANY OR DIVISION. INDICATE IF THE COMPANY IS EXEMPT FROM SUBMITTING **PRODUCT SHEETS** DUE TO EITHER OF THE TWO CONDITIONS LISTED. NOTE THAT THE **COMPANY SHEET** MUST STILL BE SUBMITTED, EVEN IF ONE OF THE TWO CONDITIONS APPLY. (IF SENDING COMPUTERIZED DATABASE INFORMATION, PLEASE INDICATE THE NUMBER OF PRODUCTS IN THE DATABASE.)
7. **CERTIFICATION.** PLEASE HAVE THE COMPANY OR DIVISION OFFICER WHO IS RESPONSIBLE FOR ENVIRONMENTAL COMPLIANCE OR GOVERNMENT AFFAIRS CERTIFY THE ACCURACY OF THE COMPLETED **COMPANY SHEET** AND **PRODUCT SHEET**.

COMPANY SHEET

1. COMPANY NAME:

DIVISION NAME:

2. PERSON TO CONTACT:

3. ADDRESS:

4. PHONE:

5. TYPE OF BUSINESS (MARK WITH "X" FOR ALL THAT APPLY):

☐ MANUFACTURER

☐ RETAILER

☐ DISTRIBUTOR

☐ PRIVATE LABEL
CONTRACT PACKAGER

☐ CUSTOM CONTRACT
PACKAGER

6. INDICATE NUMBER OF PRODUCT SHEETS ATTACHED: _____

OR ZERO PRODUCT SHEETS ARE ATTACHED BECAUSE:

☐ THIS COMPANY DOES NOT MANUFACTURE, DISTRIBUTE, OR SELL ANY OF THE REPORTABLE PRODUCTS LISTED IN ATTACHMENT A.

☐ THIS COMPANY DOES MANUFACTURE, DISTRIBUTE, OR SELL SOME OF THE REPORTABLE PRODUCTS LISTED IN ATTACHMENT A, BUT THIS COMPANY IS NOT THE PARTY RESPONSIBLE TO REPORT BECAUSE IT IS NOT NAMED ON THE PRODUCT LABEL.

7. CERTIFICATION. THE COMPANY OR DIVISION OFFICER WHO IS RESPONSIBLE FOR ENVIRONMENTAL COMPLIANCE OR GOVERNMENT AFFAIRS MUST SIGN THE CERTIFICATION STATEMENT BELOW:

"I HEREBY CERTIFY THAT, TO THE BEST OF MY KNOWLEDGE AND BELIEF, ALL INFORMATION ENTERED ON THIS COMPANY SHEET AND ANY ATTACHED PRODUCT SHEETS IS COMPLETE AND ACCURATE."

NAME

SIGNATURE

TITLE

DATE SIGNED

INSTRUCTIONS FOR COMPLETING PRODUCT SHEET(S)

A **PRODUCT SHEET** MUST BE SUBMITTED FOR EACH DIFFERENT PRODUCT OR GROUP OF PRODUCTS FOR WHICH YOUR COMPANY OR DIVISION IS RESPONSIBLE. (AS DISCUSSED IN THE **GENERAL INSTRUCTIONS** SECTION OF THIS MAILING, AN ALTERNATIVE, ELECTRONIC FORMAT IS AVAILABLE AND IS HIGHLY ENCOURAGED.) THE COMPANY RESPONSIBLE FOR REPORTING IS THE COMPANY WHICH IS IDENTIFIED ON THE PRODUCT LABEL. PLEASE COPY THE BLANK **PRODUCT SHEET** FORM PROVIDED AS NECESSARY, AND NUMBER EACH IN THE SPACE AT THE TOP OF THE FORM. DUE TO THE NEED FOR ACCURATE INGREDIENT DATA (ITEM 11A), YOU MUST SUBMIT SEPARATE **PRODUCT SHEETS** FOR DIFFERENT PACKAGE FORMS OF THE SAME TRADE NAME (AEROSOL VERSUS SPRAY PUMP, OR LIQUID VERSUS GEL, SEE ITEM 3), BUT IT MAY NOT BE NECESSARY TO SUBMIT SEPARATE **PRODUCT SHEETS** FOR DIFFERENT FLAVORS, SCENTS, COLORS, OR SIZES OF PRODUCTS HAVING ESSENTIALLY THE SAME FORMULATION DATA. SEE INSTRUCTIONS FOR ITEM 3 BELOW.

GROUPING OF PRODUCTS. PRODUCTS MAY BE GROUPED AND REPORTED ON ONE PRODUCT SHEET IF ALL OF THE FOLLOWING CONDITIONS ARE MET:

- A) ALL PRODUCTS IN THE GROUP ARE IN THE SAME PRODUCT CATEGORY (I.E., HAVE THE SAME PRODUCT CATEGORY CODE IN ITEM 2 ON THE **PRODUCT SHEET**).
- B) ALL PRODUCTS HAVE THE SAME PRODUCT FORM (ITEM 3 ON THE **PRODUCT SHEET**).
- C) EACH PRODUCT IN THE GROUP HAS A TOTAL REPORTABLE VOLATILE ORGANIC COMPOUND (RVOC) CONTENT THAT DOES NOT DIFFER BY MORE THAN 5% FROM ANY OTHER PRODUCTS IN THE GROUP. SEE **ATTACHMENT B** FOR A DESCRIPTION OF RVOC AND THE **INSTRUCTIONS FOR COMPLETING PRODUCT SHEETS**, ITEM 9 ON PAGE 11 FOR FURTHER CLARIFICATION.

IF PRODUCTS ARE BEING GROUPED, THE NET PRODUCT WEIGHT SOLD IN 1990 (ITEM 8) SHOULD BE A SUM OF THE TOTAL WEIGHT FOR ALL PRODUCTS IN THE GROUP. THE TOTAL RVOC (ITEM 9) AND ENTRIES FOR INDIVIDUAL RVOC'S (ITEM 11A) SHOULD BE BASED ON AVERAGES OF ALL PRODUCTS INCLUDED IN THE GROUP.

1. **COMPANY NAME.** ENTER YOUR COMPANY, OR COMPANY AND DIVISION NAME(S) AS RECORDED ON YOUR **COMPANY SHEET**.
2. **PRODUCT CATEGORY.** ENTER THE CODE FOR THE CATEGORY WHICH BEST DESCRIBES THE PRODUCT (OR GROUP OF PRODUCTS) FROM THOSE LISTED IN ATTACHMENT A. YOU MAY HAVE TO LOOK UNDER MORE THAN ONE MAJOR CATEGORY TO FIND THE APPROPRIATE DESCRIPTOR. PRODUCTS WHICH MAY BE USED IN MORE THAN ONE AREA (E.G., UPHOLSTERY SHAMPOO WHICH MIGHT BE USED IN EITHER THE HOME OR CAR) WILL BE LISTED IN THE MORE GENERAL CATEGORY (IN THIS CASE, HOME CARE). IF A PRODUCT IS FORMULATED FOR A SPECIALIZED USE (E.G., AUTOMOTIVE GLASS CLEANER VERSUS REGULAR GLASS CLEANER), IT SHOULD BE LISTED IN THE MORE SPECIFIC CATEGORY. IF YOU CANNOT LOCATE AN EXACT MATCH, USE THE MOST SUITABLE CATEGORY NAME ON THE LIST, AND GIVE A BRIEF DESCRIPTION OF THE PRODUCT AND ITS USE.
3. **PRODUCT FORM.** PLACE AN "X" IN ONE OF THE BOXES TO INDICATE THE FORM IN WHICH THE PRODUCT IS DISPENSED OR APPLIED. BECAUSE THE FORMULATION INFORMATION (ITEM 11A) FOR A PRODUCT LINE IS LIKELY TO VARY BY PRODUCT FORM, YOU SHOULD NOT MARK MORE THAN ONE BOX FOR THIS ITEM. PLEASE SUBMIT SEPARATE **PRODUCT SHEETS** FOR DIFFERENT FORMS OF THE SAME PRODUCT LINE.

AEROSOL DISPENSERS USE A LIQUIFIED OR COMPRESSED GAS PROPELLANT TO DELIVER THE PRODUCT, IN THE FORM OF A SPRAY, MIST, STREAM, FOAM, OR GEL.

PUMP SPRAY DISPENSERS USE A MANUAL PUMP TO DELIVER THE PRODUCT IN THE FORM OF A SPRAY.

LIQUID PRODUCTS ARE POURED OR SQUEEZED OUT OF THE CONTAINER AND DO NOT FIT THE DESCRIPTION OF AN AEROSOL, PUMP SPRAY PRODUCT, SOLID OR GEL.

SOLID PRODUCTS DO NOT DEFORM WITH USE, EXCEPT BY EVAPORATION (E.G., MOTH REPELLENTS) OR SURFACE WEAR (E.G., BAR SOAPS). THIS INCLUDES SOLID BLOCKS, GRANULES, OR POWDERS.

GEL OR PASTE PRODUCTS WILL NOT POUR, BUT WILL SPREAD OR DEFORM EASILY.

IF NONE OF THESE CATEGORIES APPLY, MARK *OTHER* AND GIVE A DESCRIPTION, E.G., "MATERIAL IMPREGNATED IN A CLOTH."

4. **FULL PRODUCT OR PRODUCT GROUP NAME.** ENTER THE PRODUCT NAME AS IT APPEARS ON THE PRODUCT LABEL. PLEASE ENSURE THAT EACH **PRODUCT SHEET** SUBMITTED HAS A UNIQUE PRODUCT NAME. IF PRODUCTS ARE BEING GROUPED, USE AN APPROPRIATE, UNIQUE, DESCRIPTIVE NAME FOR THE PRODUCT GROUP. SEE ITEM 5 BELOW.

5. **IF THE DATA ON THIS PRODUCT SHEET REPRESENT MORE THAN A SINGLE STOCK-KEEPING UNIT (SKU), ENTER THE NUMBER OF SKU'S REPRESENTED.** PRODUCTS FOR WHICH TOTAL REPORTABLE VOLATILE ORGANIC COMPOUND (RVOC) CONTENTS DO NOT DIFFER BY MORE THAN 5 PERCENT OF THE TOTAL PRODUCT WEIGHT MAY BE GROUPED TOGETHER FOR REPORTING PURPOSES ON ONE **PRODUCT SHEET** (SEE DISCUSSION ABOVE REGARDING GROUPING OF PRODUCTS). FOR EXAMPLE, SCENTED AND UNSCENTED VARIETIES OF A PRODUCT FOR WHICH THE TOTAL RVOC CONTENTS DO NOT DIFFER BY MORE THAN 5 PERCENT OF THE TOTAL PRODUCT WEIGHT MAY BE COMBINED AND REPORTED ON ONE **PRODUCT SHEET** (PRODUCT A, WITH 45% TOTAL RVOC, CAN BE INCLUDED IN A LISTING OF THE UNSCENTED PRODUCT, WITH 41% TOTAL RVOC).

6. **MAJOR CUSTOMER TYPE.** PLACE AN "X" IN ONE OR MORE OF THE BOXES TO INDICATE USERS OF THE PRODUCT.

HOUSEHOLD CONSUMERS USE THE PRODUCT THEMSELVES IN THE HOME OR IN OTHER PERSONAL AREAS, SUCH AS AUTOMOBILES OR BOATS.

COMMERCIAL/INSTITUTIONAL CONSUMERS USE THE PRODUCT IN A COMMERCIAL BUSINESS OR INSTITUTIONAL SETTING. THIS INCLUDES COMMERCIAL BUSINESSES PERFORMING SERVICES IN PRIVATE HOMES (E.G., CARPET CLEANERS, PEST CONTROL, ETC.).

INDUSTRIAL CONSUMERS USE THE PRODUCT AT AN INDUSTRIAL SITE, SPECIFICALLY IN ASSOCIATION WITH A MANUFACTURING PROCESS (E.G., MOLD RELEASE USED IN PLASTIC FORMS).

7. **PRODUCT SIZE.** MARK ANY SIZES REPRESENTING 25 PERCENT OR MORE OF YOUR NET SALES. IF THE PRODUCT IS SOLD BY VOLUME, USE THE FIRST ROW OF BOXES. IF THE PRODUCT IS SOLD BY WEIGHT, USE THE SECOND ROW OF BOXES.

8. **NET PRODUCT WEIGHT SOLD IN THE U.S. FOR 1990 (POUNDS).** ENTER THE ANNUAL U.S. SALES OF THE PRODUCT OR PRODUCTS IN UNITS OF POUNDS OF NET FINAL PRODUCT. INCLUDE ALL "CONSUMABLE" ELEMENTS OF THE PRODUCT, SUCH AS ACTIVE INGREDIENTS, PROPELLANTS, DILUENTS, ADDITIVES, OR FILLERS ADDED BY A CONTRACT FILLER. DO NOT INCLUDE THE WEIGHT OF STRUCTURAL ELEMENTS, CONTAINERS OR PACKAGING. ANY CONTINUOUS 12 MONTH PERIOD MAY BE USED, AS LONG AS THE MAJORITY OF THE PERIOD IS WITHIN THE CALENDAR YEAR 1990.

COMPLETING THE NEXT THREE ITEMS (9, 10 AND 11A) WILL REQUIRE INFORMATION ON THE SPECIFIC CHEMICAL FORMULATION OF THE PRODUCT. IF YOUR COMPANY DOES NOT HAVE ACCESS TO SUCH INFORMATION AND CANNOT OBTAIN IT, WHICH MIGHT BE TRUE IF A PRIVATE LABEL CONTRACT PACKAGER MAKES THE PRODUCT UNDER CONTRACT WITH YOUR COMPANY, PLEASE SKIP TO ITEM 11B. YOUR COMPANY IS STILL RESPONSIBLE FOR COMPLETING ALL OTHER ITEMS ON THE PRODUCT SHEET, INCLUDING THE SALES VOLUME (ITEM 8).

9. **TOTAL NET WEIGHT % REPORTABLE VOC.** ENTER THE TOTAL WEIGHT PERCENT OF THE NET FINAL PRODUCT WHICH IS REPORTABLE VOC. PROPELLANTS OR OTHER MATERIALS ADDED BY A CONTRACT FILLER SHOULD BE CONSIDERED PART OF THE NET FINAL PRODUCT. THE DEFINITION OF "REPORTABLE VOC" (RVOC) IS PROVIDED IN ATTACHMENT B. RVOC DOES NOT INCLUDE ALL VOC'S DEFINED BY EPA FOR REGULATORY PURPOSES. THE DEFINITION GIVEN IN THIS SURVEY FORM SHOULD NOT BE CONSTRUED AS REDEFINING EPA'S DEFINITION OF VOC. (ADDITIONAL INFORMATION IS REQUESTED UNDER ITEM 11 REGARDING METHYLENE CHLORIDE AND 1,1,1-TRICHLOROETHANE, BUT THESE SHOULD NOT BE INCLUDED IN THE TOTAL REPORTED HERE.) IF SEVERAL PRODUCTS ARE GROUPED, USE AN AVERAGE WEIGHT PERCENT FOR EACH INGREDIENT FROM ALL PRODUCTS IN THE GROUP.
10. **TOTAL NUMBER OF REPORTABLE INGREDIENTS.** ENTER THE NUMBER OF REPORTABLE VOC INGREDIENTS CONTAINED IN THE PRODUCT. COMPLEX MIXTURES SUCH AS FRAGRANCES AND PETROLEUM DISTILLATES CAN BE CONSIDERED A SINGLE INGREDIENT IF THEY ARE PURCHASED BY YOUR COMPANY AS A MIXTURE. IF PRODUCTS ARE BEING GROUPED, LIST THE TOTAL NUMBER OF INDIVIDUAL INGREDIENTS WITHIN THAT GROUP. FOR EXAMPLE, IF ACETONE IS LISTED AS AN INGREDIENT IN ALL FIVE PRODUCTS IN A GROUP, IT SHOULD BE COUNTED ONLY ONCE AS AN INGREDIENT COMPOUND. IF ETHANOL IS FOUND IN TWO PRODUCTS AND METHANOL IN THE OTHER THREE, EACH SHOULD BE COUNTED ONCE AS AN INGREDIENT COMPOUND FOR THAT GROUP.

- 11A. LIST THE LARGEST REPORTABLE VOC (RVOC) INGREDIENTS AND THEIR WEIGHT PERCENTS FOR ALL RVOC THAT ARE 5% OR MORE OF THE PRODUCT WEIGHT.** THE PURPOSE OF THIS ITEM IS TO IDENTIFY THE INDIVIDUAL INGREDIENTS WHICH COMPRISE THE BULK OF THE TOTAL RVOC. RVOC INGREDIENTS SHOULD BE DENOTED BY CHEMICAL ABSTRACTS SERVICE (CAS) REGISTRY NUMBER AND SIMPLE CHEMICAL NAMES **WHEN AVAILABLE**. THE WEIGHT PERCENTS ARE TO BE REPORTED TO THE NEAREST 0.1%. IF THE INGREDIENT IS A COMPLEX MIXTURE OR PROPRIETARY INGREDIENT PROVIDED BY ANOTHER SUPPLIER, REPORT THE TRADE NAME AND SUPPLIER IN THE SPACE PROVIDED FOR **RVOC NAME**, AND THE PERCENT WEIGHT OF THE INGREDIENT UNDER **WEIGHT %**. **DO NOT REPORT INDIVIDUAL COMPONENTS OF INGREDIENTS WHICH ARE FRAGRANCE MATERIALS.** A CAS NUMBER IS NOT REQUIRED FOR COMPLEX MIXTURES NOR PROPRIETARY INGREDIENTS PROVIDED BY THIRD PARTY SUPPLIERS. COMPOUNDS WITH WEIGHT PERCENTS LESS THAN 5% CAN BE REPORTED TOGETHER AS "ALL OTHER REPORTABLE VOC" IN THE LAST LINE OF THE TABLE. CONFIRM THAT THE SUM OF ALL OF THE INDIVIDUAL RVOC INGREDIENTS LISTED PLUS THE "ALL OTHER REPORTABLE VOC" EQUALS THE PERCENT REPORTED IN ITEM 10.

IF PRODUCTS ARE BEING GROUPED, USE AVERAGES FOR EACH RVOC THAT IS REPRESENTED AT LEAST ONCE IN THE PRODUCT GROUP. FOR EXAMPLE:

THERE ARE FIVE PRODUCTS IN A GROUP AND TWO CONTAIN ETHANOL AT 8% AND 10%, WHILE THE OTHER THREE CONTAIN METHANOL AT 10%, 11%, AND 12%. THE AVERAGE RVOC PERCENT WEIGHTS FOR THIS GROUP WOULD BE 3.6% ETHANOL ($18 \div 5$) AND 6.5% METHANOL ($33 \div 5$).

ADDITIONAL INFORMATION REGARDING THE PERCENT OF THE PRODUCT COMPOSED OF METHYLENE CHLORIDE AND/OR 1,1,1-TRICHLOROETHANE IS REQUESTED SEPARATELY, EVEN THOUGH THESE ITEMS ARE NOT RVOC. THESE COMPOUNDS SHOULD **NOT** BE ADDED TO THE RVOC TOTAL.

- 11B. ENTER NAME AND ADDRESS OF COMPANY WITH FORMULATION INFORMATION IF YOU DO NOT HAVE THE DATA TO COMPLETE ITEM 11A.** IF YOUR COMPANY IS IDENTIFIED ON THE PRODUCT LABEL PER FTC, EPA, CPSC, OSHA, OR FDA LABELING REQUIREMENTS BUT DOES NOT HAVE ACCESS TO THE SPECIFIC CHEMICAL FORMULATION INFORMATION, ENTER THE NAME AND ADDRESS OF THE COMPANY THAT CAN PROVIDE THAT INFORMATION FOR EACH PRODUCT LISTED. INDICATE A CONTACT PERSON AND ANY OTHER INFORMATION (SUCH AS CONTRACT NUMBERS OR PRODUCT CODES) WHICH THE EPA MAY NEED TO OBTAIN ITEM 11A INFORMATION FROM THAT COMPANY. **THIS REQUIREMENT DOES NOT APPLY TO INGREDIENTS WHICH ARE FRAGRANCE MATERIALS.**
- 12. INDICATE WHICH ITEMS CONTAIN CONFIDENTIAL BUSINESS INFORMATION.** MARK ANY OF THE ITEMS WHICH YOUR COMPANY CONSIDERS CONFIDENTIAL BUSINESS INFORMATION (CBI). PLEASE DO NOT CLAIM CBI UNLESS THE INFORMATION IS TRULY CONFIDENTIAL. PLEASE REFER TO ENCLOSURE 3 AND ENCLOSURE 5 OF THE ACCOMPANYING COVER LETTER. MARKING "SALES" INDICATES THAT THE AMOUNT OF PRODUCT SOLD IN 1990 SHOULD BE CONSIDERED CONFIDENTIAL. MARKING "TOTAL RVOC %" INDICATES THAT THE TOTAL AMOUNT OF RVOC CONTAINED IN THE PRODUCT IS CONFIDENTIAL. MARKING "INGREDIENTS" INDICATES THAT SOME OF THE NAMED COMPOUNDS IN ITEM 11A ARE CONFIDENTIAL. MARKING "INGREDIENT WEIGHT PERCENTS" INDICATES THAT WHILE THE COMPOUNDS MAY BE COMMON KNOWLEDGE, THE AMOUNTS OF EACH RVOC ARE CONFIDENTIAL.

1. COMPANY NAME : _____
DIVISION NAME : _____

2. PRODUCT CATEGORY CODE (SEE ATTACHMENT A): ☐ ☐ ☐ ☐

DESCRIPTION (FROM ATTACHMENT A AND/OR ADDITIONAL DESCRIPTIONS):

3. PRODUCT FORM : ☐ AEROSOL ☐ SPRAY PUMP ☐ LIQUID ☐ GEL ☐ SOLID

☐ OTHER _____

4. FULL PRODUCT OR PRODUCT GROUP NAME :

5. IF THE DATA ON THIS **PRODUCT SHEET** REPRESENT MORE THAN A SINGLE STOCK KEEPING UNIT (SKU), ENTER THE NUMBER OF SKU'S REPRESENTED (SEE INSTRUCTIONS ON GROUPING PRODUCTS): _____

6. MAJOR CUSTOMER TYPE : ☐ HOUSEHOLD ☐ COMM/INST ☐ INDUSTRIAL

7. PRODUCT SIZE -BY VOLUME : ☐ 0 TO 32 FL.OZ. ☐ >32 FL.OZ. TO 5 GAL.
☐ >5 TO 55 GAL. ☐ >55 GAL.
OR
-BY WEIGHT : ☐ 0 TO 1 LB. ☐ 1 TO 5 LB.
☐ 5 TO 20 LB. ☐ >20 LB.

8. NET PRODUCT WEIGHT SOLD IN THE U.S. FOR 1990 (POUNDS) :

9. TOTAL REPORTABLE VOC (WEIGHT % OF NET PRODUCTS): _____

DO NOT INCLUDE METHYLENE CHLORIDE OR 1,1,1-TRICHLOROETHANE IN THIS TOTAL.

IF FORMULATION INFORMATION IS NOT AVAILABLE TO YOUR COMPANY, GO TO ITEM 11B.

10. TOTAL NUMBER OF REPORTABLE VOC INGREDIENT COMPOUNDS : _____

- 11A. LIST THE LARGEST REPORTABLE VOC INGREDIENT COMPOUNDS AND THEIR WEIGHT %'S FOR ALL REPORTABLE VOC THAT ARE 5% OR MORE OF THE TOTAL NET PRODUCT WEIGHT. USE THE CRITERIA LISTED IN ATTACHMENT B TO DETERMINE IF THE COMPOUND IS AN RVOC. PLEASE LIST THESE COMPOUNDS IN ORDER OF HIGHEST TO LOWEST WEIGHT PERCENT, IF POSSIBLE. **DO NOT REPORT INDIVIDUAL COMPONENTS OF INGREDIENTS WHICH ARE FRAGRANCE MATERIALS.**

REPORTABLE VOC INGREDIENT COMPOUNDS

	NAME	CAS No.	WEIGHT % IN FINAL PRODUCT
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.	ALL OTHER REPORTABLE VOC		
TOTAL REPORTABLE VOC % (SHOULD MATCH ITEM 9)			

ADDITIONAL INFORMATION IS REQUESTED SEPARATELY FOR TWO OTHER COMPOUNDS: METHYLENE CHLORIDE AND 1,1,1-TRICHLOROETHANE. DO NOT INCLUDE THESE COMPOUNDS IN TOTAL RVOC.

METHYLENE CHLORIDE	75-09-2	
1,1,1-TRICHLOROETHANE	71-55-6	

- 11B. ENTER NAME AND ADDRESS OF COMPANY WITH FORMULATION INFORMATION IF YOU DO NOT HAVE THE DATA TO COMPLETE ITEM 11A. **THIS REQUIREMENT DOES NOT APPLY TO INGREDIENTS WHICH ARE FRAGRANCE MATERIALS.**

12. INDICATE WHICH ITEMS CONTAIN CONFIDENTIAL BUSINESS INFORMATION :

☐ SALES ☐ TOTAL RVOC % ☐ INGREDIENTS ☐ INGREDIENT WT. %S

ATTACHMENT B

DEFINITION OF A REPORTABLE VOLATILE ORGANIC COMPOUND (RVOC)

THIS DEFINITION OF A REPORTABLE VOLATILE ORGANIC COMPOUND (RVOC) SHOULD BE USED IN CONJUNCTION WITH THE DECISION TREE ON THE FOLLOWING PAGE TO DETERMINE IF AN INGREDIENT COMPOUND IS AN RVOC. RVOC IS A SUBSET OF EPA'S DEFINITION OF VOC. THIS IS NOT TO BE CONSTRUED AS A MODIFICATION OF THE EPA DEFINITION FOR VOC. ONLY INGREDIENT COMPOUNDS FROM PRODUCTS LISTED IN ATTACHMENT A NEED TO BE CONSIDERED. IF A COMPOUND IS FOUND TO NOT BE AN RVOC, NO OTHER CONSIDERATIONS ARE NEEDED FOR THAT COMPOUND.

- 1) ANY INGREDIENT COMPOUND FOR PRODUCTS LISTED IN ATTACHMENT A SHOULD BE CONSIDERED A POSSIBLE RVOC IF IT IS AN ORGANIC COMPOUND (CONTAINS AT LEAST ONE CARBON).

- 2) THE FOLLOWING COMPOUNDS ARE **EXCEPTIONS**, AND SHOULD NOT BE CONSIDERED AS RVOC:

- A) THE COMPOUNDS [CAS NUMBER IN BRACKETS]:

METHANE	[74-82-8]
ETHANE	[74-84-0]
CARBON MONOXIDE	[630-08-0]
CARBON DIOXIDE	[124-38-9]
CARBONIC ACID SALTS	[VARIOUS]
METALLIC CARBIDES OR CARBONATES	[VARIOUS]
AMMONIUM CARBONATE	[506-87-6]
1,1,1-TRICHLOROETHANE	[71-55-6]
METHYLENE CHLORIDE	[75-09-2]
TRICHLOROFLUOROMETHANE (CFC-11)	[75-69-4]
DICHLORODIFLUOROMETHANE (CFC-12)	[75-71-8]
CHLORODIFLUOROMETHANE (HCFC-22)	[75-45-6]
TRIFLUOROMETHANE (HFC-23)	[75-46-7]
TRICHLOROTRIFLUOROETHANE (CFC-113)	[76-13-1]
DICHLOROTETRAFLUROETHANE (CFC-114)	[1320-37-2]
CHLOROPENTAFLUROETHANE (CFC-115)	[76-15-3]
DICHLOROTRIFLUOROETHANE (HCFC-123)	[306-83-2]
TETRAFLUROETHANE (HFC-134A)	*
DICHLOROFLUROETHANE (HCFC-141B)	*
CHLORODIFLUOROETHANE (HCFC-142B)	[75-68-3]
2-CHLORO-1,1,1,2-TETRAFLUROETHANE (HCFC-124)	*
PENTAFLUROETHANE (HFC-125)	*
1,1,2,2-TETRAFLUROETHANE (HFC-134)	*
1,1,1-TRIFLUOROETHANE (HFC-143A)	*
1,1-DIFLUOROETHANE (HFC-152A)	*

AND

B) PERFLUOROCARBON COMPOUNDS IN THE FOLLOWING CLASSES:

- (1) CYCLIC, BRANCHED, OR LINEAR, COMPLETELY FLUORINATED ALKANES
 - (2) CYCLIC, BRANCHED, OR LINEAR, COMPLETELY FLUORINATED ETHERS WITH NO UNSATURATIONS
 - (3) CYCLIC, BRANCHED, OR LINEAR, COMPLETELY FLUORINATED TERTIARY AMINES WITH NO UNSATURATIONS
 - (4) SULFUR-CONTAINING PERFLUOROCARBONS WITH NO UNSATURATIONS AND WITH SULFUR BONDS ONLY TO CARBON AND FLUORINE.
- 3) THE INGREDIENT COMPOUND IS AN **RVOC** IF IT IS A SOLID AT ROOM TEMPERATURE (20°C) AND READILY SUBLIMES (BECOMES A GAS). EXAMPLES INCLUDE PARA-DICHLOROBENZENE, NAPHTHALENE, AND CAMPHOR. ALL OTHER SOLIDS ARE EXEMPT AND ARE NOT **RVOC**'S UNLESS THE INGREDIENT COMPOUND BECOMES A VAPOR AT A TEMPERATURE AT WHICH IT IS USED (SUCH AS COMPONENTS OF HOT GLUES, PLUG-IN AIR FRESHENERS, ETC.).
- 4) THE INGREDIENT COMPOUND IS AN **RVOC** IF IT IS AN ORGANIC GAS OR LIQUID WITH A VAPOR PRESSURE ABOVE 0.1 MM HG AT 20°C.
- 5) IF THE VAPOR PRESSURE FOR THE INGREDIENT COMPOUND IS UNKNOWN AND IT CONTAINS LESS THAN OR EQUAL TO 12 CARBONS, IT IS AN **RVOC**.

ATTACHMENT A

CONSUMER AND COMMERCIAL PRODUCTS SURVEY CATEGORIES

PERSONAL CARE PRODUCTS

HAIR CARE PRODUCTS

1101	BLEACHES AND LIGHTENERS
1102	BRILLIANTINES
1103	CONDITIONERS
1104	CONDITIONING SPRAYS
1105	CURL ACTIVATORS
1106	CURL REVITALIZERS
1107	DYES - PERMANENT
1108	DYES - SEMIPERMANENT
1109	DYES - TEMPORARY
1110	FINISHING HAIR SPRAYS
1111	FINISHING SPRITZES
1112	GROOMING CREAMS
1113	GROWTH PRODUCTS
1114	MOUSSES
1115	PERMANENT WAVE TREATMENTS
1116	POMADES
1117	PROTECTIVE SPRAYS
1118	RINSES
1119	SETTING LOTIONS
1120	SHAMPOOS
1121	SPRAY SHINES
1122	STRAIGHTENERS
1123	STYLING GELS
1124	STYLING SPRAYS
1125	STYLING SPRITZES
1126	THICKENERS
1127	TONICS
1199	OTHER HAIR CARE PRODUCTS

DEODORANTS AND ANTIPERSPIRANTS

1201	UNDERARM DEODORANTS
1202	UNDERARM ANTIPERSPIRANTS
1203	FOOT DEODORANTS
1204	FEMININE HYGIENE DEODORANTS
1299	OTHER DEODORANT AND ANTIPERSPIRANT PRODUCTS

FRAGRANCE PRODUCTS

1301	COLOGNES
1302	PERFUMES
1303	TOILET WATERS
1304	AFTER SHAVE TREATMENTS
1305	BODY FRAGRANCE SPRAYS
1306	BATH OILS, BEADS, AND CAPSULES
1399	OTHER FRAGRANCE PRODUCTS

POWDERS

1401	BABY POWDERS
1402	BODY POWDERS
1403	FOOT POWDERS
1499	OTHER POWDER PRODUCTS

NAIL CARE PRODUCTS

1501	POLISHES
1502	BASE COATS, UNDERCOATS
1503	POLISH REMOVERS
1504	NAIL EXTENDERS
1505	CUTICLE SOFTENERS
1506	MANICURE PREPARATIONS
1599	OTHER NAIL CARE PRODUCTS

FACIAL AND BODY MAKEUP AND TREATMENTS

1601	ASTRINGENTS
1602	CREAMS, SCRUBS, CLEANERS
1603	ROUGES AND BLUSHES
1604	MAKEUP BASES, FOUNDATIONS, AND FIXATIVES
1605	LIPSTICKS
1606	MOISTURIZERS
1607	SKIN LIGHTENERS
1608	FACIAL MASQUES
1609	LEG AND BODY PAINTS
1610	MASCARA
1611	EYELINER
1612	EYE SHADOW
1613	EYE MAKEUP REMOVER
1614	EYEBROW PENCIL
1615	HAND AND BODY LOTIONS
1616	SKIN PROTECTANTS
1617	DEPILATORIES

1618	SELF-TANNING PREPARATIONS
1619	SUNTAN OILS AND LOTIONS
1620	SUNSCREENS
1699	OTHER FACIAL AND BODY MAKEUP AND TREATMENTS

ORAL CARE PRODUCTS

1701	MOUTHWASHES
1702	BREATH FRESHENERS
1703	TOOTHPASTES, GELS, AND POWDERS
1704	PLAQUE REMOVAL SOLUTIONS
1705	FLUORIDE RINSES
1706	DENTURE CARE PRODUCTS
1799	OTHER ORAL CARE PRODUCTS

HEALTH USE PRODUCTS

1801	OVER-THE-COUNTER (OTC) DRUGS (EXTERNAL ONLY)
1802	PRESCRIPTION PHARMACEUTICALS (EXTERNAL ONLY)
1899	OTHER HEALTH USE PRODUCTS

MISCELLANEOUS PERSONAL CARE PRODUCTS

1901	HAND CLEANERS AND SOAPS
1902	RUBBING ALCOHOL
1903	SHAVING CREAMS, GELS, AND SOAPS
1999	OTHER MISCELLANEOUS PERSONAL CARE PRODUCTS

HOUSEHOLD PRODUCTS (INCLUDING INSTITUTIONAL USES)

HARD SURFACE CLEANERS

2101	GENERAL PURPOSE CLEANERS
2102	GLASS CLEANERS
2103	OVEN CLEANERS
2104	TUB, TILE, AND SINK CLEANERS
2105	MILDEW REMOVERS
2106	TOILET BOWL CLEANERS
2107	HARD SURFACE RUST STAIN REMOVERS
2108	METAL CLEANERS
2109	SOAP SCOURING PADS
2199	OTHER HARD SURFACE CLEANERS

LAUNDRY PRODUCTS

2201	DETERGENTS
2202	SOAPS
2203	PRESOAKS
2204	PREWASH SPOT AND STAIN REMOVERS
2205	BLEACHES
2206	WHITENERS/BRIGHTENERS
2207	BLUING
2208	FABRIC SOFTENERS
2209	WATER SOFTENERS AND CONDITIONERS
2210	STARCHES, SIZINGS, AND FABRIC FINISHES
2299	OTHER LAUNDRY PRODUCTS

FABRIC, CARPET, AND UPHOLSTERY CARE PRODUCTS

2301	CARPET CLEANERS
2302	CARPET DEODORIZERS AND FRESHENERS
2303	UPHOLSTERY CLEANERS
2304	SPOT REMOVERS
2305	FABRIC STAIN REPELLENTS
2306	WATER REPELLENTS
2307	FABRIC DYES
2308	ANTISTATIC SPRAYS
2309	DRY CLEANING FLUIDS
2399	OTHER FABRIC, CARPET, AND UPHOLSTERY CARE PRODUCTS

DISHWASHING PRODUCTS

2401	DISH DETERGENTS (MANUAL)
2402	DISH DETERGENTS (MACHINE)
2403	RINSE AIDS
2404	FILM AND SPOT REMOVERS
2499	OTHER DISHWASHING PRODUCTS

WAXES AND POLISHES

2501	FURNITURE WAXES AND POLISHES
2502	FLOOR WAXES AND POLISHES
2503	DUSTING AIDS
2599	OTHER HOUSEHOLD WAXES AND POLISHES

AIR FRESHENERS

2601	ROOM AIR FRESHENERS
2602	TOILET DEODORANT BLOCKS
2699	OTHER AIR FRESHENERS

SHOE AND LEATHER CARE PRODUCTS

2701	LEATHER PRESERVATIVE TREATMENTS
2702	LEATHER DYES
2703	SHOE POLISHES
2799	OTHER SHOE AND LEATHER CARE PRODUCTS

MISCELLANEOUS HOUSEHOLD PRODUCTS

2801	LUBRICANTS
2802	DRAIN OPENERS
2803	CHARCOAL LIGHTERS
2804	WICK LAMP FUELS
2805	PLANT LEAF CLEANERS AND WAXES
2806	DRIVEWAY CLEANERS
2899	OTHER MISCELLANEOUS HOUSEHOLD PRODUCTS

AUTOMOTIVE AFTERMARKET PRODUCTS

DETAILING PRODUCTS

3101	WAXES, POLISHES, AND FINISH SEALERS
3102	VINYL AND LEATHER CLEANERS
3103	UPHOLSTERY FABRIC CLEANERS
3104	TIRE CLEANERS
3105	WHEEL CLEANERS
3106	BUG AND TAR REMOVERS
3107	CHROME CLEANERS AND POLISHES
3108	RUBBER AND VINYL PROTECTANTS
3199	OTHER AUTOMOTIVE DETAILING PRODUCTS

MAINTENANCE AND REPAIR PRODUCTS

3201	ENGINE DEGREASERS
3202	CARBURETOR AND CHOKE CLEANERS
3203	BRAKE CLEANERS
3204	BRAKE ANTI-SQUEAL COMPOUNDS
3205	TIRE SEALANTS AND INFLATORS
3206	BELT DRESSINGS
3207	ENGINE STARTING FLUIDS
3208	LUBRICANTS (OTHER THAN ENGINE OIL)
3209	ANTIFREEZES
3210	BRAKE FLUIDS
3211	BODY REPAIR PRODUCTS (OTHER THAN COATINGS)
3212	WINDSHIELD DEICERS
3213	WINDSHIELD WASHER FLUIDS
3299	OTHER AUTOMOTIVE MAINTENANCE AND REPAIR PRODUCTS

ADHESIVES AND SEALANTS

ADHESIVES

4101	HOUSEHOLD GLUES AND PASTES
4102	ARTS AND CRAFTS ADHESIVES
4103	CARPET AND TILE ADHESIVES
4104	WALLPAPER ADHESIVES
4105	WOODWORKING GLUES
4106	PLASTIC PIPE CEMENTS AND PRIMERS
4107	THREAD LOCKING COMPOUNDS
4108	SPECIALTY AUTOMOTIVE ADHESIVES
4109	CONSTRUCTION ADHESIVES
4199	OTHER ADHESIVES

SEALANTS

4201	SPACKLING COMPOUNDS
4202	CAULKING COMPOUNDS
4203	WINDOW GLAZING COMPOUNDS
4204	PIPE THREAD SEALANTS
4205	PLUMBER'S PUTTIES
4206	PAINTER'S PUTTIES
4207	WOOD FILLERS
4208	INSULATING AND SEALING FOAMS
4209	DRIVEWAY PATCHING COMPOUNDS
4210	COLD PROCESS ROOF CEMENTS
4299	OTHER SEALANTS

FIFRA-REGISTERED PRODUCTS

INSECTICIDES

5101	LAWN AND GARDEN INSECTICIDES
5102	SPACE INSECTICIDES AND ROOM FOGGERS
5103	FLYING INSECT SPRAYS
5104	RESIDUAL INSECTICIDES
5105	HORNET AND WASP SPRAYS
5106	FLEA AND TICK SOAPS, SPRAYS, AND DIPS
5199	OTHER INSECTICIDES

FUNGICIDES AND NEMATICIDES

5201	LAWN AND GARDEN TREATMENTS
5202	WOOD PRESERVATIVES
5203	MOLD AND MILDEW RETARDANTS
5299	OTHER FUNGICIDES AND NEMATICIDES

HERBICIDES

5301	AQUATIC HERBICIDES
5302	SWIMMING POOL ALGICIDES
5303	TERRESTRIAL HERBICIDES, DEFOLIANTS, DESICCANTS
5399	OTHER HERBICIDES

ANTIMICROBIAL AGENTS

5401	SANITIZERS
5402	DISINFECTANTS
5403	STERILANTS
5499	OTHER ANTIMICROBIAL AGENTS

MISCELLANEOUS FIFRA-CONTROLLED PRODUCTS

5501	INSECT REPELLENTS
5502	DOMESTIC CAT AND DOG REPELLENTS
5503	RODENT POISONS AND BAITS
5504	REPTILIAN AND AMPHIBIAN CONTROL AGENTS
5599	OTHER MISCELLANEOUS FIFRA-CONTROLLED PRODUCTS

COATINGS AND RELATED PRODUCTS

AEROSOL SPRAY PAINTS AND COATINGS

6101	NONFLAT ENAMELS
6102	FLAT ENAMELS
6103	NONFLAT LACQUERS
6104	FLAT LACQUERS
6105	METALLIC PIGMENTED COATINGS
6106	CLEAR COATINGS
6107	GROUND/TRAFFIC MARKING COATINGS
6108	EXACT MATCH AUTOMOTIVE PAINTS
6109	VINYL/FABRIC COATINGS
6110	GLASS COATINGS
6111	AUTOMOTIVE SANDING PRIMERS
6112	RUST-INHIBITIVE PRIMERS
6113	SPATTER FINISHES
6114	WOOD STAINS
6115	ENGINE ENAMELS
6116	HIGH TEMPERATURE COATINGS
6199	OTHER AEROSOL SPRAY PAINTS AND COATINGS

RELATED PRODUCTS

6201	PAINT THINNERS
6202	PAINT REMOVERS
6203	BRUSH CLEANERS AND RECONDITIONERS
6204	SOLVENTS
6299	OTHER RELATED PRODUCTS

MISCELLANEOUS PRODUCTS (NOT OTHERWISE COVERED)

ARTS AND CRAFTS SUPPLIES

7101	ARTISTS PAINTS, PIGMENTS, AND THINNERS
7102	FIXATIVE SPRAYS
7103	SPECIALTY CLEANING PRODUCTS
7104	CERAMIC FINISHING PRODUCTS
7199	OTHER ARTS AND CRAFTS SUPPLIES

NON-PESTICIDAL VETERINARY AND PET PRODUCTS

7201	ANIMAL DRUGS (EXTERNAL ONLY)
7202	LIVESTOCK AND PET GROOMING PRODUCTS
7203	CAT LITTERS
7299	OTHER NON-PESTICIDAL VETERINARY AND PET PRODUCTS

PRESSURIZED FOOD PRODUCTS

7301	CHEESE SPREADS
7302	PAN SPRAYS
7303	WHIPPED DESSERT TOPPINGS
7399	OTHER PRESSURIZED FOOD PRODUCTS

OFFICE SUPPLIES

7401	PENS
7402	INK
7403	PERMANENT MARKERS
7404	DRY ERASABLE MARKERS
7405	HIGHLIGHTERS
7406	CORRECTION FLUIDS
7407	LIQUID TONERS (FOR COPIERS, FAX MACHINES, PRINTERS, ETC.)
7408	INKED RIBBONS (FOR TYPEWRITERS, PRINTERS, ETC.)
7499	OTHER OFFICE SUPPLIES

VOLUME III: CHAPTER 6

SOLVENT CLEANING

September 1997



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Eastern Research Group

Prepared for:
Area Sources Committee
Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

Solvent cleaning operations are an integral part of many industries and involve the use of solvents or solvent vapor to remove water-insoluble contaminants such as grease, oils, waxes, carbon deposits, fluxes, and tars from metal, plastic, glass, and other surfaces. Solvent cleaning is usually performed prior to painting, plating, inspection, repair, assembly, heat treating, and machining (EPA, 1991; EPA, 1993a).

Section 2 of this chapter contains general descriptions of the solvent cleaning source category, a listing of emission sources commonly associated with solvent cleaning operations, and an overview of the available control technologies for various solvent cleaning operations. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation methods for solvent cleaning operations, and Section 5 presents alternative emission estimation techniques. Quality assurance (QA) and quality control (QC) procedures are described in Section 6 and data coding procedures are discussed in Section 7. Section 8 lists references. Refer to Chapter 1, *Introduction to Area Source Emission Inventory Development*, for general concepts and technical approaches.

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SOURCE CATEGORY DESCRIPTION

There are two basic types of cleaning machines: batch and in-line cleaning machines (also called continuous cleaning machines). Both of these equipment types are designed to use solvent to clean parts. The solvent is either used to clean in its nonvapor liquid form (at a temperature below the boiling point, referred to as cold cleaning), or heated to a temperature above its boiling point (referred to as vapor cleaning). Other solvent cleaning operations involve the use of solvent in wipe-cleaning and equipment cleanup.

Solvents used in cleaning machines include 1,1,1-trichloroethane (TCA), trichloroethylene (TCE), methylene chloride, perchloroethylene (PERC), carbon tetrachloride, chloroform, chlorofluorocarbons (CFCs), petroleum distillates (e.g., Stoddard solvent, mineral spirits, naphthas), and alcohols. Solvents used in cleanup include acetone, alcohols, butyl acetate, cyclohexanone, ethyl acetate, ethylbenzene, ethylene glycol, methyl ethyl ketone, methyl isobutyl ketone, naphthas, toluene, and xylene. Acetone, CFCs, methylene chloride, PERC, and TCA are specifically exempted from the EPA's definition of reactive volatile organic compounds (VOCs) due to their low photochemical reactivity. TCA, carbon tetrachloride, and CFCs such as CFC-11 and CFC-13 will not be produced after January 1, 1996 as part of the Montreal Protocol to reduce stratospheric ozone depletion. Higher molecular weight organics (i.e. naphthas) usually have lower vapor pressures and thus lower emissions and less impact on ozone levels. Water-based cleaners may also be substituted for organic solvents to eliminate any ozone impacts.

2.1 SOLVENT CLEANING ACTIVITIES

2.1.1 BATCH COLD CLEANING MACHINES

Batch cold cleaning machines use solvent in the liquid phase to clean and remove foreign material such as oils and grease from the surface of materials. These machines are batch loaded, and cleaning operations include spraying, flushing, solvent or parts agitation, wipe cleaning, brushing, and immersion. Both halogenated and nonhalogenated solvents are used in batch cold cleaning machines. Carburetor cleaners use halogenated solvents and Stoddard solvent. The predominant solvent used for all other batch cleaning machines are nonhalogenated solvents.

Nonhalogenated solvents used in cold cleaning machines include aliphatic petroleum distillates (e.g., mineral spirits, Stoddard solvent, petroleum naphthas), alcohols, ketones, glycol ethers and others. In some carburetor cleaners, a mixture containing halogenated solvents, such as methylene chloride and nonhalogenated solvents, is used. The total halogenated and nonhalogenated solvents used in cold cleaning machines in the past has been estimated as

430,000 tons, based on several year's data (EPA, 1991). However, halogenated solvent use in cold cleaning machines has been estimated as 65,000 tons for the year of 1991 (EPA, 1993a). Cold cleaners are usually individually small emission sources and, because they are widely scattered and frequently used, they are most easily treated as area sources. If they are collocated at a major source, they may be included in the point source inventory and those emissions will need to be subtracted from the area source estimate.

Ninety percent of Stoddard solvent batch cold cleaning machines use a remote reservoir and 10 percent use immersion; however, many cold cleaning machines are a combination of both types (EPA, 1991; EPA, 1994a). Remote reservoir cleaning machines pump solvent through a sink-like work area. The solvent drains back into an enclosed container through a small drain while the contaminated parts (called workload) are being cleaned. Fewer vapors are emitted from the solvent in the enclosed container during nonuse compared to immersion cleaners. In immersion cold cleaning machines, the workload is simply immersed in the liquid solvent (EPA, 1994a). Solvent may also be sprayed on the parts to enhance cleaning. Combination remote reservoir/immersion cleaning machines resemble a remote reservoir machine in that solvent is pumped to a sink-like work area. However, the machine's work area contains a shelf that can be removed; once the shelf is removed, the workload can be cleaned by immersion (EPA, 1994a). Machines that can be either a remote reservoir or an immersion cleaning machine are considered to be immersion cleaning machines by the Environmental Protection Agency (EPA) (*Federal Register*, 1994).

Approximately one million cold cleaning machines were estimated to be in operation in the United States in 1994 (EPA, 1994a). Approximately 50 percent of batch cold cleaning machines are used in automotive repair shops (Standard Industrial Classification [SIC] Code 753). This includes top, body, and upholstery repair and paint shops (SIC Code 7532), automotive exhaust system repair shops (SIC Code 7533), tire retreading and repair shops (SIC Code 7534), automotive glass replacement shops (SIC Code 7536), automotive transmission repair shops (SIC Code 7537), general automotive repair shops (SIC Code 7538), and automotive repair shops not elsewhere classified (SIC Code 7539). Automotive repair shops generally use smaller cold cleaning machines with a solvent/air interface less than or equal to 0.4 m². Larger immersion batch cold cleaning machines are used in manufacturing processes as well as automotive rebuilding and repair, and machining industries (EPA, 1991; EPA, 1994a).

2.1.2 BATCH VAPOR CLEANING MACHINES

Batch vapor cleaning machines represent the largest source of halogenated solvent (e.g., TCA, TCE, methylene chloride, PERC, carbon tetrachloride, and chloroform) emissions. The most common type of batch vapor cleaning machine is the Open Top Vapor Cleaner (OTVC). The OTVC is a tank designed to generate and contain solvent vapor. The tank is equipped with a heating system that uses steam, electricity, hot water, or a heat pump to boil the liquid solvent. As the solvent boils, dense solvent vapors rise and displace the air in the tank. Coolant is

circulated in condensing coils on the top of the tank to create a controlled vapor zone within the tank. Condensing solvent vapors dissolve the contaminants on the surface of the workload and flush both the dissolved and undissolved contaminants from the workload. When the temperature of the workload equals the temperature of the vapor, no further cleaning will occur by this mechanism (because solvent will no longer condense on the part). The vapor cleaning phase may be supplemented, or even replaced, by the immersion of the workload into the hot liquid solvent. Several operational variations are possible. The cleaning cycle can be modified from a basic vapor cleaning cycle to improve cleaning efficiency. One OTVC operational variation is the immersion-vapor-spray cycle where the workload is first immersed in the warm or boiling solvent for precleaning. The workload is then cleaned in the vapor section and sprayed with the solvent. Organic impurities (e.g., grease and oil) do not contaminate the vapor because of their higher boiling points. Because the solvent remains clean, it can be used for longer periods of time compared to cold cleaning.

Non-OTVC batch vapor cleaning machines are a hybrid of the OTVC and in-line machines. They tend to be larger, with an enclosed design with conveyORIZED systems for moving large parts and parts baskets. Non-OTVC batch cleaning machines include the cross-rod, the vibra, the Ferris wheel, and the carousel cleaners. All of these cleaning machines tend to have multiple loads within the machine simultaneously. The cross-rod degreaser contains rods with suspended parts baskets and is fully enclosed with the exception of one opening. Through this opening, parts enter and exit the machine. Since parts tend to be loaded semicontinuously and typically manually, the machine is classified as a batch unit. In the vibra cleaning machine, the soiled parts are fed in a batch into a pan and flooded with boiling solvent at the bottom of the machine. The machine includes a vibrating spiral elevator that lifts the parts through the increasing cleaner solvent baths (either vapor or liquid). This unit can clean large volumes of small parts. The Ferris wheel machine is so named because it is typically characterized by four baskets rotating in a vertical plane. The cleaner would typically have four stages; at any one time, one parts basket is in each stage. One stage is for loading and unloading of parts and is located at the only opening in the machine. The other three stages are various cleaning stages including spray, solvent bath, and/or vapor cleaning. The carousel cleaning machine is similar to the Ferris wheel machine except that parts move through a horizontal plane.

In 1991, 16,400 batch vapor cleaning machines using halogenated solvents were estimated to be in operation in the United States, and it is estimated that those machines used approximately 104,500 tons of methylene chloride, PERC, TCE, TCA, and 1,1,1-trichloro-2,2,2-trifluoroethane (CFC-113) (EPA, 1993a). Stoddard solvent is not used in batch vapor cleaning machines due to its flammability. Thus, only machines using TCE would need to be considered for a VOC inventory.

An estimated 10,000 to 13,500 small vapor cleaning machines could potentially be small sources for hazardous air pollutants (HAPs) that would need to be inventoried as area sources unless they are collocated and counted as part of a major source. Assuming no emissions control, it is

estimated that half of the large vapor cleaning machines (those with an average 16 ft² working area) emit less than 10 tons per year of a HAP, and could also be counted as area sources (EPA, 1993a).

The largest amounts of halogenated solvent used for cleaning are in the manufacture of furniture and fixtures (SIC Code 25), fabricated metal manufacturing (SIC Code 34), electric and electronic equipment (SIC Code 36), transportation equipment (SIC Code 37), and miscellaneous manufacturing industries (SIC Code 39). Other industries that use halogenated solvents for cleaning include food and kindred products (SIC Code 20), primary metals (SIC Code 33), nonelectric machinery (SIC Code 35), and instruments and clocks (SIC Code 38). Nonmanufacturing industries such as railroad, bus, aircraft, and truck maintenance facilities, automotive and electric tool repair shops, automobile dealers, service stations, and miscellaneous repair services (SIC Codes 40, 41, 42, 45, 49, 55, 75, and 76, respectively) also use halogenated solvents for solvent cleaning (EPA, 1993a).

2.1.3 IN-LINE CLEANING MACHINES

In-line cleaners are usually inventoried as point sources (EPA, 1991). In-line cleaning machines employ automated loading on a continuous basis. These machines are often custom made for large-scale operations and can work in a vapor or nonvapor mode. However, the vapor mode is most commonly used. A continuous or multiple-batch loading system greatly reduces or even eliminates the manual parts handling associated with batch cleaning. The cross-rod batch cleaning machine can also be designed to operate continuously with no manual loading. The same cleaning techniques are used for in-line cleaning as for batch cleaning but on a larger scale. In-line cleaning machines are enclosed to prevent solvent losses; however, entry and exit openings cannot be sealed (EPA, 1993a). The four types of in-line cleaning machines are: monorail, belt, strip, and printed circuit board processing equipment (e.g., photoresist strippers, flux cleaners, and developers). The monorail vapor cleaning machine is used when the workload to be cleaned is being transported between manufacturing operations on a monorail conveyor (EPA, 1993a). A belt cleaning machine conveys the workload through a long and narrow boiling chamber where the workload is cleaned by condensing vapor or immersion. The strip cleaning machine is similar to the belt cleaner except the strip is the material being cleaned. Printed circuit boards are cleaned with photoresist strippers and circuit board cleaning machines (EPA, 1993a).

The five most common halogenated solvents used in in-line solvent cleaning operations are methylene chloride, PERC, TCE, TCA, and CFC-113 (EPA, 1993a). PERC, TCE, and TCA are commonly used because they are not flammable and their vapors are much heavier than air (EPA, 1991). In 1991, an estimated 39,000 tons of halogenated solvents were used by vapor in-line solvent cleaning machines (EPA, 1993a). Approximately 2,500 to 4,000 in-line cleaners employing halogenated solvents were estimated to be in operation in 1991 (EPA, 1991).

In-line solvent cleaning machines are used by a broad spectrum of industries but are most often found in plants where there is a constant stream of parts to be cleaned, such as printed circuit boards for the electronic and electrical components industry (EPA, 1991; EPA, 1993a).

2.1.4 CLEANUP SOLVENT USE (EPA, 1994B)

Cleanup solvents are used to clean external surfaces, such as products, parts and equipment, floors, tables, and walls, and internal surfaces or containers, such as tanks and supply lines. Cleaning processes may include wiping using mops, brushes, and rags, spraying, flushing the interiors of equipment, purging spray equipment, or dipping small parts in vessels of solvents. These processes are used to clean products as part of the manufacturing process, such as before painting, cleaning of process equipment, and cleaning before maintenance.

Wiping is perhaps the most common cleaning activity because the contaminant is quickly removed. Wipe cleaning is easily performed anywhere in the plant and is a frequent part of maintenance activities (e.g., cleaning machinery, floors). Surfaces can be cleaned while in place without disassembly. Wipe cleaning is an integral part of many production processes including automotive manufacturing, truck and bus manufacturing, and automotive parts and accessories manufacturing; in the manufacture of adhesives, packaging, plastics, furniture, fiberglass boats, electrical equipment, magnetic tape, and photographic chemicals; and rotogravure printing and autobody refinishing as well as offset lithographic printing.

Frequently used industrial cleaning solvents include acetone, butyl acetate, cyclohexanone, ethanol, ethyl acetate, ethylbenzene, ethylene glycol, isopropyl alcohol, methanol, methyl ethyl ketone, methyl isobutyl ketone, naphtha, PERC, toluene, and xylene. Estimated annual cleaning solvent usage ranges from 270,000 to 1,400,000 tons per year; however, this estimate is for the industries listed above. Nationwide use of cleaning solvents has not been quantified and is expected to be much higher.

2.2 EMISSION SOURCES

2.2.1 CLEANING MACHINES

Batch and in-line solvent cleaning machines are characterized by three operating modes that have characteristic emission mechanisms. The operating modes are idling, working, and downtime. Cold cleaners do not have an idling mode. Fugitive emissions also occur as a result of leaks, filling/draining losses, wastewater losses, start-up/shutdown losses, distillation losses, and solvent decomposition losses.

Idling emissions occur when the cleaning machine is turned on and ready to operate, but is not actively processing parts. Air and solvent interface losses consist of solvent vapor diffusion (or

evaporation from liquid solvent in cold cleaning machines) and solvent convection caused by a warm freeboard (freeboard is the distance between the top of the tank and the solvent/air interface). Diffusion occurs because solvent molecules move from areas of higher concentration in the vapor zone to areas of lower concentration in the air. Idling diffusion is the greatest when air flow is introduced across the solvent/air interface from room drafts. Drafts can also sweep solvent-laden air from the freeboard area into the ambient air. Convection occurs from the tank walls being heated from the heated liquid solvent and vapor. Emissions occur as a result of the convective flow up along the freeboard that carries solvent vapor out of the cleaning machine. If freeboards are kept at ambient temperatures, emissions will be minimized. Emission rate variance can be explained by the varying primary condensing temperatures; however, emission rates are lowest when the primary condenser temperature of the cleaning machine is the lowest. Typical idling losses are 0.03 lb/ft²/hr (EPA, 1993a).

Working emissions occur when the cleaning machine is turned on and operating and include idling emissions with additional emissions from the introduction of parts being cleaned, the cleaning process (e.g., spraying), the evaporation of solvent from the part as the workload is pulled out of the cleaning machine, and solvent carryout. Working emissions from cold cleaners include solvent carryout and cleaning process losses. The typical emission rate for working emissions is 0.40 lb/ft²/hr. Emission rate variability is caused by varying operational parameters (EPA, 1993a).

Downtime emissions occur when the heat to the sump (cleaning machine tank) is turned off and the cleaning machine is not operating. Downtime emission mechanisms include evaporation of solvent from the liquid solvent surface and subsequent diffusion into the air. Downtime emission rates are estimated to be 0.30 lb/ft²/hr (EPA, 1993a).

2.2.2 CLEANUP SOLVENTS

Emission sources from the use of cleanup solvents occur due to solvent evaporation. Typical sources of evaporation are emissions from storage and handling of fresh and spent solvents, solvent evaporation from the cleaned surfaces, evaporation as the solvent is splashed or sprayed, fugitive emissions from flushing or spray systems, and evaporation from solvent-soaked rags or cleaning tools. All solvent not recycled or sent to waste disposal is eventually emitted into the atmosphere (EPA, 1994b).

2.3 FACTORS INFLUENCING EMISSIONS

Process operating factors largely influence emissions from cleaning machines and wipe cleaning. These are:

- Leaks from manufacturing defects or equipment use;

- Manual filling and draining of cleaning machines, especially with open buckets and drums;
- Water/solvent separators;
- Start-up operations that cause solvent-laden air to be dispersed into the ambient air when a new solvent vapor layer is being established;
- Shutdown operations that create emissions from evaporation of hot solvent;
- Emissions from distillation/sludge disposal that occur when spent solvent is regenerated on-site;
- Excessive pooling/entraining of solvents on improperly oriented or drained parts;
- Solvent decomposition;
- Turbulence from high conveyor belt speeds and from manual removal of parts;
- Exhaust systems used without a carbon adsorber;
- Careless or improper use of cleaning tools (e.g., rags, brushes) or parts during and after cleaning;
- Splashing and spilling of the solvent;
- Lack of a cover over solvent;
- Drying of parts in areas vented directly to the atmosphere; and
- Using adsorbent or porous items such as ropes and bags for handling solvent-soaked items (EPA, 1993a, 1994b).

Emissions from cold cleaning machines may also be influenced by physical and chemical properties of the solvent in the machine. These chemical factors include volatility, viscosity, boiling points, and surface tension.

2.4 CONTROL TECHNIQUES

2.4.1 CLEANING MACHINES

Techniques used to control emissions from solvent cleaning machines include both machine design controls as well as improved operating procedures. Control technologies are based on the size, design, application, and operation of the machines. Many of these control techniques are required on all sizes of halogenated cleaners by the National Emission Standards for Hazardous Air Pollutants: Halogenated Solvent Cleaning. Design features that control solvent emissions from batch cold cleaning machines include:

- Increased freeboard ratio;
- Covers;
- Internal drainage rack; and
- Visible fill line.

Emissions from carburetor cold cleaning machines are well controlled because the cleaning solutions contain water, which forms a layer above the solvent mixture in the tank. This water layer significantly reduces the evaporation of methylene chloride into the air (EPA, 1994a).

Design features that decrease emissions from batch vapor and in-line cleaning machines include the following:

- Covers to eliminate drafts, control vapor/air interface emissions, and reduce diffusion losses;
- Freeboard refrigeration devices that use a second set of cooling coils cool the air directly above the vapor zone forming a cool air blanket and decreasing diffusional losses;
- Hot vapor recycle or superheated vapor designs to create a zone of superheated solvent vapor within the vapor layer. Cleaned parts are passed through the superheated zone so the liquid solvent is evaporated prior to the part being withdrawn from the batch or in-line cleaner. This method is expected to be used mostly with chlorofluorinated solvents;

- Increased freeboard height to decrease turbulence caused by room drafts and increase the diffusion column;
- Vacuum chamber cleaning machines, a new type of batch cleaning machine that decreases emissions by cleaning items in a sealed decompression chamber. Emission concentrations of less than 50 parts per million (ppm) per cleaning cycle have been reported (EPA, 1993a);
- In-line cleaning machines that can be designed with a U-turn to decrease entrance and exit opening emissions by reducing drafts within the in-line cleaning machines. Hanging flags over these openings will also reduce drafts;
- Freeboard refrigeration devices, which are similar to those used in batch cleaning machines, to decrease emissions;
- A drying tunnel, which is an added enclosure that extends the exit area for drying purposes, to reduce carryout emissions because evaporated solvent will sink back into the vapor zone instead of the atmosphere;
- Rotating baskets to prevent the trapping of liquid solvent in parts and, therefore, also reduce carryout emissions; and
- The use of carbon adsorption when a lip exhaust system is used to reduce solvent concentration around the top perimeter of the cleaner. This is done by capturing solvent vapors from peripheral exhaust ducts and ducting to an activated carbon bed before the vent stream is exhausted to the atmosphere. The bed is desorbed and the recovered solvent can be reused in the cleaning machine. This option may increase solvent usage and waste if the solvent is not removed (EPA, 1994a).

Work practice modifications to decrease emissions from batch, in-line, and cold cleaning machines include the following:

- Decreasing the speed at which parts are moved in and out of openings in a solvent cleaning machine;
- Reducing room drafts;
- Limiting the horizontal area of the load to be cleaned to 50 percent or less of the batch cleaning machine solvent/air interface area;

- Spraying within the vapor zone at a downward angle helps control excess emissions;
- Turning on the primary condenser before heating the solvent will reduce solvent emissions at start-up;
- Allowing the cooling system to stay on after the heater is shut off will reduce shutdown emissions;
- Using covers and freeboard refrigeration devices during downtime;
- Pumping the solvent into an airtight storage container during downtime;
- Detecting and repairing routine leaks on a regular schedule;
- Employing submerged pipe filling to decrease solvent transfer losses;
- Not bypassing carbon adsorbers during the desorption cycle; and
- Replacing the carbon bed often to prevent solvent breakthrough (EPA, 1993a).

Many of these work practices have been proposed in the New Source Performance Standards for cold cleaning machines.

In addition, alternative cleaning solvents are being developed that may be substituted for halogenated or nonhalogenated solvents in some cases. Alternative cleaning solvents are generally grouped into the following categories: (1) hydrochlorofluorocarbons (HCFCs); (2) aqueous; (3) semiaqueous; and (4) organic solvents. HCFCs are used to replace CFCs and TCA; however, the use of these HCFCs are temporary because their production will be banned by the Montreal Protocols. Aqueous cleaners can be substituted for solvents, because they use water as the primary solvent with alkaline salts, surfactants, and other additives. Aqueous cleaners can effectively clean inorganic or polar soils, oils, greases, and films. Semiaqueous cleaners can be substituted for halogenated solvents. These solutions combine terpenes or hydrocarbons with surfactants along with additives such as corrosion inhibitors. These cleaners can effectively remove heavy grease, tar, waxes, hard-to-remove soil, and polar and nonpolar contaminants. Organic solvent cleaners use no water and include oxygenated hydrocarbon formulations, aliphatic hydrocarbons, esters, glycol ethers, alcohols, aromatics, and ketones. These solvent alternatives should be identified and included in a VOC inventory.

Alternative cleaning technologies currently being developed include ice particle cleaning, plasma cleaning, and cleaning with high-pressure gases, supercritical fluids, and ultraviolet ozone (EPA,

1993a). The Solvent Alternatives Guide (SAGE), a software system distributed by EPA, can provide recommendations for solvent replacements in cleaning operations.^a

2.4.2 CLEANUP SOLVENTS

Emission reduction techniques for solvent cleaning activities include substituting a less volatile solvent, reducing usage rates, and better management of the spent solvent and the wipes, rags, other cleaning tools. Improved work practices are particularly important in minimizing evaporative emissions.

2.5 REGULATORY STATUS

Based on the high usage and emissions of these cleaners throughout industry as well as the large number of cleaners, the EPA determined that there is a great potential for exposure to HAPs used as solvents in solvent cleaning machines. In addition, the EPA has determined that these compounds present a threat of adverse effects to human health or the environment.

Control technique guidelines for solvent cleaning were established in 1977 for the control of VOCs from solvent cleaning machines. These recommended requirements were adopted by 33 states. In 1980, a New Source Performance Standard (NSPS) was proposed for the solvent cleaning industry. An Alternative Control Techniques (ACT) document for halogenated solvent cleaning machines was published in 1989 after substantial review by industry. In 1994, a National Emission Standard for Hazardous Air Pollutants (NESHAP) was promulgated to regulate HAP emissions from halogenated solvent cleaning machines. The most recent information about the regulatory status of solvent cleaning processes can be found on the EPA Technology Transfer Network (TTN). See Chapter 1 of this volume for more information about the EPA TTN.

2.5.1 SOLVENT CLEANING MACHINES

The halogenated solvent cleaning NESHAP promulgated in December 1994 (59 FR 61801, December 2, 1994) established standards for both area and major sources of solvent cleaners using HAP solvent. The NESHAP requires batch vapor solvent cleaning machines and in-line solvent cleaning machines to meet emission standards reflecting the application of the maximum achievable control technology (MACT). Area source batch cold cleaning machines are required

^a SAGE can be downloaded from the Control Technology Center (CTC) portion of the EPA Technology Transfer Network (TTN) web site. For Internet access to the EPA TTN, use: <http://www.epa.gov/ttn/chief/>.

to achieve generally available control technology (GACT). The rule regulates the emissions of the following halogenated solvents: methylene chloride, PERC, TCE, TCA, carbon tetrachloride, and chloroform.

The proposed NSPS for cold cleaning operations requires sources to control emissions to the level achievable by the best demonstrated technology (BDT) (*Federal Register*, 1994). The proposed BDT is a combination of equipment and work practice standards that allow for the best emission control and enforceability. The BDT for large cold cleaning machines ($>1.8 \text{ m}^2$) includes requirements for covers, drain racks, increased drain time, a visible fill line, a freeboard ratio (the relationship of freeboard height divided by the interior width of the cleaning machine) of at least 0.5, solvent pump pressure design limits, work practice labels, and reporting and recordkeeping of solvent usage and disposition.

Twenty-six state agencies currently regulate in-line batch cold, batch vapor, and solvent cleaning machines. These states are listed in Table 6.2-1. All 26 states require the use of control equipment (e.g., covers, increased freeboard ratio) and specify work practices such as leak detection and repair programs.

Consumption of TCA, CFC, and carbon tetrachloride is expected to decline rapidly in solvent cleaning operations because of their scheduled phaseout as a result of the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, Title VI of the 1990 Clean Air Act Amendments (CAAA), and an Executive Order (58 FR 65018, December 10, 1993). Production of these solvents is scheduled to cease in 1996.

However, their use will extend into the future. As a result of the Montreal Protocol and the 1994 solvent cleaning NESHAP, it is expected that 27 percent of the 1994 population of cleaning machines will be replaced with new machines. The industry has been shifting from halogenated solvents to nonhalogenated solvents, including aqueous and semiaqueous solvents.

2.5.2 CLEANUP SOLVENTS

Cleanup solvents have not been addressed by federal regulations in the Clean Air Act; however the *Alternative Control Techniques Document - Industrial Cleaning Solvents* (EPA, 1994b) has been developed to assist state and local agencies reducing VOC emissions.

Sixteen states currently regulate VOC emissions from cleanup solvents. In addition, regulations at the city and county level have been developed to control VOCs. Approximately 46 percent of these regulations have only recordkeeping requirements. Eleven agencies regulate control equipment, and 14 agencies regulate work practices. Only five agencies limit VOC emissions, and eight agencies regulate the type of solvents used. A summary of state, county, and city regulations is shown in Table 6.2-2.

2.5.3 SUMMARY

At this time, two federal rules apply to the solvent cleaning source category, the NESHAP promulgated in 1994 for halogenated solvent cleaning and CAAA Title VI, which resulted from the Montreal Protocol on Substances that Deplete the Ozone Layer. The NESHAP requires that all machines (batch vapor, in-line, and batch cold cleaning machines) using halogenated solvents either demonstrate that each machine emits less than a defined limit, or demonstrate compliance through tracking of consumption. All affected facilities must submit an initial notification report at a minimum.

TABLE 6.2-1
STATE REGULATIONS

State	Citation
Alabama	Code of Alabama 22-28-14, 22-22A5, 6, 8
California Bay Area	Regulation 8, Rule 16
California South Coast	Regulation IX Section 1122
Colorado	Colorado Code of Regulations Section 5
Delaware	Dept. of Natural Resources; Regulation 24 Section 33
Florida	F.A.C. Rule 62-296.511
Georgia	391-3-1-.02(w)-(2)(ff)
Illinois	Title 35 Subtitle B Chapter I Section 215-182, 183, 184
Indiana	326 IAC 8-3-1
Kansas	KSA 65-3005, 3010
Kentucky	401 KAR 59:185
Louisiana	LAC 33: III Chapter 21, Subchapter C
Michigan	Rule 336.1612, 1614, 1708, 1710
Missouri	10 CRS 10
New York	Title 6, Chapter 111, Subchapter A, Part 226

North Carolina	Title 15A, Chapter 2, Subchapter 2D
Ohio	Title 3745, Chapter 21
Oregon	Chapter 340, Division 22-180, 182, 186
Pennsylvania	Title 25, Chapter 129.63
South Carolina	Chapter 61-62
Tennessee	TCA 1200-3-18-.31

TABLE 6.2-1**(CONTINUED)**

State	Citation
Texas	19 TexReg 3703, 30 TAC Chapter 115, Subchapter E, Sections 115.412-115.419 ^a
Utah	R307-1-4.9.4
Virginia	VR 120-04-2403, 2404
Washington	Title 173, Chapter 173-490-40
West Virginia	4521-30
Wisconsin	Natural Resources 423.03

^a Texas regulations are available on-line in hypertext mark-up language (HTML), PDF, or text versions on the World Wide Web at <http://www.tnrcc.state.us>.

The processes regulated through the NESHAP use solvents that are mostly non-VOCs. The exceptions are TCE and chloroform. The Montreal Protocol and associated CAAA Title VI rules further reduce the likelihood of emissions of solvents that are being phased out after 1997. Both the NESHAP and Title VI rules simplify tracking and information collection for these processes and the chemicals used in them. It is important to note that the processes regulated under the NESHAP may be limited in importance as VOC emitters, but would be important processes to investigate for a HAP inventory.

The cold cleaner NSPS planned to be promulgated in 1997 will affect cold cleaners with a surface area greater than 1.8 m² (19 ft²), which is a small proportion of cold cleaners that use nonhalogenated solvents. Recordkeeping or reporting requirements have not yet been defined. Cold cleaner processes must be evaluated for emissions to be included in VOC and HAP inventories. No federal rules exist for the use of cleanup solvents. If solvent cleaning machines covered by the NESHAP are inventoried as part of the point source inventory, then cleanup solvent use and cold cleaners will be the only processes that need to be inventoried for a VOC area source inventory.

TABLE 6.2-2

CLEANUP SOLVENT REGULATIONS BY STATE

State	Control Equipment	Work Practice	Recordkeeping	Emission Limits	Solvent Type Restrictions	Source Category Regulated
Alabama, Jefferson County			x			Surface coating operations
Alabama, Huntsville			x			Surface coating operations
Arizona, State				x		
Arkansas, State			x			
California, State		x	x			
California South Coast	x	x			x	Coating, ink, and adhesive applications
California Bay Area	x	x	x			Surface coating operations
California, Ventura County	x	x	x		x	Surface coating operations; aerospace assembly
Colorado, State			x			
Colorado, Denver City/County		x	x			
Florida, Jacksonville	x	x			x	

TABLE 6.2-2

(CONTINUED)

State	Control Equipment	Work Practice	Recordkeeping	Emission Limits	Solvent Type Restrictions	Source Category Regulated
Georgia, State			x			
Indiana, State	x	x	x			
Indiana, Evansville			x			
Iowa, State		x		x		
Iowa, Polk County			x			
Kansas, State	x	x	x			Lithographic printing, metal parts cleaning
Kentucky, State			x			
Louisiana, State			x			
Maryland, Baltimore					x	
Michigan, Wayne County					x	Paint manufacturing
Minnesota, State			x			
Missouri, State	x	x	x		x	Lithographic, rotogravure and flexographic printing
Nevada, Washoe County	x		x			
North Carolina, Buncombe County			x			

TABLE 6.2-2

(CONTINUED)

State	Control Equipment	Work Practice	Recordkeeping	Emission Limits	Solvent Type Restrictions	Source Category Regulated
North Carolina, Forsyth County			x			
Ohio, Dayton		x		x	x	
Oklahoma, Tulsa City/County		x	x			
Pennsylvania, Allegheny County			x	x		Surface coating operations
Pennsylvania, Philadelphia			x			
Pennsylvania, State	x		x			
Tennessee, Memphis County			x			
Tennessee, Shelby County			x			
Tennessee, Metropolitan	x	x	x		x	
Tennessee, State			x			
Texas, selected counties ^a	x	x	x	x ^c	^b x ^d	Cold cleaning, open-top vapor cleaning, conveyORIZED cleaning, auto refinishing, and lithographic printing
Virginia, State			x			

TABLE 6.2-2

(CONTINUED)

State	Control Equipment	Work Practice	Recordkeeping	Emission Limits	Solvent Type Restrictions	Source Category Regulated
Washington, Puget Sound	x		x			
Wisconsin, State		x	x	x		

^a Not all counties in Texas are affected. See footnote to Table 6.2-1 of this chapter for more information about Texas regulations.

^b Recordkeeping is required for open-top vapor cleaning, conveyORIZED cleaning, and lithographic printing.

^c Emission limits apply to open-top vapor cleaning only.

^d Solvent type restrictions apply to lithographic printing only.

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3

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATION METHODOLOGIES

A number of methods are available for estimating emissions from solvent cleaning activities. The choice of method depends on the desired degree of accuracy for the estimate while taking into account the availability of data and resources. This section presents and ranks each of the available methods. The first part of this section describes the general methods for estimating emissions. The second part provides ways to determine the species-specific emission estimates. Section 4 of this chapter describes the preferred method, and Section 5 covers the alternative methods for estimating solvent cleaning activity emissions.

Emissions from solvent cleaning machines can also be considered to be point sources; therefore, the estimation process for the source category must take this into account to prevent double-counting of emissions. Additionally, emissions from solvent cleanup may be included as a part of an industry- or process-specific emission estimate. The inventory preparer will need to evaluate how these other sources are inventoried to ensure that double-counting is avoided. Sources of solvent cleaning emissions that will not be addressed through the use of facility-specific data include smaller cold cleaners (less than 1.8 m² or 19 ft²) that are exempt from the NSPS, cleanup solvent uses for permitted facilities that need not report all sources of the pollutant, and nonpermitted facilities.

3.1.1 SOLVENT EMISSIONS

There are four general approaches available for estimating solvent emissions from solvent cleaning:

- Surveys of:
 - Users
 - Suppliers who provide both equipment and solvent ("full service" suppliers), for example, as a part of a service contract (cold cleaners primarily)
 - Solvent suppliers
 - Equipment suppliers
- Facility-specific data;

- Emission factors:
 - Population-based (per capita)
 - Employee-based (per employee)
 - Equipment-based (per unit in use); and
- Apportionment of national/regional/local area solvent uses ("top down" approach).

Emissions from solvent cleaning activities occur as a result of solvent evaporation. Consequently, annual emissions can be estimated based on the amount of solvent used per year. Where the solvent is recycled, reclaimed, or disposed of off-site, the annual usage must be adjusted for this amount. Also, if emissions are being captured by an air emissions control device, this amount must be subtracted from the annual usage.

Table 6.3-1 summarizes and ranks the emission estimation methods for each of the categories of solvent cleaning.

TABLE 6.3-1

**SUMMARY OF AVAILABLE ESTIMATION METHODS
FOR SOLVENT CLEANING ACTIVITIES**

Category	Methods		
	Surveys	Facility-specific Data	Emission Factors
• Halogenated solvent cleaning equipment	Alternative 1	Preferred	Alternative 2
• Cold cleaning equipment	Preferred ^a	Alternative 1	Alternative 2
• Solvents used for cleanup	Preferred	Alternative 1	Alternative 2

^a The final NSPS may require facility-specific data for larger cold cleaners. These data would become the preferred method. A survey would still be needed for the smaller cold cleaners.

3.1.2 SURVEYS

Survey methods can usually provide the most locality-specific information, and a higher quality emission estimate. From a practical standpoint, the method is the most expensive, and it is often difficult to identify facilities to participate in the survey and to assure that the group is a representative subset of the entire population. The success of surveys depends heavily on the rate and completeness of the responses, and many small facilities who use solvents for cleaning do not have the resources to participate fully. An example of a large-scale survey for solvent cleaning emissions can be found in Roe, et. al., 1995.

Of the four possible survey populations for this source category, data from the user is theoretically more complete. Not only will the responses supply the kinds of solvent uses, the associated types and quantities of solvents, and the level of emission control, but the detailed information allows for better control strategy development. Furthermore, facilities that have been identified as point sources can be more easily subtracted from the area source inventory so that the inventory preparer can avoid double counting. Because of the wide variety of solvents used for cleaning, surveying the user is the only practical approach for vapor cleaning machines. Even then, the practical difficulties of surveying so many users of solvent cleaning equipment limit the utility of this approach. Industries that may use solvent cleaning processes can be identified through their SIC Codes in permit files, Chamber of Commerce listings, or local property tax listings for solvent cleaning equipment. See Sections 2.1.1, 2.1.2, and 2.1.3 of this chapter for SIC Codes of businesses that may use solvent cleaning.

Surveying the full services supplier (company supplying equipment, solvent, and/or service) instead of the user is primarily feasible for cold cleaners. Surveys of suppliers who provide just equipment or just solvent for cleaning machines are not generally recommended. These groups are too removed from the use of the solvents and many assumptions must be made that introduce a higher degree of inaccuracy in the emission estimates. More detail could be obtained by surveying a subset of users for emissions from specific processes, then using information from suppliers and recyclers to scale up emissions to the entire inventory area.

For solvent cleanup activities, a survey of solvent suppliers is one of the few options available unless facility-specific data include these uses. Even though the solvent supplier may provide usage data for the different solvents, the inventory preparer must still determine what other uses the solvents might have and estimate how much is actually used for cleaning. As in the case for cold cleaners, a survey of a small subset of users could be used to determine the type and amounts of solvents used for cleaning, and emissions could be scaled up with a surrogate such as amounts of solvents distributed or recycled.

3.1.3 FACILITY-SPECIFIC DATA

The use of facility-specific data that may already be in house at the state or local agency has some clear advantages. With reporting requirements under the halogenated solvent cleaning NESHAP

soon to take effect, all users of halogenated solvent cleaning equipment will be required to submit an initial notification to state agencies. As a part of the notification, users also are to provide annual solvent consumption and control practices information. Emissions can be estimated from this information. A requirement for initial notification has also been proposed under the cold cleaners NSPS, thus information for this part of the solvent cleaning category may soon be available as well. Facility permit files such as those required by Title V are also a possible source of information.

Solvent cleaning activities that either are not or are unlikely to be subject to the standards include small cold cleaners and solvent cleanup. For some facilities, estimates may be available if the facility has had to report these sources as a part of a permit application. These data would need to be available for a majority of the facilities to be inventoried, or at least for a representative number of the facilities where the number and type of facilities are known, and the data should be reasonably current.

Facility-specific data are often already incorporated into point source inventories. The goal in an area source inventory is to account for emissions that have not been included in the point source inventory, but information being compiled is less detailed. In some cases, it may be possible to define some assumptions about industries that allow for less data collection and compilation. The first step in area source inventory preparation is to determine how much of the source category emissions have been included in the point source inventory.

3.1.4 EMISSION FACTORS

Emission factors are an alternative estimation method to surveys and facility-specific data. Some emission factors may need to be used in conjunction with surveys where a survey would be used to determine activity (e.g., number of cold cleaners in use). Several emission factors are available for VOCs from solvent cleaning machines. There are three types:

- Per capita;
- Per employee; and
- Per equipment unit in use.

Of these, per unit-in-use emission factors would be the most accurate, followed by per employee emission factors. Per capita emission factors would be the least accurate because solvent cleaning is not necessarily related to population.

For solvent cleanup emissions, solvent use and emission estimates presented in the EPA document *Alternative Control Techniques - Industrial Cleaning Solvents* (industrial solvent

cleaning ACT) are based on emission factors (EPA, 1994b). However, the emission factors are not presented in that document.

To apportion national/regional/local area solvent uses, a "top-down" approach has the benefit of providing a conservative estimate of emissions but runs the risk of overestimating the contribution of solvent use for cleanup. All of the solvents used in cleaning have other applications; therefore, care must be taken to subtract these other uses from the total if a reasonable estimate of emissions attributable to solvent cleaning is to be determined. Identifying these other uses and the associated solvent consumption can be difficult. Consequently, the resulting emission estimate may be inaccurate. This method is not recommended as an inventory method, and is perhaps best used as an order-of-magnitude reality check on estimates derived using one of the recommended methods.

3.1.5 SPECIATED EMISSIONS (VOCs, HAPs)

Cold cleaners can be divided into two groups: carburetor cleaners and other cold cleaners. Carburetor cleaners may use halogenated cleaners such as methylene chloride, and nonhalogenated solvents. As a result, carburetor cleaners that use halogenated solvents are subject to NESHAP reporting requirements. Other types of cold cleaning equipment use nonhalogenated solvents and are not subject to NESHAP reporting. For batch vapor and in-line degreasers, TCE is the only common solvent that is a VOC. In general, cold cleaner solvents are not EPA-listed HAPs. For the batch and in-line degreasers, all the common solvents except CFC-113 are EPA-listed HAPs.

Solvents frequently used in cleanup tend to be used both as pure solvents and as mixtures. The solvents identified as commonly used in the industrial solvent cleaning ACT are listed in Table 6.3-2. Also shown is whether the solvent is classified as a reactive VOC for inventory purposes, and/or a HAP. Please note that acetone and perchloroethylene are not listed as reactive VOCs.

For purposes of future inventory development, it is important to note that production of CFC-113 and TCA, which are regulated under Title VI of the Clean Air Act Amendments, will cease in 1996. Inventory preparers should also be aware that air toxics regulations may cause the types of solvents used for cleaning to change further. Some companies have begun moving away from the more toxic solvents as a part of corporate objectives to be more environmentally conscientious.

TABLE 6.3-2
COMMONLY USED CLEANUP SOLVENTS^a

Solvent	Volatile Organic Compound ^b	Hazardous Air Pollutant ^c
Acetone	No	No
Alcohols ^d	Yes	— ^e
Butyl Acetate	Yes	No
Cyclohexanone	Yes	No
Ethanol	Yes	No
Ethyl Acetate	Yes	Yes
Ethylbenzene	Yes	Yes
Ethylene Glycol	Yes	Yes
Isopropyl Alcohol	Yes	No
Methanol	Yes	Yes
Methyl Ethyl Ketone	Yes	Yes
Naphtha ^f	Yes	— ^g
Perchloroethylene	No	Yes
Toluene	Yes	Yes
Xylene	Yes	Yes

^a EPA, 1994b, p. 3-15.

^b These are reactive VOCs.

^c The HAPs are subject to regulation under Section 112 of the 1990 Clean Air Act Amendments.

^d Total nonspecified production of C₁₁ or lower unmixed alcohols.

^e This class may include the use of methanol, phenol and cresols, which are HAPs.

^f This solvent includes naphthas, petroleum naphtha, VM&P naphtha, mineral spirits, Stoddard solvent, naphthols, and naphthanols.

^g Naphthas may include HAPs but generally only in trace amounts.

Speciated emission factors are not generally available. When a survey or facility-specific data from reporting and permits are used for the inventory, VOC and HAP contents of the solvents used can be obtained along with the rest of the inventory data. This is the preferred method of speciating emissions for this source category. For vapor cleaning equipment, the solvent is usually a single compound. The second alternative method for cold cleaners recommends using cleaning unit solvent information from suppliers to develop a VOC emission factor. This solvent information also can be used to estimate HAP emissions.

3.2 DATA NEEDS

3.2.1 DATA ELEMENTS

The data needed to estimate emissions depend on the estimation method selected. Minimum elements for a survey on solvent cleaning machines would include:

- The type of solvent cleaning machine(s) used; and
- For each solvent cleaning machine:
 - The type of solvent(s) used;
 - Solvent composition and characteristics (supplying a material safety data sheet will suffice);
 - How much solvent is used per year, on average (annual purchases can serve as a surrogate);
 - How much of the solvent used is recycled off-site and not returned to the site;
 - How much of the solvent used is disposed of off-site (i.e., is not recycled);
 - The types of emission controls in use; and
 - Work practices that may affect emissions.

For a cleanup solvents survey, information requested should include:

- The types of solvents used;
- A general description of the use for each solvent;
- The annual amount of each solvent used; and
- Any recycling, reclamation, and off-site disposal amount for the reporting year.

Facility-specific information will include initial reports submitted under the halogenated solvent cleaning NESHAP that contain solvent usage and emission control information. For larger cold

cleaners, similar reports may be required under the cold cleaners NSPS as well. For smaller cold cleaners and solvent cleanup, data would only have been provided to the state as a part of another requirement, such as a part of the facility's operating permit required under Title V. To use this information, facilities likely to do solvent cleaning must be identified, then the facility files must be located and the relevant data extracted.

If an emission factor approach is to be used, the relevant activity data must be collected. Adjustments may be necessary if the activity data do not exactly match the area to be inventoried. Additionally, if speciated emissions are desired, solvent composition information is needed that can be applied to the VOC emission factor. Further adjustments may also be needed depending on the use of controls.

3.2.2 APPLICATION OF CONTROLS

In determining emissions, the inventory preparer should take any existing emission controls into account. The importance of the emission controls on the estimate depends on how the estimate is derived. If, for example, solvent use is the basis for the estimate, the only control technique that will affect emissions is one where the solvent evaporative losses are captured but not recovered and returned to the process. As another example, if the estimate is based on the rate of evaporation from the exposed surface of the cold cleaner, then controls that prevent evaporation must be considered.

Some controls will be established by regulatory requirements; therefore, the inventory preparer can assume some percentage of the industry is applying the required controls and can adjust the emission estimate accordingly. For example, by 1997 the halogenated solvent cleaning NESHAP will impact all solvent cleaning machines using halogenated solvents. Similarly, once the cold cleaners NSPS has been promulgated, larger cold cleaners will be subject to requirements that reduce emissions. These issues are discussed in Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development*, in the section on Control, Rule Effectiveness, and Rule Penetration.

3.2.3 SPATIAL ALLOCATION

Spatial allocation may be needed in two cases during inventory preparation: (1) allocation of state or regional activity to a county level, and (2) allocation of county-level emission estimates to a modeling grid cell. Facility-specific data may be used if they are available and comprehensive. However, more often a surrogate for activity must be used to approximate spatial allocation for solvent cleaning activities. One readily available surrogate is employment data by SIC Code published by the U.S. Department of Commerce, Bureau of the Census in

County Business Patterns.^a This is preferred over population data because employment is expected to be better correlated to solvent cleaning than population. SIC codes for industries that use solvent cleaning are listed with the cleaning type descriptions in Section 2.1 of this chapter.

3.2.4 TEMPORAL RESOLUTION

For most solvent cleaning activities, seasonal variability is not expected. Daily variations may apply for some of the industries. Some industries operate seven days per week, others only five days. Some industries are likely to operate two or three shifts per day, others may only have one. Information on the operating schedule may be available from existing files at the agency doing the inventory. Alternatively, State Implementation Plan (SIP) Inventory Guidance material provides a default value of uniform activity throughout the year, six days per week (EPA, 1991).

3.2.5 PROJECTING EMISSIONS

In many instances, the inventory will be used as the baseline from which future emissions are estimated. Projecting emissions is discussed in Chapter 1 of this volume. The most common way to project emissions is to apply a growth factor to the baseline estimate. If surveys are used to collect data, another option is to request the forecasting information from the recipient.

The following should be used when emissions are calculated by methods other than use of an emission factor (EPA, 1993b):

$$EMIS_{PY} = EMIS_{BY,O} * \left[\frac{1 - \left(\frac{CE_{PY}}{100} * \frac{RE_{PY}}{100} * \frac{RP_{PY}}{100} \right)}{1 - \left(\frac{CE_{BY}}{100} * \frac{RE_{BY}}{100} * \frac{RP_{BY}}{100} \right)} \right] * GF$$

where:

$EMIS_{PY}$	=	Projection year emissions for an ozone season, typical weekday (mass of pollutant/day)
$EMIS_{BY,O}$	=	Base year ozone season actual emissions (mass of pollutant/day)
CE_{PY}	=	Projection year control efficiency (percent)

^a See the publication for the inventory year, which can be obtained from the U.S. Bureau of the Census, Department of Commerce, Washington, D.C.

CE_{BY}	=	Base year control efficiency (percent)
RE_{PY}	=	Projection year rule effectiveness (percent)
RE_{BY}	=	Base year rule effectiveness (percent)
RP_{PY}	=	Projection year rule penetration (percent)
RP_{BY}	=	Base year rule penetration (percent)
GF	=	Growth factor (dimensionless)

The following equation should be applied when emissions are calculated using an emission factor and control efficiencies are used to reflect current or future control strategies (EPA, 1993b):

$$EMIS_{PY} = ORATE_{BY,O} * EMF_{PY,pc} * \left[1 - \left(\frac{CE_{PY}}{100} * \frac{RE_{PY}}{100} * \frac{RP_{PY}}{100} \right) \right] * GF$$

where:

$EMIS_{PY}$	=	Projection year emissions for an ozone season, typical weekday (mass of pollutant/day)
$ORATE_{BY,O}$	=	Base year operating rate (activity level): ozone season, daily (production units/day)
$EMF_{PY,pc}$	=	Projection year pre-control emission factor (mass of pollutant/production unit)
CE_{PY}	=	Projection year control efficiency (percent)
RE_{PY}	=	Projection year rule effectiveness (percent)
RP_{PY}	=	Projection year rule penetration (percent)
GF	=	Growth factor (dimensionless)

4

PREFERRED METHODS FOR ESTIMATING EMISSIONS

4.1 EMISSION ESTIMATION METHODOLOGIES

The preferred method for estimating emissions from solvent cleaning operations varies with the type of solvent cleaning activity. For halogenated solvent cleaning machines, use of the facility-specific data submitted under the halogenated solvent cleaning NESHAP is the preferred method. For cold cleaners until the NSPS is promulgated, the preferred method is to conduct a survey of suppliers. For solvent cleanup, the preferred method is to conduct a survey of a subset of users.

4.2 FACILITY-SPECIFIC DATA

Facility-specific data already collected by the agency can be a good source of emissions information. First, the inventory preparer must identify:

- Facilities reporting under the halogenated solvent cleaning NESHAP; and/or
- Facilities permitted as VOC and/or HAP sources.

The initial report required by the halogenated solvent cleaning NESHAP must include an estimate of annual halogenated HAP solvent consumption for each solvent cleaning machine. These reports are due to EPA by August 29, 1995 (59 FR 61814, December 2, 1994). These numbers may or may not include amounts sent off-site for recycling, reclamation, or disposal, and the emissions calculated may overestimate emissions. To address this potential problem, the inventory preparer may be able to identify cases where no adjustment appears to have been made by comparing all the reports by cleaning machine type and looking for outliers. A follow-up with the facility can be used to determine whether all necessary adjustments have been made.

Many of the solvent cleaning machine reports received to comply with the NESHAP will be large individual emitters or part of an operation that emits large amounts of VOCs or HAPs. The facilities that will be reported as point sources should be identified to avoid double counting, but data from these reports do not need to be compiled as part of the area source inventory.

4.3 SURVEYS

An example of a survey of solvent cleaning operations and the survey's results can be found in Roe et al. (1995). Specific discussion of surveys for area sources is provided in Chapter 1 of this volume. However, the general approach for surveys is as follows:

- Identify the industries most likely to have solvent cleaning operations and the facilities to be surveyed within each of these industries. Use the data quality objectives of the inventory to determine the size of the survey subset. Manufacturing directories, or local or state property tax records may be useful for identifying businesses with certain types of equipment.
- Decide whether to prescreen survey recipients. Prescreening can be helpful to identify survey recipients when a subset of facilities are to be surveyed, and to define scaling factors for scaling up the results of the survey. Conduct prescreening;
- Develop and distribute a survey;
- Design a database if the number of responses is expected to be large;
- Collect surveys, follow up with respondents if there are any questions, and transfer information to the database; and
- Compile the data and develop the emission estimate(s).

4.3.1 COLD CLEANERS

For cold cleaners, a survey of the equipment suppliers who also provide service for the facility ("full service" suppliers) is the preferred method. These suppliers are limited in number and maintain accurate records on solvent usage because this is the basis upon which the facility is billed. A potential drawback to this method is that some suppliers may be reluctant to report the information needed for an emission estimate. In addition, some cold cleaning activity can be overlooked if not all of the suppliers are included in the survey or if some facilities in the inventory area service their own equipment. An example survey is provided in Figure 6.4-1. The survey may be designed to identify some of the cold cleaners that may be overlooked (see Part III of Figure 6.4-1). Point source emissions from cold cleaners will need to be totaled and then subtracted from the area source estimate.

FIGURE 6.4-1. EXAMPLE SURVEY FOR COLD CLEANING FULL SERVICES SUPPLIERS

SURVEY NO: _____

DATE: _____

PAGE: 1 of _

PART I

Company Name: _____

Address: _____

Contact Name, Title: _____

Contact Phone No: _____

Region for which information is provided: _____

PART II

For equipment that you service, please provide the following:

Model Number	Equipment Description ^a	No. of Services in year	Solvent Type	Annual Amt. of Solvent Delivered ^b (gal)	Annual Amt. of Solvent Returned (gal)

^a Attach equipment information.

^b Attach material safety data sheets.

PART III

For equipment that you sold since year^a but do not service, please provide the following:

Model Number	Equipment Description ^b	Solvent Type ^c	Description of Client's Business ^d	Typical Annual Solvent Usage per Unit (gal) ^e

^a Select a time period based on the datedness of the existing equipment population data. ^b Attach equipment information.

^c Attach material safety data sheets. ^d If known. ^e Provide a range if necessary.

4.3.2 CLEANUP

The preferred method for estimating emissions from solvent cleanup is to conduct surveys of key industries using solvents in this manner. To identify and survey all industries that use solvent for cleanup would be impractical. A recent EPA publication, *Alternative Control Techniques Document - Industrial Cleaning Solvents* (EPA, 1994b), identifies 15 industries using solvents for cleanup and surveyed 6 of these for specific solvent cleanup information. The 15 industries and their solvent uses are shown in Table 6.4-1. Given resource constraints, state and local agencies should focus on these first. Some industries may not be located in the areas to be inventoried; however, the agency may want to include others in their area that they have reason to believe may have significant solvent cleanup emissions. The agency may also want to limit the survey to facilities that are area sources. Otherwise, emissions calculated from the survey data will need to be corrected for point source emissions.

An example survey for solvent cleaning activities used by the EPA is provided in Appendix A. Questions were developed to collect the data based on a material balance around a unit operation system (UOS) at the facility. The UOS provides a framework for describing and understanding the cleaning activities. Based on the survey results, nine such UOSs appear to represent most solvent cleanup activities. These are spray gun cleaning, spray booth cleaning, large manufactured parts cleaning, small manufactured parts cleaning, equipment cleaning, floor cleaning, line cleaning, tank cleaning, and parts cleaning (each column in Table 6.4-1 represents a UOS). General descriptions of these UOSs are provided as an attachment to the survey; more detailed descriptions with diagrams are provided in the Industrial Cleaning Solvents ACT (EPA, 1994b).

Although the Industrial Cleaning Solvents ACT specifically excluded metal parts cleaning using vapor and cold cleaning equipment [this is addressed in another report: *Control of Volatile Organic Emissions from Solvent Metal Cleaning* (EPA-450/2-77-022)], a survey using the UOSs may collect this information as well. To avoid double-counting between cleanup operations and solvent cleaning machine use of solvents, these results must be compared to estimates derived from solvent cleaning equipment. The solvent cleaning equipment emissions will need to be subtracted from the total.

4.3.3 SURVEY COMPILATION AND CALCULATIONS

From the survey data collected, emissions can be calculated for a given facility as the difference between annual solvent use and the amount of solvent that is sent off-site for recycling, reclamation, or is otherwise captured such as in an emission control device. The assumption is that any solvent that is not accounted for through recycling, reclamation, or captured by a control device like carbon adsorption, evaporates.

TABLE 6.4-1

SOLVENT CLEANUP ACTIVITIES BY INDUSTRY^a

Industry	Spray Gun	Spray Booth	Equip.	Floor	Line	Tank	Parts	Large Mfd Components	Small Mfd Components
Automotive-Manufacturing (SIC Code 3711)	X	X	X	X	X	X	X	X	X
Automotive-Parts/Access. (SIC Code 3714)	X		X				X		
Automotive-Trucks and Buses (SIC Code 3713)	X							X	
Automotive-Stamping (SIC Code 3465)							X		X
Electrical Equipment	X		X	X			X		X
Furniture	X		X				X	X	X
Magnetic Tape			X		X	X	X		
Packaging			X	X			X		
Photographic Supplies (chemicals)	X		X	X		X	X		

^a Adapted from EPA, 1994b, Table 3-6, p. 3-19. No data were provided for adhesives, autobody refinishing, fiber-reinforced plastic (FRP) boats, offset lithographic printing, plastics, or rotogravure printing.

Emissions are calculated from survey data by the following equation:

$$\text{Annual emissions} = \text{Annual solvent use} - \left(\text{Annual amount of solvent recycled off-site} + \text{Annual amount of solvent reclaimed off-site} + \text{Annual amount of solvent sent off-site for disposal} \right)$$

Where only a subset of the population of facilities provided data, the estimated emissions will need to be scaled up. This is discussed in Chapter 1 of this volume; however, for this source category, scaling can be done using the total number of facilities, the total number of employees, or the total number of units in use. The choice of which to use will depend on which best represents the population of interest, and how accurate and readily available the chosen scaling factor may be.

5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

To estimate emissions from halogenated solvent cleaning equipment, the alternatives to the preferred method are to conduct a survey and to use emission factors. For cold cleaners and solvent cleanup, the alternatives are to use facility-specific data and emission factors. Surveys were described in Section 4 and are covered in detail in Chapter 1 of this volume. Additional information concerning facility-specific data and use of emission factors is provided below.

5.1 SOLVENT CLEANING EQUIPMENT

5.1.1 FACILITY-SPECIFIC DATA

Use of facility-specific data is the first alternative method for estimating emissions from cold cleaners and for the use of solvents for cleanup. This method is usable only if facility-specific information is available for a reasonable subset of cold cleaners and operations where cleanup solvents are used. The subset will need to include a cross-section of the industries, processes, and solvents present in the inventory area, or there will need to be a way to estimate emissions from occurrences that have not been included in the subset. Facility-specific information will be available for facilities that are permitted as VOC and/or HAP sources as well as facilities that are reporting under the NSPS requirements once the cold cleaner NSPS is promulgated.

Sources of solvent cleaning emissions that will not be addressed through the use of facility-specific data include smaller cold cleaners (less than 1.8 m² or 19 ft²) that are exempt from the NSPS, cleanup solvent uses for permitted facilities that need not report all sources of the pollutant, and nonpermitted facilities. As a result, these will need to be addressed separately. This step may have already been completed during the point source inventory development process; therefore, preparing the point and area source inventories for this source category should be coordinated to minimize duplication of effort. The remaining uncounted emissions can then be estimated by either scaling up the existing data or by using one of the other alternative methods.

5.1.2 EMISSION FACTORS

Emission factors are another alternative to surveys for estimating emissions from solvent cleaning equipment, and these are available in EPA publications. Recent data on cold cleaners collected

by the EPA as a part of NSPS development for cold cleaners are reproduced in Table 6.5-1 (EPA, 1994c). Submitted by Safety-Kleen, these data represent model-specific emission estimates for several of their cold cleaner models. Table 6.5-1 provides typical annual solvent loss estimates for five cold cleaner models, and for five service intervals. Service intervals for these machines vary based on how often customers need the solvent in their cold cleaners replaced. A longer service interval indicates a lower level of use of the cold cleaner and results in lower emissions, which are reflected in the lower solvent loss numbers. Although manufacturer models will vary, the broad range is probably representative of the industry. Furthermore, Safety-Kleen holds a significant share of the market so these data will be accurate for a high percentage of the cold cleaners in use.

Two emission factors from *Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone: Volume I: General Guidance for Stationary Sources* (EPA, 1991) may be used to estimate emissions from solvent cleaning. Based on how the category is described, this does not include cleanup solvent uses. The basis for the emission factors is 1989 industrial solvent consumption and (1) 1989 U.S. population (245.7 million) and (2) industrial employment in SIC Codes 25, 33-39, 417, 423, 551, 552, 554-556, and 753. Per capita and per employee emission factors are presented in Table 6.5-2.

State and local agencies may want to update the emission factors using the same or similar references used in the *EPA Procedures* document and recalculating the emission factors to reflect more recent usage, and to reflect the delisting of acetone and PERC as reactive VOCs. The solvent usage data in EPA's *Procedures* report were taken from *Industrial Solvents - Winter 1989* (Frost and Sullivan, Inc., New York, NY, 1990), *Chemical Economics Handbook* (SRI International, Menlo Park, CA, 1991), *Chemical Marketing Reporter* (Schnell Publishing Company, Inc., New York, NY, 1991) and *Chemical Products Synopsis* (Mannsville Chemical Products Corporation, Asbury Park, NJ, 1991). Population data are collected by the U.S. Department of Commerce, Bureau of the Census, and published in *Statistical Abstracts of the United States (year)*. The employment data are available from *Employment and Wages Annual Averages (year)*, published by the U.S. Department of Labor, Bureau of Labor Statistics. Such data may also be found in *County Business Patterns*^a, published annually by the Bureau of the

^a See the publication for the inventory year, which can be obtained from the U.S. Bureau of the Census, Department of Commerce, Washington, D.C.

TABLE 6.5-1

1994 SAFETY-KLEEN EMISSIONS DATA FOR COLD CLEANERS^a

Service Interval (weeks)	Typical Annual Solvent Loss (gallons) ^{b,c} by Safety-Kleen Model Number ^d				
	14	16	30	34	44
4	19	33	51	64	81
5	16	26	41	52	66
6	13	22	34	44	55
7	11	19	30	38	48
8	10	17	26	34	43

^a EPA, 1994c. Safety-Kleen caveat: emissions may not reflect true losses of a particular customer's equipment. Emissions include losses during machine use, carry-off on parts, and carry-off in small cups for remote cleaning.

^b Based on SK-105 Solvent: 85% mineral spirits, 12% C₈ and aromatics, 1% xylene, 0.5% each toluene and ethylbenzene, 0-1% chlorinated solvents (TCA, PERC).

^c To obtain the weight of solvent loss, multiply number of gallons by 6.5 pounds per gallon.

^d From the reference, descriptions of the models are as follows:

Model 16: 9-gallon parts cleaner

Model 30: 17-gallon parts cleaner

Census. Local planning departments may also have population and employment data that are specific to the area of interest.

Because EPA emission factors are based on national consumption and may not accurately reflect local consumption, state and local agencies may consider using local solvent usage data where these are available (a top-down approach). In some cases, local solvent usage data may be available but the total includes more uses than just solvent cleaning. These additional uses must be identified and quantified, then subtracted from the total. Because such information is typically limited and the level of effort is significant, the cost of using this approach outweighs the benefit (accuracy) of the resulting estimate.

TABLE 6.5-2

**PER CAPITA AND PER EMPLOYEE SOLVENT CLEANING EMISSION FACTORS
(EPA, 1991)**

Subcategory	SIC Codes	Per Capita Factor (lb/yr/person)		Per Employee Factor (lb/yr/employee)	
		VOCs	Organics	VOCs	Organics
Solvent Cleaning (total)	25, 33-39, 417, 423, 551, 552, 554-556, 753	4.3	7.2	87	144
Cold Cleaning					
Automobile Repair	417, 423, 551, 552, 554-556, 753	2.5	2.5	270	270
Manufacturing	25, 33-39	1.1	1.1	24	24
Vapor and In-Line Cleaning					
Electronics and Electrical	36	0.21	1.1	29	150
Other	25, 33-39, 417, 423, 551, 552, 554-556, 753	0.49	25	9.8	49

5.2 SOLVENT CLEANUP ACTIVITIES

Alternative methods for estimating solvent cleanup emissions are the facility-specific method described in Section 5.1.1 and emission factors developed from information collected for the Industrial Cleaning Solvents ACT, which will be described here (EPA, 1994b).

The Industrial Cleaning Solvents ACT provides estimates of solvent amounts used at the national level for cleanup for 15 industries (Table 6.5-3). These estimates were drawn from references that were prepared as early as 1979 and as recently as 1993. For 9 of the 15 industries, the ACT provides estimates of national VOC emissions from cleanup

processes (Table 6.5-4). These estimates are based on usage-per-employee and emissions-per-employee factors from studies at a small number of test facilities.

There are limitations to using this study for inventory preparation that should be kept in mind. Although these industries are not the only industries that use the solvent cleanup process, they are thought to be most significant sources. The study had to use assumptions based on studies of only a few facilities for each industry. The study was limited to 15 solvents (see Table 6.3-2), but there may be others that could also be used as cleaners. Using a material balance method to develop an emission factor for this process will result in a very conservative estimate for emissions. Some of the solvent can be expected to be collected and reclaimed off-site or disposed of in some other manner. Even with these limitations, these estimates provide industry-specific estimates of a subcategory of solvent cleaning that is otherwise difficult to characterize and may have previously not been included in emission estimates.

Please note that in order to avoid double-counting within the area source inventory, inventory preparers should note when other area source categories include solvent cleanup. In particular, area source emission estimating methods for the printing, packaging, and furniture (as a surface coating process) industries and the autobody refinishing industry may include solvent cleanup emissions.

Emission factors for the nine industries listed in Table 6.5-4 can be developed by dividing the national emissions number by either national employment for that industry or by national population.

The national numbers presented in Tables 6.5-3 and 6.5-4 may be used to estimate local emissions for the 15 industries by developing a national per employee or per capita emission factor. A per employee factor should more accurately reflect emissions, but the per capita emission factor will be easier to calculate. A per employee emission factor is calculated from any of the national emission estimates by the following steps:

- Determine the national-level number of employees in the industry. Employment information at the national level can be found in the Census Bureau report, *Statistics for Industry Groups and Industries*.^a

^a See the publication for the year matching the year of the usage estimate, which can be obtained from the U.S. Bureau of the Census, Department of Commerce, Washington, D.C.

TABLE 6.5-3

ESTIMATES OF THE AMOUNT OF VOC CLEANING SOLVENT USED BY INDUSTRY, x 10³ TONS/YR^a

Industry (SIC Code)	Reference Year					Low	High
	1990	1988	1979	1988	1993		
Automotive-Manufacturing (3711)	89 - 410	^b			72	72	410
Automotive-Trucks and Buses (3713)					16	16	16
Automotive-Parts/Access. (3714)					7.7	7.7	7.7
Automotive-Stamping (3465)					1.0	1.0	1.0
Adhesives	73 - 330		46 - 210			46	330
Packaging ^c					30	30	30
Plastics			28 - 130			28	130
Furniture ^c	19 - 88				230	19	230
Rotogravure Printing ^c		14 - 62				14	62
FRP Boats ^d		8.3 ^d				8.3	8.3
Autobody Refinishing ^g	7.8 - 35		16 - 72	26 - 120		7.8	120
Electrical Equipment					5.6	5.6	5.6
Magnetic Tape		5.5	^e		11	5.5	11

TABLE 6.5-3

(CONTINUED)

Industry	Reference Year					Low	High
	1990	1988	1979	1988	1993		
Offset Lithographic Printing		1.1 - 6.6 ^e				1.1	6.6
Total						270	1,400

^a Adapted from EPA, 1994b, pp. 3-11.

^b This range may represent usage in more than the 3711 SIC Code subcategory.

^c Please note that for these industries, cleaning solvent use may be estimated as part of another area source category. Preparation of emission inventories for these categories should be coordinated.

^d FRP = fiber-reinforced plastic.

^e Estimate based on a usage equals emissions assumption.

TABLE 6.5-4

**NATIONWIDE VOC SOLVENT USAGE AND EMISSION ESTIMATES FOR SELECTED INDUSTRIES, TONS/YR^a
(EPA, 1994B)**

Industry	Equipment Cleaning	Floor Cleaning	Large Manuf'd. Component Cleaning	Line Cleaning	Parts Cleaning	Small Manuf'd. Component Cleaning	Spray Booth Cleaning	Spray Gun Cleaning	Tank Cleaning	Total
Automotive - Manufacturing										
Solvent Usage	220	570	8,400	14,000	129	180	17,000	28,000	3,100	72,000
Emissions	220	570	7,700	130	130	180	15,000	9,500	110	34,000
Automotive - Trucks and Buses										
Solvent Usage			6,900					8,800		16,000
Emissions			6,900					8,800		16,000
Automotive - Parts/Accessories										
Solvent Usage	15				7,600			130		7,700
Emissions	15				2,100			55		2,200
Automotive - Stamping										
Solvent Usage					1,000	13				1,000
Emissions					320	13				330
Electrical Equipment										
Solvent Usage	500	77			1,900	290		2,800		5,600
Emissions	450	77			520	220		1,100		2,400

TABLE 6.5-4

(CONTINUED)

Industry	Equipment Cleaning	Floor Cleaning	Large Manuf'd. Component Cleaning	Line Cleaning	Parts Cleaning	Small Manuf'd. Component Cleaning	Spray Booth Cleaning	Spray Gun Cleaning	Tank Cleaning	Total
Furniture										
Solvent Usage	7,300		900	39,000	1,800	130		180,000		230,000
Emissions	5,600		840	3,800	540	72		36,000		47,000
Magnetic Tape										
Solvent Usage	670			330	2,400				7,700	11,000
Emissions	230			6.6	440				430	1,100
Packaging										
Solvent Usage	1,300	5,900			23,000					30,000
Emissions	960	2,500			3,500					7,000
Photographic Supplies										
Solvent Usage	4,400	3.1			130			5.3	36,000	41,000
Emissions	110	3.1			1.3			5.3	360	480
Total Usage ^c	14,000	6,600	16,200	53,000	38,000	610	17,000	220,000	47,000	410,000
Total Emissions ^c	7,600	3,200	15,400	3,900	7,600	490	15,000	55,000	900	109,000

^a Usage and emission values are from a 1990 report.

^b Estimates based on nationwide extrapolation of usage-per-employee factors from surveyed plants (using total plant employment).

^c Totals are different due to rounding.

- Divide the usage estimate by the national-level employment. The resulting number is a per employee emission estimate for that industry for that year.
- Determine the employment in the industry for the inventory area and the inventory year. Using local employment data or employment data from the U.S. Census Bureau report, *County Business Patterns*.
- Local employment multiplied by the per employee emission factor calculates the emission estimate for the industry.

A per capita emission factor is calculated by dividing the usage value by the national population for the year of the data.

6

QUALITY ASSURANCE/ QUALITY CONTROL (QA/QC)

Prior to inventory preparation during the planning process, the agency must delineate the data quality objectives for the inventory. As a part of these objectives, the agency may elect to establish specific goals for individual categories. Depending on the data quality objectives, the QA and QC methods to be applied will vary. *Quality Assurance Procedures*, Volume VI of this series of reference volumes, is dedicated to the discussion of methods to be used to ensure the development of a quality inventory. QA for area source inventories is discussed in Chapter 1 of this volume.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

The preferred method will produce the most accurate estimate of emissions; however, surveys can be an expensive undertaking. Furthermore, the success of the survey depends heavily on the rate and completeness of the responses. The accuracy of facility-specific data and the top-down approach vary depending on the availability of information. Both can be resource-intensive too. Emission factors are the easiest method but may be relatively inaccurate.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

One way to evaluate the estimates calculated using each of the alternatives is to calculate the DARS scores for each. The DARS methodology is presented in the *Quality Assurance Procedures* volume. The resulting scores for estimates based on facility-specific data for halogenated solvent cleaning equipment, surveys of cleaning solvent equipment uses, and uses of emission factors are presented in Tables 6.6-1 through 6.6-5. All scores assume that good QA/QC measures have been performed and that no significant deviations from the prescribed methods have been made. If these assumptions are not met, new DARS scores should be developed according to the guidance in the *Quality Assurance Procedures* volume.

6.1.2 SOURCES OF UNCERTAINTY

Another way to assess the emission estimate is to look at the associated uncertainty. For estimates derived from survey data, the uncertainty can be quantified. Similarly, the uncertainty can be determined for the facility-specific data if the basis for the emission estimate is provided

(see *Quality Assurance Procedures*, Volume VI, Chapter 4). Statistics needed to quantify the uncertainty for the emission factor and top-down approaches are incomplete.

For a per capita emission factor, the uncertainty of the resulting emission estimate depends on how closely related solvent cleaning activities are to population and how well the emission factor represents the area to be inventoried. Although it is reasonable to expect more commercial and industrial activity near centers of population, a statistical correlation has not been attempted; therefore, the association between population and solvent cleaning activity is weak. A per employee emission factor assumes that solvent cleaning is related to employment in specific industries identified as conducting solvent cleaning activities. Again, the estimate depends on how well the emission factor represents local practices. Emissions based on a per unit emission factor would intuitively seem to produce a more accurate estimate than those derived from the other types of emission factors but uncertainty is introduced in determining the total number and types of units in use. There is also variability in emissions that depend on the unit type and operating practices that may not be accommodated in the emission factor. A choice of emission factor based on the uncertainty would require an assessment of the basis for each.

Determining sources of uncertainty associated with an estimate derived using the top-down approach begins with the solvent usage data. Each step taken to apportion the total solvent usage to solvent cleaning in the inventory area introduces additional sources of uncertainty. Even if care is taken in the apportionment of solvent usage, the resulting estimate may not truly represent emissions, for example, where local recycling or add-on controls have not been taken into account.

TABLE 6.6-1

**FACILITY-SPECIFIC EQUIPMENT SOLVENT CLEANING: PREFERRED FOR HALOGENATED
CLEANERS, ALTERNATIVE 1 FOR NONHALOGENATED
COLD CLEANING AND SOLVENT CLEANUP**

Attribute	Scores ^a		
	Factor	Activity	Emissions
Measurement	0.7	0.9	0.63
Source Specificity	1.0	1.0	1.0
Spatial	1.0	1.0	1.0
Temporal	1.0	0.7 - 1.0	0.7 - 1.0
Composite Scores	0.93	0.9 - 0.98	0.83 - 0.9

^a This is essentially a point source methodology. Temporal activity depends on whether an annual, daily, or other time period is needed (The score for when solvent consumption annual emissions are used to calculate daily emissions is 0.7).

TABLE 6.6-2

**SURVEY OF SOLVENT CLEANING USES (EQUIPMENT OR SOLVENT) IN THE
INVENTORY REGION: PREFERRED FOR NONHALOGENATED CLEANERS AND
SOLVENT CLEANUP, ALTERNATIVE 1 FOR HALOGENATED COLD CLEANERS**

Attribute	Scores ^a		
	Factor	Activity	Emissions
Measurement	0.7	0.7	0.49
Source Specificity	0.8	0.7 - 0.9 ^b	0.56 - 0.72
Spatial	0.8	0.9	0.72
Temporal	1.0	0.9 - 1.0 ^b	0.9 - 1.0
Composite Scores	0.83	0.8 - 0.88	0.67 - 0.72

^a Scores for activity will depend on how good and thorough the survey is. These scores assume that less than 100 percent of the population is sampled; therefore, the estimate is scaled up by the ratio of the number surveyed to the number in the population.

^b Activity score ranges depend on the accuracy of the surrogate used to scale the survey subset to the entire inventory area.

TABLE 6.6-3**COLD CLEANING UNIT EMISSION FACTOR: ALTERNATIVE 2 FOR COLD CLEANERS**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.3 - 0.4	0.6 - 0.7	0.18 - 0.28
Source Specificity	0.7	0.7	0.49
Spatial	0.7	0.7	0.49
Temporal	0.8	0.7	0.56
Composite Scores	0.63 - 0.65	0.68 - 0.7	0.43 - 0.46

TABLE 6.6-4**SOLVENT CLEANUP EMISSION FACTORS: ALTERNATIVE 2 FOR SOLVENT CLEANUP**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.3 - 0.5	0.9	0.27 - 0.45
Source Specificity	0.6	0.5	0.3
Spatial	0.7	0.8	0.56
Temporal	0.5	0.6	0.3
Composite Scores	0.53 - 0.58	0.7	0.36 - 0.41

TABLE 6.6-5

**NATIONAL FACTORS APPLIED TO LOCAL ACTIVITY DATA (NUMBER OF EMPLOYEES):
ALTERNATIVE 2 FOR ALL CLEANING TYPES**

Attribute	Scores ^a		
	Factor	Activity	Emissions
Measurement	0.3	0.9	0.27
Source Specificity	0.5 - 0.6	0.5 - 0.6	0.25 - 0.36
Spatial	0.5	0.8	0.40
Temporal	0.5 - 0.8	0.6	0.3 - 0.48
Composite Scores	0.45 - 0.55	0.7 - 0.73	0.31 - 0.40

^a Notes:

Factor measurement: does not include all losses.

Source specificity: cleanup solvent use may not be included.

Spatial: national taken to the county level.

Temporal: annual taken to the daily level, 1989 to inventory year.

Activity: assumes some estimation/scaling from national or state data was used. Also, assumes some variability in employment with the year and from year to year.

TABLE 6.6-6

**NATIONAL FACTORS APPLIED TO LOCAL ACTIVITY DATA (POPULATION):
ALTERNATIVE 2 FOR ALL CLEANING TYPES**

Attribute	Scores ^a		
	Factor	Activity	Emissions
Measurement	0.3	0.9	0.27
Source Specificity	0.5 - 0.6	0.3	0.15 - 0.18
Spatial	0.5	0.8	0.4
Temporal	0.5 - 0.8	0.6	0.3 - 0.48
Composite Scores	0.45 - 0.55	0.65	0.28 - 0.36

^a Notes:

Factor measurement: does not include all losses.

Source specificity: cleanup solvent use may not be included.

Spatial: national taken to the county level.

Temporal: annual taken to the daily level, 1989 to inventory year.

Activity: assumes some estimation/scaling from national or state data was used. Also, assumes some variability in employment with the year and from year to year.

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DATA CODING PROCEDURES

This section describes the codes available to characterize solvent cleaning emission estimates. Consistent categorization and coding will result in greater uniformity between inventories. Inventory planning for data collection calculations and inventory presentation should take the data formats presented in this section into account. Available codes and process definitions may impose constraints or requirements on the preparation of emission estimates for this category.

7.1 PROCESS AND CONTROL CODES

The source category process codes for solvent cleaning operations are shown in Table 6.7-1. These codes are derived from the EPA's Aerometric Information Retrieval System (AIRS) Area and Mobile Source (AMS) source category codes (EPA, 1994d). Codes have not been assigned for all the individual solvents in this source category or for all of the industries where solvent cleaning may take place.

The control codes for use with AMS are shown in Table 6.7-2. The "099" control code can be used for miscellaneous control devices that do not have a unique identification code. The "999" code can be used for a combination of control devices where only the overall control efficiency is known. Federal, state, and local regulations can be used as guides to estimate the type of control used and the level of efficiency that can be achieved. Be careful to apply only the regulations that specifically include area sources. If a regulation is applicable only to point sources, it should not be assumed that similar controls exist at area sources without a survey. The equations used to apply control efficiency, rule penetration, and rule effectiveness for area sources are discussed in Chapter 1 of this volume.

TABLE 6.7-1

AIRS AMS CODES FOR SOLVENT CLEANING MACHINES BY INDUSTRY

SIC Code	Industry	Process Description	AMS Code^a
	All Industries	All processes	24-15-000-x
25	Furniture and Fixtures	All processes	24-15-005-x
33	Primary Metal	All processes	24-15-010-x
33	Secondary Metal	All processes	24-15-015-x
34	Fabricated Metal Products	All processes	24-15-020-x
35	Industrial Machinery & Equipment	All processes	24-15-025-x
36	Electronic & Other Electronics	All processes	24-15-030-x
37	Transportation Equipment	All processes	24-15-035-x
38	Instruments & Related Products	All processes	24-15-040-x
39	Miscellaneous Manufacturing	All processes	24-15-045-x
40-45	Transportation Maintenance Facilities	All processes	24-15-050-x
55	Automotive Dealers	All processes	24-15-055-x
75	Auto Repair Services	All processes	24-15-060-x
76	Miscellaneous Repair Services	All processes	24-15-065-x
	All Industries	Open top degreasing	24-15-100-x
25	Furniture and Fixtures	Open top degreasing	24-15-105-x
33	Primary Metal	Open top degreasing	24-15-110-x
33	Secondary Metal	Open top degreasing	24-15-115-x
34	Fabricated Metal Products	Open top degreasing	24-15-120-x
35	Industrial Machinery & Equipment	Open top degreasing	24-15-125-x
36	Electronic & Other Electronics	Open top degreasing	24-15-130-x
37	Transportation Equipment	Open top degreasing	24-15-135-x
38	Instruments & Related Products	Open top degreasing	24-15-140-x
39	Miscellaneous Manufacturing	Open top degreasing	24-15-145-x
40-45	Transportation Maintenance Facilities	Open top degreasing	24-15-150-x

TABLE 6.7-1

(CONTINUED)

SIC Code	Industry	Process Description	AMS Code ^a
55	Automotive Dealers	Open top degreasing	24-15-155-x
75	Auto Repair Services	Open top degreasing	24-15-160-x
76	Miscellaneous Repair Services	Open top degreasing	24-15-165-x
	All Industries	Conveyorized degreasing	24-15-200-x
25	Furniture and Fixtures	Conveyorized degreasing	24-15-205-x
33	Primary Metal	Conveyorized degreasing	24-15-210-x
33	Secondary Metal	Conveyorized degreasing	24-15-215-x
34	Fabricated Metal Products	Conveyorized degreasing	24-15-220-x
35	Industrial Machinery & Equipment	Conveyorized degreasing	24-15-225-x
36	Electronic & Other Electronics	Conveyorized degreasing	24-15-230-x
37	Transportation Equipment	Conveyorized degreasing	24-15-235-x
38	Instruments & Related Products	Conveyorized degreasing	24-15-240-x
39	Miscellaneous Manufacturing	Conveyorized degreasing	24-15-245-x
40-45	Transportation Maintenance Facilities	Conveyorized degreasing	24-15-250-x
55	Automotive Dealers	Conveyorized degreasing	24-15-255-x
75	Auto Repair Services	Conveyorized degreasing	24-15-260-x
76	Miscellaneous Repair Services	Conveyorized degreasing	24-15-265-x
	All Industries	Cold cleaning	24-15-300-x
25	Furniture and Fixtures	Cold cleaning	24-15-305-x
33	Primary Metal	Cold cleaning	24-15-310-x
33	Secondary Metal	Cold cleaning	24-15-315-x
34	Fabricated Metal Products	Cold cleaning	24-15-320-x
35	Industrial Machinery & Equipment	Cold cleaning	24-15-325-x
36	Electronic & Other Electronics	Cold cleaning	24-15-330-x

TABLE 6.7-1

(CONTINUED)

SIC Code	Industry	Process Description	AMS Code ^a
37	Transportation Equipment	Cold cleaning	24-15-335-x
38	Instruments & Related Products	Cold cleaning	24-15-340-x
39	Miscellaneous Manufacturing	Cold cleaning	24-15-345-x
40-45	Transportation Maintenance Facilities	Cold cleaning	24-15-350-x
55	Automotive Dealers	Cold cleaning	24-15-355-x
75	Auto Repair Services	Cold cleaning	24-15-360-x
76	Miscellaneous Repair Services	Cold cleaning	24-15-365-x

^a x = solvent type:
 000 = total: all solvent types
 300 = monochlorobenzene
 350 = perchloroethylene
 370 = special naphthas
 385 = trichloroethylene
 999 = solvents: not elsewhere classified (NEC)

TABLE 6.7-2

AIRS CONTROL DEVICE CODES

Control Device	Code
Vapor Recovery System	047
Activated Carbon Adsorption	048
Process Enclosed	054
Miscellaneous Control Device	099
Combination Control Device	999

REFERENCES

EPA. 1994a. *Cold Cleaning Machine Operations New Source Performance Standards. Background Information Basis and Purpose Document*. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, EPA-453/D-94-067. Research Triangle Park, North Carolina. August.

EPA. 1994b. *Alternative Control Techniques Document - Industrial Cleaning Solvents*. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emission Standards Division, EPA-453/R-94-015. Research Triangle Park, North Carolina. February.

EPA. 1994c. *Emission Losses from Safety-Kleen Parts Cleaner Models: 14, 16, 30, 34 and 44*. Docket No. A-94-08, Item No. II-D-5. Information provided by Safety-Kleen during information gathering for Standards of Performance for New Stationary Sources, Cold Cleaning Machine Operations.

EPA. 1994d. AIRS Database. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina.

EPA. 1993a. *National Emission Standards for Hazardous Air Pollutants: Halogenated Solvent Cleaning - Background Information Document for the Proposed Rule*. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, EPA-453/R-93-054. Research Triangle Park, North Carolina. November.

EPA. 1993b. *Guidance for Growth Factors, Projections and Control Strategies for the 15 Percent Rate-of-Progress Plans*. U.S. Environmental Protection Agency, Office of Quality Planning and Standards, EPA-453/R-93-002. Research Triangle Park, North Carolina. March.

EPA. 1991. *Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone. Volume I: General Guidance for Stationary Sources*. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, EPA-450/4-91-016. Research Triangle Park, North Carolina. May.

Federal Register. September 9, 1994. Standards of Performance for New Stationary Sources Cold Cleaning Machine Operations. 40 CFR Part 60. Office of the Federal Register, Washington, D.C. Volume 59, page 46602.

Roe, S.M., P. Costello, L. Jones, C. DiSogra, and R. Grant. 1995. Improved VOC Emission Estimates for Solvent Cleaning and Degreasing in California. In: *The Emission Inventory: Programs and Progress*. Proceedings of a Specialty Conference, VIP-56, Air Waste Management Association, Pittsburgh, Pennsylvania.

APPENDIX A

EXAMPLE SURVEY FOR SOLVENT CLEANUP ACTIVITIES

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REQUESTED INFORMATION FROM MANUFACTURERS

The information received in response to this information request will be used to develop a control technique guideline (CTG) document for industrial cleanup solvent operations. The document is intended for State and local agencies to use as a guide in estimating emissions of volatile organic compounds (VOCs) from the use of cleanup solvents and in developing regulations to reduce such emissions. For the purposes of this document, cleanup solvent operations are defined as those which remove adhesives, inks, uncured coatings, and contaminants such as dirt, soil, oil, and grease from parts, products, tools, machinery, process vessel interiors, piping, equipment, and general work areas. The definition of a VOC is provided, for your information, on the last page of this enclosure.

The intent of this information request is to quantify the amount of solvent evaporated (resulting in VOC emissions) that results from cleaning operations. The specific techniques employed may include wiping, dipping (immersing), spraying, or flushing. Specialized items of equipment which may be used include ultrasonic cleaners, spray gun washers, and parts washers. A broad range of solvent cleaning operations is being considered in the "source category" for this CTG.

Intermittent swabbing of oil drips on a floor with a solvent-soaked rag and large-scale solvent flushing of process lines and batch reactors would both be considered cleanup solvent operations. Vapor degreasers, conveyORIZED degreasers, and batch-loaded cold cleaners, used for solvent metal cleaning, are excluded from consideration in the current study because a CTG already exists for these specific cleaning operations. Perchloroethylene dry cleaning is also excluded because a CTG exists for it as well.

Please feel free to report any information which you consider to be relevant to the development of this document that is not specifically addressed in the information request. If you are unable to respond to an item as stated or would like clarification of some question, please contact _____.

Please return the completed information request to:

This request should be completed for each plant using cleanup solvents. If multiple plants exist, reproduce and complete the forms for each plant and identify each plant by a number (e.g., Plant Nos. 1, 2, 3).

Name of company: _____

Name of plant: _____

SIC Code for this plant: _____

Response completed by: _____

Title: _____

Plant address: Physical (No. and Street):

City _____

State _____ Zip _____

Plant mailing address (No. and Street or Post Office Box):

City _____ State _____ Zip _____

Plant telephone No.: () _____

Mailing address of respondent (if different from above):

Telephone No. of respondent (if different from above):

() _____

I. Plant/Process Information

- A. Provide a general description of the product(s) manufactured and the process(es) used to produce them. (Or attach brochures, handouts, or other prepared material that includes this information)

- B. How many production lines? _____

How many are currently operating? _____

C. Plant layout

1. Provide a simplified flowchart of product flow through the plant.
2. Provide a floor plan highlighting those areas where cleanup solvents are used, handled, and stored.

- D. How many working days per year? _____

E. What are the hours of operation

(hr/d _____, hr/wk _____, hr/yr _____)?

- F. What is the typical duration of a run? _____

G. What is the number of employees for 1990:

1. For the site? _____

2. That occasionally use cleanup solvents in the normal course of their work?

3. Whose primary job function is the use of cleanup solvent? _____

H. What is the production rate?

1. Maximum hourly? _____
2. Maximum yearly? _____
3. Average hourly? _____
4. Average yearly? _____

II. Description of all Processes Requiring Use of Cleanup Solvents

In Table 6.A-1 (attached), indicate all process steps in your plant that require the use of cleanup solvents. For the purpose of this document, cleanup solvent operations are defined as those which remove adhesives, inks, uncured coatings, and contaminants such as dirt, soil, oil, and grease from parts, products, tools, machinery, process vessel interiors, piping, equipment and general work areas. Please identify the particular type of cleaning operation - wiping, dipping, spraying, or flushing - that is used in each process step. If these words for type of cleaning "operation" do not accurately describe the way the cleanup solvent is used, please use (and define) your own terminology. The type of solvent used (brand name and/or chemical composition or formulation) and the frequency of use should also be included in Table 6.A-1.

For each solvent listed in Table 6.A-1, please provide a copy of the manufacturer's Material Safety Data Sheet (MSDS). If the MSDS does not have a detailed breakdown of composition, which will enable the VOC content to be calculated, then please provide the composition, by chemical name (and CAS number, if available). For in-house solvent blends, please provide the composition of the resulting mixture, or the "recipe" used to generate the mixture.

Note: Section C of this information request asks that a copy of Table 6.A-2A be completed for each process step listed in Table 6.A-1. To simplify the completion of Section C, if a particular process step involves more than one cleanup operation, e.g., dipping a part to remove the majority of contaminants and then wiping the excess solvent from the part, choose the operation which constitutes the majority of the process. Furthermore, if you cannot determine if a particular operation involves wiping, dipping, spraying, or flushing, please describe the operation as thoroughly as possible and complete the table in Section C that most closely resembles the operation.

III. Detailed Description of Cleanup Solvent Operations

Attached are four tables labeled Tables 6.A-2A through 6.A-2D; each is titled with a specific cleanup operation, such as "wiping" (Table 6.A-2A). For each of the process steps listed in Table 6.A-1, please fill out the appropriate Table 6.A-2A for the cleanup operation associated with that step. If your plant has more than one process step employing a cleanup operation (i.e., wiping), then multiple copies of the appropriate table should be made and completed individually for each process step.

IV. Total Cleanup Solvent Consumption

Please complete Table 6.A-3 for all of the cleanup solvents used in your plant. If VOC emissions from cleanup operations is included in your State or local air permit, please answer the following questions:

- A. Total VOC emissions permitted, tons/yr: _____
- B. Cleanup VOC emissions permitted, tons/yr: _____
- C. Actual total VOC emissions, tons/yr: _____
- D. Actual cleanup VOC emissions, tons/yr: _____

V. Solvent Recovery

- A. Is any solvent used in your plant (process and/or cleanup) recovered, reclaimed, or recycled? _____

In house or by an outside firm? _____

- 1. If in house, describe process (e.g., distillation).

- 2. If by an outside firm, give name and address, and pickup and delivery interval (e.g., weekly, bimonthly).

- B. If not currently practiced, are there any plans to institute recovery/recycle programs? (for example, to reduce the cost of solvent disposal.) Why or why not?

- C. Are the cleanup solvent wastes segregated from other solvent wastes?

- D. Are waste cleanup solvents that are used in different process steps or different cleanup operations segregated, even though they are the same material? (e.g., are spent "manufacturing" cleanup solvents segregated from spent "maintenance" cleanup solvents?)

Why and how is this done?

Are other wastes from equipment cleanup (e.g., caustic wash water) segregated from solvent wastes?

- E. Can the waste cleanup solvent from one operation be used for another cleaning operation?

Is this technique practiced at your plant?

How is it done?

- F. Can the number of different cleaning agents be reduced to simplify the waste solvent mixtures, thereby enabling reuse or recycling? Why or why not?

VI. Recordkeeping Requirements

- A. Describe the recordkeeping practices for cleanup solvents at your facility:

- B. What is the frequency with which measurements are made and recorded?

- C. Are the recordkeeping practices based on corporate, site, or regulatory requirements?

- D. Provide copies of recordkeeping forms and material balance worksheets. Include forms/worksheets relating to solvent recovery.

- E. Evaluate and briefly discuss the feasibility and additional manpower requirements associated with recording the following information on an hourly basis:

1. Surface area cleaned.
2. The aggregate total amount of cleanup solvent used (gallons).
3. Name and total amount of each individual cleanup solvent used (gallons).

- F. Evaluate the feasibility of and additional recordkeeping burden associated with recording the same information on a daily and monthly basis.

VII. Reduced VOC Cleaners

- A. Are you aware of substitute cleaners not containing VOCs, or that are very low in VOCs, that will meet your needs? If so please identify the alternatives and the solvents and uses for which they could be substituted.

- B. Will the use of these alternative cleaners pose any operating problems such as requiring modification of your process operation, additional cleaning steps/ time, or reduced effectiveness/quality? Please explain.

- C. Will the use of alternatives affect the cost of your clean-up operations? _____ If yes, by how much and on what is that estimate based? _____

- D. Do you have a program in place at your plant to reduce VOC emissions from cleanup solvent operations? _____ If so, please describe.

VIII. Hazardous Air Pollutants

The 189 HAPs defined by the 1990 CAAA are listed in Enclosure . For each solvent listed in Table 6.A-1 that contains one or more HAPs please answer the following questions:

- A. If you were required to eliminate the use of HAPs from your clean-up operations, are you aware of substitute solvents not containing HAPs that would meet your needs? _____ If so please identify the alternative solvents.

- B. Will the use of these alternative solvents pose any operating problems such as requiring modification of your process operation, additional cleaning steps/ time, or reduced effectiveness/quality? _____

-
- C. Will the use of alternatives affect the cost of your clean-up operations? _____
If yes, by how much, and or what is that estimate based?
-
-

IX. Definitions

Volatile Organic Compounds (VOC)

[NOTE: This definition may subsequently change. The Code of Federal Regulations (40 CFR 51.100[s]) will provide the current legal definition.] Any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions.

1. This includes any such organic compound other than the following, which have been determined to have negligible photochemical reactivity: methane; ethane; methylene chloride (dichloromethane); 1,1,1-trichloroethane (methyl chloroform); 1,1,1-trichloro-2,2,2-trifluoroethane (CFC-113); trichlorofluoromethane (CFC-11); dichlorodifluoromethane (CFC-12); chlorodifluoromethane (CFC-22); trifluoromethane (FC-23); 1,2-dichloro 1,1,2,2-tetrafluoroethane (CFC-114); chloropentafluoroethane (CFC-115); 1,1,1-trifluoro 2,2-dichloroethane (HCFC-123); 1,1,1,2-tetrafluoroethane (HFC-134a); 1,1-dichloro 1-fluoroethane (HCFC-141b); 1-chloro 1,1-difluoroethane (HCFC-142b); 2-chloro 1,1,1,2-tetrafluoroethane (HCFC-124); pentafluoroethane (HFC-125); 1,1,2,2-tetrafluoroethane (HFC-134); 1,1,1-trifluoroethane (HFC-143a); 1,1-difluoroethane (HFC-152a); and perfluorocarbon compounds which fall into these classes:
 - (a) Cyclic, branched, or linear, completely fluorinated alkanes;
 - (b) Cyclic, branched, or linear, completely with fluorinated ethers with no unsaturations;
 - (c) Cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations; and
 - (d) Sulfur containing perfluorocarbons with no unsaturations and with sulfur bonds only to carbon and fluorine.

2. For purposes of determining compliance with emission limits, VOC will be measured by the test methods in the approved State implementation plan (SIP) or 40 CFR Part 60, Appendix A, as applicable. Where such a method also measures compounds with negligible photochemical reactivity, these negligibility-reactive compounds may be deducted from the reported VOC if the amount of such compounds is accurately quantified, and such exclusion is approved by the enforcement authority.
3. As a precondition to excluding these compounds as VOC or at any time thereafter, the enforcement authority may require an owner or operator to provide monitoring or testing methods and results demonstrating, to the satisfaction of the enforcement authority, the amount of negligibly-reactive compounds in the source's emissions.
4. For the purposes of Federal enforcement for a specific source, the EPA shall use the test method specified in the applicable EPA-approved SIP, in a permit issued pursuant to a program approved or promulgated under Title V of the Act, or under 40 CFR Part 51, Subpart I or Appendix S, or under 40 CFR Parts 52 or 60. The EPA shall not be bound by any State determination as to appropriate methods for testing or monitoring negligibly-reactive compounds if such determination is not reflected in any of the above provisions.

TABLE 6.A-1**GENERAL INFORMATION OF CLEANUP OPERATIONS**

Process No.	Cleanup Description	Surface Being Cleaned	Cleanup Operation^a	Solvent Used^b	Frequency of Operation
Example 1	Blanket wash	Press roll	Wiping	SK 105	Once/shift
Example 2	Press cleaning	Machine	Wiping	SK 105	Continuous
Example 3	Spill mopping	Floor	Wiping	SK 105	When spills occur; estimated three times/shift
Example 4	Gun wash	Spray gun	Flushing	Lacquer thinner	Once per hour

^a Use terminology corresponding to Tables 6.A-2A, 6.A-2B, 6.A-2C, or 6.A-2D (wiping, dipping, spraying, or flushing) or other, more precise terms, with definition appended.

^b Provide copy of MSDS plus other documentation (if required) to establish VOC content of each solvent listed in this table.

TABLE 6.A-2A

WIPING OPERATION QUESTIONNAIRE

Question	Response and Comments
Process step (taken from Table 6.A-1)	
Description of part or machine being cleaned	
How much labor time is spent in this cleaning operation?	
Cleanup solvent used/Brand Name/Identification No.	
Is the cleanup solvent diluted with water before use?	
If so, what is the ratio of solvent to water?	
How much of the concentrated cleanup solvent is used: For this operation? Per shift?	
How much of the spent solvent is collected?	
How much of the solvent evaporates during this wiping operation?	
Describe the contaminant or soil that is being removed.	
<p>To what degree do the following factors affect your selection of the cleanup solvent used in this cleaning operation?</p> <p>A - Primary consideration B - Secondary consideration C - Not important</p> <p>If your answer is "A" or "B", please elaborate.</p>	
Physical and chemical properties of contaminant to be removed	A B C

TABLE 6.A-2A

(CONTINUED)

Question	Response and Comments
Physical and chemical properties of the substrate on which the contaminant is deposited	A B C
The degree of cleaning efficiency required	A B C
The size, shape, and complexity of parts or objects to be cleaned	A B C
The volume or number of parts or objects to be cleaned per unit of time	A B C
The substrate preparation required	A B C
Solvent costs	A B C
Worker exposure concerns	A B C
Fire code or insurance protection requirements	A B C
Recycle and recovery options	A B C
Regulatory requirements	A B C
Ventilation requirements	A B C
Waste disposal (including wastewater treatment)	A B C
Availability of factory floor space	A B C
Other special considerations	A B C
Does this cleanup activity have particular requirements that either require or preclude the use of any specific types(s) of cleanup solvent(s)? If so, specify.	
What material is used to wipe the solvent on the substrate (e.g., rag, brush, sponge, paper towel, etc.)?	
How is the solvent applied to the wiping material?	

TABLE 6.A-2A

(CONTINUED)

Question	Response and Comments
If rags are used:	
What is the size of the rags?	
How many rags are used per week?	
Are they reusable?	
How are the used rags handled for cleaning or disposal (i.e., hand wrung, stored wet in closed drum, left to air dry, sent out for laundering, washed on the premises, etc.)?	
Is the spent or dirty solvent collected from this operation reused, recycled, or disposed? If so, how much?	
Explain how a dirty solvent is handled.	
Are any steps taken in this wiping operation to minimize the release of organic vapors into the <u>workplace</u> (e.g., by working in a hood)? If so, describe.	
Are any steps taken to minimize the release of organic vapors into the <u>atmosphere</u> (e.g., is there an emission control device on hood exhaust)? If so, describe.	

A - Primary consideration, B - Secondary consideration, C - Not important.

TABLE 6.A-2B

DIPPING OPERATION QUESTIONNAIRE

Question	Response and Comments
Process step number (taken from Table 6.A-1)	
Description of part or machine being cleaned	
How much labor time is spent in this operation?	
Cleanup solvent used/Brand Name/Identification No.	
Is the cleanup solvent diluted with water before use?	
If so, what is the ratio of solvent to water?	
How much of the concentrated cleanup solvent is used: For this operation? Per shift?	
How much of the spent solvent is collected?	
How much of the solvent evaporates during this dipping operation?	
Describe the contaminant or soil that is being removed.	
<p>To what degree do the following factors affect your selection of the cleanup solvent used in this cleaning operation?</p> <p>A - Primary consideration B - Secondary consideration C - Not important</p> <p>If your answer is "A" or "B", please elaborate.</p>	
Physical and chemical properties of contaminant to be removed	A B C

TABLE 6.A-2B

(CONTINUED)

Question	Response and Comments
Physical and chemical properties of the substrate on which the contaminant is deposited	A B C
The degree of cleaning efficiency required	A B C
The size, shape, and complexity of parts or objects to be cleaned	A B C
The volume or number of parts or objects to be cleaned per unit of time	A B C
The substrate preparation required	A B C
Solvent costs	A B C
Worker exposure concerns	A B C
Fire code or insurance protection requirements	A B C
Recycle and recovery options	A B C
Regulatory requirements	A B C
Ventilation requirements	A B C
Waste disposal (including wastewater treatment)	A B C
Availability of factory floor space	A B C
Other special considerations	A B C
Does this cleanup activity have particular requirements that either require or preclude the use of any specific types(s) of cleanup solvent(s)? If so, specify.	
Describe the type of equipment used (dip tank, vessel, etc.) to apply the solvent to the substrate (how are parts added/removed, etc.).	
Are capture/control devices for VOC emissions (hoods, etc.) in place and operating during dipping operations? If so, explain.	

TABLE 6.A-2B

(CONTINUED)

Question	Response and Comments
Is the spent or dirty solvent collected from this operation reused, recycled, or disposed of? If so, how much?	
Explain how a dirty solvent is handled.	

A - Primary consideration, B - Secondary consideration, C - Not important.

TABLE 6.A-2C

SPRAYING OPERATION QUESTIONNAIRE

Question	Response and Comments
Process step number (taken from Table 6.A-1)	
Description of part or machine being cleaned	
How much labor time is spent in this operation?	
Cleanup solvent used/brand name/identification No.	
Is the cleanup solvent diluted with water before use?	
If so, what is the ratio of solvent to water?	
How much of the concentrated cleanup solvent is used: For this operation? Per shift?	
How much of the spent solvent is collected?	
How much of the solvent evaporates during this spraying operation?	
Describe the contaminant or soil that is being removed.	
<p>To what degree do the following factors affect your selection of the cleanup solvent used in this cleaning operation?</p> <p>A - Primary consideration B - Secondary consideration C - Not important</p> <p>If your answer is "A" or "B", please elaborate.</p>	
Physical and chemical properties of contaminant to be removed	A B C
Physical and chemical properties of the substrate on which the contaminant is deposited	A B C
The degree of cleaning efficiency required	A B C

TABLE 6.A-2C

(CONTINUED)

Question	Response and Comments
The size, shape, and complexity of parts or objects to be cleaned	A B C
The volume or number of parts or objects to be cleaned per unit of time	A B C
The substrate preparation required	A B C
Solvent costs	A B C
Worker exposure concerns	A B C
Fire code or insurance protection requirements	A B C
Recycle and recovery options	A B C
Regulatory requirements	A B C
Ventilation requirements	A B C
Waste disposal (including wastewater treatment)	A B C
Availability of factory floor space	A B C
Other special considerations	A B C
Does this cleanup activity have particular requirements that either require or preclude the use of any specific types(s) of cleanup solvent(s)? If so, specify.	
Describe the type of spray equipment used to apply the solvent to the substrate.	
Are solvents applied in-place, or is the part/machine taken to a designated station?	
Are capture/control devices for VOC emissions (hoods, etc.) in place and operating during this spraying operation? If so, explain.	
Is any spent or dirty solvent collected from this operation reused, recycled or disposed of? If so, how much?	
Explain how a dirty solvent is handled.	

A - Primary consideration, B - Secondary consideration, C - Not important.

TABLE 6.A-2D

FLUSHING OPERATION QUESTIONNAIRE

Question	Response and comments
Process step number (taken from Table 6.A-1)	
Description of part or machine being cleaned	
How much labor time is spent in this operation?	
Cleanup solvent used/brand name/identification No.	
Is the cleanup solvent diluted with water before use?	
If so, what is the ratio of solvent to water?	
How much of the concentrated cleanup solvent is used: For this operation? Per shift?	
How much of the spent solvent is collected?	
How much of the solvent evaporates during this flushing operation?	
Describe the contaminant or soil that is being removed.	
<p>To what degree do the following factors affect your selection of the cleanup solvent used in this cleaning operation:</p> <p>A - Primary consideration B - Secondary consideration C - Not important</p> <p>If your answer is "A" or "B", please elaborate.</p>	
Physical and chemical properties of contaminant to be removed	A B C

TABLE 6.A-2D

(CONTINUED)

Question	Response and Comments
Physical and chemical properties of the substrate on which the contaminant is deposited	A B C
The degree of cleaning efficiency required	A B C
The size, shape, and complexity of parts or objects to be cleaned	A B C
The volume or number of parts or objects to be cleaned per unit of time	A B C
The substrate preparation required	A B C
Solvent costs	A B C
Worker exposure concerns	A B C
Fire code or insurance protection requirements	A B C
Recycle and recovery options	A B C
Regulatory requirements	A B C
Ventilation requirements	A B C
Waste disposal (including wastewater treatment)	A B C
Availability of factory floor space	A B C
Other special considerations	A B C
Does this cleanup activity have particular requirements that either require or preclude the use of any specific types(s) of cleanup solvent(s)? If so, specify.	
Describe the type of equipment used in the flushing operation (i.e., is there a drain, how is the operation done, etc.).	

TABLE 6.A-2D

(CONTINUED)

Question	Response and Comments
Does the drain direct the waste to a sludge reservoir or a water treatment system?	
Does any of your solvent enter the local municipal waste treatment system? If so, how much?	
Are capture/control devices for voc emissions in place and operating during flushing operations? If so, explain.	
Is the spent or dirty solvent collected from flushing reused, recycled, or disposed of? If so, how much?	
Explain how dirty solvent from flushing is handled.	

A - Primary consideration, B - Secondary consideration, C - Not important.

TABLE 6.A-3

PLANT CONSUMPTION OF CLEANUP SOLVENT

Solvent ^a	Source (supplier)	Amount purchased per year	Amount of used solvent recovered as liquid waste	Amount of cleanup solvent that is contained in solid waste or product shipped	Net loss of cleanup solvent by evaporation ^b

^a Use the same identification for each solvent in this table that was used in Table 6.A-1.

^b If any of this evaporated solvent is subsequently treated by an emission control device, please explain.

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GRAPHIC ARTS

Final Report

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Prepared for:
Area Sources Committee
Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

This chapter describes the procedures and recommended approaches for estimating emissions from graphic arts. Section 2 of this chapter contains a general description of the graphic arts category and an overview of available emission control technologies. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation method for the graphic arts industry, and Section 5 presents alternative emission estimation techniques. Quality assurance/quality control (QA/QC) issues are discussed in Section 6. Data coding procedures are discussed in Section 7, and Section 8 is the reference section.

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2

SOURCE CATEGORY DESCRIPTION

The graphic arts industry can be divided by technology into six different printing segments: rotogravure, flexographic, offset lithographic, letterpress, screen, and plateless (xerographic, electrostatic, magnetic, thermal, ink-jet, etc.). The technology (i.e., the type of press equipment) dictates the types of inks and coatings that can be used and defines to a large extent the emissions and the control techniques that are applicable (Environmental Protection Agency [EPA], 1995a).

The printing industry can also be divided by the type of substrate that is used. Among the flexible substrates, paper, foil, and films are used. Paper can be further classified in many ways, including coated versus uncoated. Films include polyethylene and a number of other polymers. Rigid substrates include cardboard, vinyl, and metal cans. A given substrate may be printed upon using different technologies depending on factors such as the end use, quality requirements, quantity, cost, and environmental considerations (EPA, 1995a). Textiles are specifically excluded from the graphic arts operations source category.

A third way to segment the printing industry is by the type of product or end use. In general, the end use falls into the broad categories of publications, packaging, or products. Publication printing includes newspapers, magazines, books, and advertising. Packaging includes paper, plastic and foil bags, wrappers, cardboard cartons, and metal cans. Products include wall and floor covering, greeting cards, and paper towels. Various technologies can be used to print specific items within the broad categories (EPA, 1995a). Table 7.2-1 shows the six major types of printing and the types of products printed by each (EPA, 1995b).

Graphic arts operations are performed on printing presses that are made up of one or more "units." Each unit can print only one color. The substrate in graphic arts operations is either continuous and called a "web," or individual pieces of substrate called "sheets." The pattern that is printed on the substrate is called the "image."

The graphics arts industry includes operations classified by Standard Industrial Classification (SIC) Codes 2752 (Commercial Printing-Lithography), 2754 (Commercial Printing-Gravure), and 2759 (Commercial Printing Not Elsewhere Classified [n.e.c.], which includes letterpress, flexographic, screen, and other commercial printing). Other four-digit codes under major SIC Code 27 cover printing-related industries such as

TABLE 7.2-1

PRODUCTS PRINTED BY EACH GRAPHICS ARTS TECHNOLOGY^a

Technology	Products
Rotogravure	Packaging, advertising, greeting cards, art books, catalogues, and directories
Flexography	Packaging, advertising newspapers, books, magazines, financial and legal document directories
Offset Lithography	Magazines, catalogues and directories, newspapers, books, stationary, financial and legal documents, advertising, journals, packaging, metal cans
Letterpress	Magazines, catalogues and directories, newspapers, books, stationary, financial and legal documents, advertising, journals, packaging, metal cans
Screen	Signs, electronics, wallpaper, greeting cards, ceramics, decals, banners, plastic bottles
Plateless	Images printed on paper by laser printers, xerographic copiers, fax machines, and ink jets

^a Source: EPA, 1995a and 1995b.

publishing, book printing, and other printing-related service trades. Because graphic arts operations include not only those whose primary business involves printing, potentially any entities classified under the major SIC Code 27 may perform graphic arts operations. The SIC Codes 26 (Paper and Allied Products), 30 (Rubber and Miscellaneous Plastic Products), 32 (Stone, Clay, and Glass Products), 34 (Fabricated Metal Products), 39 (Miscellaneous Manufacturing Industries), and 86 (Membership Organizations) may also include graphic arts operations. Some of these operations may be inventoried as part of the industrial surface coating source category. Inventory preparers should take care to avoid double counting between these two source categories within an area source inventory. Also, the point source and area source inventory definitions of graphic arts and industrial surface coating should match. This is particularly important when subtracting point source emissions from total estimated emissions in order to get area source emissions. Table 7.2-2 lists the SIC Codes that are likely to have graphic arts operations.

The following six sections discuss the six types of graphic arts operations grouped by printing technology. The importance of the type of printing on a national level, in regard to total emissions, is likely to be a reflection of the product market share and ink sales data presented in Table 7.2-3. The importance of each type of printing on a regional and local level may differ from these national trends.

2.1 (ROTO)GRAVURE PRINTING

Gravure is a printing process in which an image is etched or engraved below the surface of a plate or cylinder. Nearly all gravure printing is done by rotogravure. On the gravure plate or cylinder (roto), the printing image consists of millions of minute cells. Gravure printing requires very fluid inks that flow from the cells to the substrate at high press speeds. Solventborne or waterborne ink systems can be used in gravure printing but these ink systems are not interchangeable. Both the printing cylinders and the drying systems are specific to the solvent system in use. Rotogravure printing is usually performed on a web (EPA, 1995b).

Rotogravure printing can be divided into publication and product/package segments. Publication gravure presses in the United States use solventborne (toluene/xylene-based) ink systems exclusively. Because of the expense and complexity of rotogravure cylinder engraving, it is particularly suited to long-run printing jobs. Package/product gravure inks include nitrocellulose and water-based inks (EPA, 1995b).

TABLE 7.2-2**SIC CODES THAT MAY INCLUDE GRAPHIC ARTS OPERATIONS^a
(EPA, 1995B)**

SIC Code	Industry Description
2652	Set up paperboard boxes
2653	Corrugated and solid fiber boxes
2655	Fiber cans, drums, and similar products
2656	Sanitary food containers
2657	Folding paperboard boxes
2671	Paper coated and laminated, packaging
2672	Paper coated and laminated, n.e.c.
2673	Bags: plastics, laminated, and coated
2674	Bags: uncoated paper and multiwall
2676	Sanitary paper products
2677	Envelopes
2678	Stationary products
2679	Converted paper products, wall coverings, gift wrap, n.e.c.
271x	Newspapers
272x	Periodicals
2731	Book publishing
2732	Book printing
274x	Miscellaneous publishing
2752	Commercial printing, lithographic
2754	Commercial printing, gravure
2759	Commercial printing, n.e.c.
2761	Manifold business forms
2771	Greeting cards
3081	Unsupported plastics, film and sheet

TABLE 7.2-2

(CONTINUED)

SIC Code	Industry Description
3083	Laminated plastics, plate and sheet
3085	Plastic bottles
3089	Plastics, n.e.c.
3221	Glass containers
3411	Metal cans
3412	Metal barrels, drums, and pails
3466	Crowns and closures
3996	Floor coverings
86xx	Membership organizations

^a n.e.c. = not elsewhere classified.

TABLE 7.2-3**DISTRIBUTION OF PRODUCTS AND INK SALES BY PRINTING TYPE**

Type of Printing	Estimated Number of Facilities^a	Estimated Percentage of Product Market Share^a	Percentage of Ink Solvent Use^b
Rotogravure	427	18	22
Flexography	1,587	18	16
Offset Lithography	54,000	47	35
Letterpress	21,000	8	8
Screen	21,000	3	part of remaining 19 percent
Plateless	unknown	3	

^a Source: EPA, 1995a.

^b Compiled from: Darnay, 1990; Renson, 1991; and National Association of Printing Ink Manufacturers, 1988.

Gravure ink solvents include alcohols, aliphatic naphtha, aromatic hydrocarbons, esters, glycol ethers, ketones, and nitroparaffins. Gravure water-based inks are in regular production use at some facilities to reduce volatile organic compound (VOC) emissions from the press (EPA, 1993a).

In rotogravure printing, the web is printed on one side at a time and must be dried after the application of each color. Thus, for four-color, two-sided publication printing, eight passes through the press are employed, each including a pass over a steam drum or through a hot-air dryer at temperatures from ambient up to 120°C (250°F) to remove nearly all of the solvent (EPA, 1993a).

In addition to inks, other materials including adhesives, primers, coatings, and varnishes may be applied with rotogravure cylinders. These materials dry by evaporation as the substrate passes through hot air dryers. Cleaning solutions containing solvents are also used in the rotogravure printing process (EPA, 1995a).

2.2 FLEXOGRAPHIC PRINTING

In flexographic printing, the image area is raised from the surface of a plate (like a typewriter) with a rubber (flexible) image carrier. Alcohol-based inks are generally used. The process is usually webfed and used for medium or long multicolor runs on a variety of substrates, including heavy paper, fiberboard, and metal and plastic foil. Almost all milk cartons and multiwall bags, and half of all flexible packaging are printed by this process (EPA, 1993a).

Steam-set inks, employed in the "water flexo" or "steam-set flexo" process, are low-viscosity inks of a paste consistency that are gelled by water or steam. Steam-set inks are used for paper bag printing and produce no significant emissions (EPA, 1993a).

Solvent-based inks are used primarily in publication printing and contain about 75 percent (by volume) organic solvent. The solvent, which must be rubber compatible, may be alcohol or alcohol mixed with an aliphatic hydrocarbon or ester. Typical solvents also include nonaromatic glycols, ketones, and ethers. The inks dry by solvent absorption into the web and by evaporation, usually in high-velocity steam drums or hot-air dryers, at temperatures below 120°C (250°F). Most of the solventborne flexographic inks contain few or no hazardous air pollutants (HAPs). As in rotogravure publishing, the web is printed on only one side at a time. The web passes over chill rolls after drying; no emissions occur from chilling (EPA, 1993a).

When flexography is used to print corrugated board and most paperboard, water-based inks can be used; however, fast-drying inks are required for plastic films and packaging papers so

the web can be rewound or processed into the final product at the end of the press. Flexography is becoming popular for printing pressure-sensitive labels, a process in which the ink must dry quickly without penetration. Use of inks that dry by exposure to ultraviolet radiation (producing no emissions) have been used in label printing with much success (EPA, 1995b).

Additional converting operations, which are often done at the flexographic press stations or in-line with the presses, such as film blowing, laminating, coating, adhesive application, and cutting, may result in additional emissions. Cleaning operations also use solvents that contribute to emissions (EPA, 1995b).

2.3 OFFSET LITHOGRAPHIC PRINTING

Lithographic printing is characterized by a planographic printing process (i.e., the image and nonimage areas are on the same plane). The image area is ink-wettable and water-repellent, and the nonimage area is chemically repellent to ink and hydrophilic. The inks used in lithography are either heatset or nonheatset. In offset printing, the graphic image is applied from an ink-covered print plate to a rubber-covered "blanket" cylinder and then transferred onto the substrate, hence the name "offset" lithography (EPA, 1993a). The substrate in offset lithography can be either a web or sheet. A web substrate can be used with either heatset or nonheatset inks; sheets are used with nonheatset inks only. Some offset presses print on both sides of the paper at the same time (called "perfecting"); others print on one side only or two sides sequentially (EPA, 1994a).

An aqueous solution of isopropyl alcohol is commonly used to dampen the nonimage area on the plate and is called the "fountain" or "dampening" solution. The fountain solution in offset lithographic printing has traditionally contained about 15 percent alcohol; at times as high as 30 percent alcohol could be used. Because of environmental pressures, the use of isopropyl alcohol (a VOC) is decreasing. Fountain solutions that contain lower VOCs and/or alcohol substitutes are now in use. The newspaper industry segment of offset lithographic printing predominantly uses alcohol substitutes. Some facilities may use both alcohol and alcohol substitutes; in this case, the alcohol is generally much lower than 15 percent in the fountain solution (EPA, 1994a).

Offset lithographers also use cleaning solutions to clean the press and parts. These cleaning solutions have traditionally been high-solvent-containing (90 to 100 percent) solutions. Some lower- or no-solvent cleaners are becoming available, in which the solvent content is 0 to 30 percent (EPA, 1994a).

2.4 LETTERPRESS PRINTING

Letterpress printing is the oldest form of movable type printing. Letterpress printing uses a relief printing plate (as does flexography) and viscous inks similar to lithographic inks. Various types of letterpress plates are available. These plates differ from flexographic plates in that they have a rigid backing (metal or plastic) and are not "flexible." Both sheetfed and web presses are in use. Web letterpress equipment uses heatset and nonheatset inks. Letterpress printing uses no fountain solutions; the cleaning solvents are similar to those used in lithography. Traditionally, letterpress printing dominated periodical and newspaper publishing; however, the majority of newspapers have converted to nonheatset web offset printing (EPA, 1995a).

Letterpress printing uses a paper web that is printed on both sides, one side at a time, and uses heatset inks, usually of about 40 percent (by volume) solvent. The web is dried after each color is applied. Heatset letterpress ink is similar to heatset lithographic ink. These inks contain resins dissolved in aliphatic hydrocarbons and are dried in hot-air ovens. The inks can be entirely HAP free (EPA, 1993a).

"Moisture set" inks used in some packaging applications contain trimethylene glycol (a HAP). "Water washable" letterpress inks are sometimes used for printing paper and corrugated boxes. These inks contain glycol-based solvents that may contain HAPs (EPA, 1995a).

2.5 SCREEN PRINTING

Screen printing involves forcing ink through a stencil in which the image areas are porous. The screens are generally made of silk, nylon or metal mesh. Screen printing is used for signs, displays, electronics, wallpaper, greeting cards, ceramics, decals, banners, and textiles. Nearly half of the screen printing plants in the United States print on textiles. Ink systems used in screen printing include ultraviolet cure, waterborne, solventborne, and plastisol, with plastisol (polyvinyl chloride) being mainly used in textile printing. Solvent-based ink systems contain aliphatic, aromatic, and oxygenated organic solvents (EPA, 1995a).

Both sheetfed and web presses are used in screen printing. Depending on the substrate printed, the substrate can be dried after each printing station or, for absorbent substrates, after all colors are printed. Solvent- and waterborne inks are dried in hot-air or infrared drying ovens. Dryer gases are partially recycled and partially vented (EPA, 1995a).

2.6 PLATELESS PRINTING

This technology is a relatively new process used primarily for short runs on paper substrates. Plateless printing processes include electronic (e.g., laser printers), electrostatic (e.g.,

xerographic copiers), magnetic, thermal (e.g., facsimile machines) and ink jet printing. Plateless printing processes are estimated to account for only 3 percent (by value) of printed products. Electrostatic toners and ink jet printer inks may contain HAPs; however the quantities emitted at any location are small (EPA, 1995a).

2.7 POINT SOURCE CONSIDERATIONS

Although 80 percent of graphic arts facilities are estimated to have fewer than 20 employees and less than 10 tons per year (tpy) VOC emissions (Ulconovic, 1991), there are likely to be some point sources and/or point source emissions for this source category in most inventory areas. Forty percent of VOC emissions from graphic arts operations are estimated to be from plants in the 10- to 100-tpy range.

This indicates that the interface between point and area sources, as well as the attainment status of the region, will be especially important for inventories of this source category. A typical scenario is to find a few large graphic arts operations and numerous small graphic arts operations with an equal potential for a significant amount of emissions from both size groups.

Table 7.2-4 presents the available information about the estimated percentage of facilities that are area sources among the various printing processes. These estimates substantiate the assumption that there are a significant number of area source facilities among all types of printing.

Also, many of these small graphic arts operations may be located at facilities whose predominant operation is not printing. This fact is reflected in the SIC Codes for graphic arts operations (Table 7.2-2) that are outside of major SIC Code 27 (Printing and Publishing).

According to Title V permit requirements, if a source qualifies as a major source for one HAP, the facility needs to inventory all HAP sources, regardless of their size. Therefore, data may exist for some small printing operations if they are located in facilities large enough to qualify for Title V permitting. These sources will also be included in a point source inventory.

TABLE 7.2-4**ESTIMATED SMALL BUSINESS DISTRIBUTION OF PRINTING FACILITIES**

Type of Printing	Estimated Number of Facilities^a	Estimated Percentage of Small Businesses
Rotogravure	427	0 for publication; 48 percent of packaging/product printing are small businesses (<500 employees) ^b
Flexography	1,587	Out of 600 responses to an EPA survey of flexographic printing, 98 percent were considered small businesses (<500 employees) ^b
Offset Lithography	54,000	Many ^c
Letterpress	21,000	Unknown
Screen	21,000	Many ^d
Plateless	Unknown	Many ^d

^a EPA, 1995a.^b EPA, 1995b.^c EPA, 1994a.^d Assumed.

2.8 EMISSION SOURCES

The predominant emissions from graphic arts printing are VOCs contained in the printing inks, fountain solutions, and cleaning solutions. Many of these VOCs are also likely to be HAPs. To a lesser extent, VOCs and HAPs are emitted from binding and laminating operations (EPA, 1995a).

Printing inks vary widely in composition, but all consist of three major components: pigments, which produce the desired colors and are composed of finely divided organic and inorganic materials; binders, the solid components that lock the pigments to the substrate and are composed of organic resins and polymers or, in some inks, oils and rosins; and solvents, which dissolve or disperse the pigments and binders and are usually composed of organic compounds. The binder and solvent make up the "vehicle" part of the ink (EPA, 1993a).

In "heatset" printing processes, the solvent evaporates from the ink into the atmosphere during a drying step. In nonheatset processes, minimal VOCs or HAPs are emitted from inks, although emissions still result from fountain solution (offset lithographic printing only) and cleaning solution use. Ultraviolet inks may be used in graphic arts operations; in this case, there will be no emissions from inks (EPA, 1994a).

Emissions from proofing presses, cleaning operations, ink storage tanks, and ink mixing operations are relatively minor compared to the emissions during the printing process, but they do contribute to overall emissions (EPA, 1995a).

2.9 FACTORS INFLUENCING EMISSIONS

2.9.1 PROCESS OPERATING FACTORS

The type of printing and/or ink (offset heatset, offset nonheatset, gravure, flexographic, etc.) is the most important process operating factor for estimating emissions from graphic arts operations. For similar processes, the next most important process operating factor affecting emissions is the production volume (i.e., amount of material printed [area times length]). The amount of ink used per unit of substrate (i.e., the relative amount of inked versus noninked areas), which is determined by the type of product (newspaper, cereal box, greeting card, etc.), is another important factor. All things being equal, the production volume will be the determining factor in the relative magnitude of emissions. The type of substrate has little effect on the quantity of emissions.

Since printing is not a high-profit-margin production activity, it is in the interest of the printer to minimize the use of raw materials and time needed for each product. Therefore, it would appear that emissions minimization would be an auxiliary goal of the printer to minimize the

use of raw materials. A factor that supersedes these goals, however, is customer satisfaction. It is because of the customer's perception of the final product that this source category retains the descriptor of an "art." Consequently, the printer may alter process variables that increase chemical use and, thus, possibly emissions, to achieve an end result that meets the customer's scrutiny. Chemical use may also be increased in the interest of shorter production time and less product waste to increase the profit margin.

One example of this trend in graphic arts operations is in offset lithographic printing, where the use of alcohol, one of the more expensive raw materials, may be used at a higher rate if it appears to be the only way to print a product that pleases the customer. This was shown in the case of a press operator who was found to purchase his own alcohol--at his own expense--to ensure high quality of a printing job when alcohol purchases had been eliminated by the plant management for environmental reasons (EPA, 1994a).

The following process variables relate to specific types of printing or operations common to all types:

Rotogravure

In publication rotogravure printing, the inks contain from 55 to 95 percent (by volume) low-boiling-point solvent (average is 75 percent by volume) with low viscosities (EPA, 1993a). It is important that the ink or other coating dry quickly between each color; therefore, the ink vehicle must be evaporated between stations (EPA, 1995b). Organic solvents (such as toluene, xylene, and ethylbenzene, which are HAPs) and alcohol are mainly used as the volatile portion of the ink, but water-based inks are becoming more popular because of their lower cost and less potential for air pollution. However, a single press is not compatible for use with both systems because water-based inks require more equipment drying capacity and a different cell design.

Although some rotogravure inks contain solvents, additional solvents may be mixed into the ink as well to obtain the desired viscosity. Publication gravure plants recover a large portion of spent solvents from their ink, some of which is reused and some excess that is sold back to the ink suppliers. Some virgin solvent, which has the same composition as the solvent in the inks, is purchased for replenishment purposes, and a small amount is used for cleaning the presses (EPA, 1995a).

Flexography

The ink used in flexography is of low viscosity because the ink must be fluid to print properly. Most flexographic printing (including all flexographic newspaper and corrugated carton printing) is done with waterborne inks, but alcohol or other low-viscosity, volatile liquids are also used as the ink base. Solvents used must be compatible with the rubber or

polymeric plates; thus, aromatic solvents are not used. Some of the components of solvent-based flexographic ink include ethyl, methyl, n-propyl, and isopropyl alcohols; glycol ethers; ethylene glycol; aliphatic hydrocarbons; acetates; and esters. Most of the solventborne flexographic inks contain little or no HAPs (EPA, 1995b).

When flexography is used to print corrugated board and most paperboard, water-based inks can be used; however, fast-drying inks are required for plastic films and packaging papers so the web can be rewound or processed into the final product at the end of the press. When printing pressure-sensitive labels, the ink must dry quickly without penetration (EPA, 1995b).

Offset Lithography

The solvents (high-boiling-temperature petroleum oils >400°F) in heatset inks are driven off in a hot air or direct-flame dryer (400-500°F) to set the ink. Nonheatset inks dry by adsorption or oxidation and are not released from the substrate under normal conditions. Approximately 20 to 40 percent of the solvent remains in the substrate with heatset inks; 95 to 100 percent remains in the substrate with nonheatset inks (EPA, 1993a).

Emissions from the fountain solution will depend on whether alcohol or nonalcohol additives are used. The concentration of VOCs in the fountain solution can vary from facility to facility, and from job to job within any one facility (EPA, 1994a).

Solvents used for press cleanup are usually kerosene-type high-boiling-point hydrocarbons, sometimes mixed with detergents (EPA, 1995a). These materials can contain up to 100 percent VOCs but are generally free of HAPs. Low-VOC cleaning solutions are also in use where the VOC content is less than 70 percent, and often less than 30 percent VOCs (EPA, 1994a).

Letterpress

Only web presses using solventborne inks are sources of emissions in this industry. Letterpress newspaper and sheetfed printing use oxidative drying inks and are not a source of emissions. Cleaning solutions are used with all letterpress operations (EPA, 1993a).

Screen Printing

Ink systems used in screen printing include ultraviolet cure, waterborne, solventborne, and plastisol, with plastisol (polyvinyl chloride) being mainly used in textile printing. Solvent-based ink systems contain aliphatic, aromatic, and oxygenated organic solvents (EPA, 1995a).

In-Process Fuel

Fuels such as oil or natural gas are used to operate the dryers used in heatset offset lithography, heatset letterpress, gravure, and alcohol-based flexography. In some cases, recovered solvent may be used as supplemental fuel in the dryer. A boiler may be used to generate steam for steam-/water-based flexography and to regenerate the activated carbon beds used as control devices. The combustion byproducts include particulate matter (PM), particulate matter with diameters less than 10 μg (PM_{10}), sulfur oxides (SO_x), nitrogen oxides (NO_x), VOCs, and carbon dioxide (CO). Recovered solvent may be burned in the dryer (EPA, 1994a).

Storage Tanks

Graphic arts operations may use storage tanks to store inks, solvents, and fuels (oil).

2.9.2 CONTROL TECHNIQUES

Afterburners, both thermal and catalytic, can be used to control VOC emissions from the heatset web offset lithography, rotogravure printing, and flexography. Activated carbon adsorption can be used to control VOC emissions from rotogravure printing and flexography (EPA, 1995a). Condenser filters with and without activated carbon can be used to control VOC emissions from heatset offset lithography (EPA, 1994a). The condensers alone can achieve 90 percent control, while activated carbon increases the control to 95 percent. Total enclosure, with venting of collected VOCs to a control device, is used with rotogravure printing. Pebble-bed incinerators that combine the functions of a heat exchanger and a combustion device also can be used to control VOCs in the graphic arts industry (EPA, 1995a).

Refrigeration of the dampening solution is a process change that can achieve approximately 40 percent reduction of the alcohol emissions (which are VOCs) from offset lithographic printing operations. The use of alcohol substitutes in the dampening solution of offset lithographic printing operations can reduce or eliminate the use of alcohol (EPA, 1994a).

The use of lower-VOC-containing or lower-vapor-pressure cleaning solutions can reduce VOC and HAP emissions from cleaning operations in all types of printing. Storing cleaning rags in closed containers can control some of the fugitive emissions from cleaning (EPA, 1994a). In screen printing, low-VOC- and/or HAP-emitting screen printing cleaning products are available for the removal/reclamation of the stencil from the screen. Process modifications to lower VOC/HAP emissions in screen reclamation are also being used, such as the Screen Printing Association International (SPAI) Workshop Process, high-pressure water blaster, and automatic screen washing system.

In 1978, a control technique guidelines (CTG) document (EPA, 1994a) was published for the control of VOCs from rotogravure and flexographic printing operations (EPA, 1978). New

Source Performance Standards (NSPS) for VOC emissions from publication rotogravure printing were proposed in the Federal Register (FR) October 28, 1980 (45 FR 71538), and promulgated November 8, 1982 (47 FR 50644). NSPS for VOC emissions from rotogravure printing and coating of flexible vinyl were promulgated June 29, 1984 (49 FR 26885). In 1993, a draft CTG document was published for the control of VOC emissions from offset lithographic printing. The draft CTG document was presented as an "Alternative Control Techniques" (ACT) document and announced in June 1994, with modifications, as a result of public comments submitted to EPA in response to the draft CTG (EPA, 1994a).

The following is a chronology of VOC regulations for the graphic arts industry:

- 1978: A CTG document was published for the control of VOCs from rotogravure and flexographic printing operations (EPA, 1978).
- 1982: NSPS for VOC emissions from publication rotogravure were proposed October 28, 1980 (45 FR 71538) and promulgated November 8, 1982 (47 FR 50644).
- 1984: NSPS for VOC emissions from rotogravure printing and coating of flexible vinyl were promulgated June 29, 1984 (49 FR 26885).
- 1994: A draft CTG document was published for the control of VOC emissions from offset lithographic printing in November 1993. The draft CTG was reclassified as an ACT document and announced in June 1994. The ACT information included revisions made in response to public comments to the 1993 draft CTG document (EPA, 1994a).

Although none of these above regulatory efforts were specifically directed towards HAPs, many HAPs of concern in the printing industry are VOCs and, therefore, the same control devices used to limit VOC emissions are also applicable to control of HAPs. A National Emission Standard for Hazardous Air Pollutant (NESHAP) for the printing and publishing industry was proposed in March 1995 (60 FR 13664; 40 CFR Part 63); the background information document for the NESHAP is available (EPA, 1995a).

Table 7.2-5 summarizes the national regulations that affect the graphic arts industry. Note that in most cases there is no size cutoff for applicability of the regulation. State regulations may also be in effect that are more stringent than federal regulations. The size cutoffs of these regulations should be noted when preparing an area source inventory; in many cases the state may make the federal rule more stringent by eliminating the size cutoff or facility age exemption that will bring all sources under the regulation or extend the regulations statewide that are primarily targeted for nonattainment areas.

TABLE 7.2-5

NATIONAL REGULATIONS FOR THE GRAPHIC ARTS INDUSTRY

Type of Printing	Type of Regulation	Applicability	Regulated Pollutant	Control Requirement	Control Method(s)
Rotogravure	CTG (1978) ^a	Packaging facilities in nonattainment areas	VOCs	70-80% capture	
				90% destruction	Incineration
				65% overall control	
		Publication facilities in nonattainment areas	VOCs	75-85% capture	
				90% removal	Carbon adsorption
				75% overall control	
		Packaging and publication facilities in nonattainment areas	VOCs	Inks with 25% or less solvent	Material substitution
				Ink with 60% nonvolatile component	Material substitution
	NSPS (1982) ^b	Publication facilities	VOCs	84% overall control	Solvent recovery systems or waterborne inks
	NESHAP (proposed 1995)	Publication facilities that are major sources ^c	HAPs	92% overall control	
		Product and packaging facilities that are major sources ^c	HAPs	95% overall control	
				≤0.2 kg emitted per kg ink solids	
				≤0.04 kg emitted per kg ink solids for presses with a common solvent recovery system	

TABLE 7.2-5

(CONTINUED)

Type of Printing	Type of Regulation	Applicability	Regulated Pollutant	Control Requirement	Control Method(s)
Flexography	CTG (1978) ^a	Packaging facilities in nonattainment areas	VOCs	70-80% capture	
				90% destruction	Incineration
				65% overall control	
		Publication facilities in nonattainment areas	VOCs	75-85% capture	
				90% removal	Carbon adsorption
				75% overall control	
		Packaging and publication facilities in nonattainment areas	VOCs	Inks with 25% or less solvent	Material substitution
				Inks with 60% nonvolatile component	Material substitution
	NESHAP (proposed 1995)	Wide web flexographic facilities that are major sources ^c	HAPs	95% overall control	
				≤0.2 kg emitted per kg ink solids	
				≤0.04 kg emitted per kg ink solids for presses with a common solvent recovery system	

TABLE 7.2-5

(CONTINUED)

Type of Printing	Type of Regulation	Applicability	Regulated Pollutant	Control Requirement	Control Method(s)
Offset Lithography	ACT (1994) ^{d,e}	Heatset web facilities that emit ≥ 15 lb per day total emissions	VOCs	95% control of ink emissions	
				Fountain solution VOCs $\leq 1.6\%$ (weight)	
				Fountain solution VOCs $\leq 3\%$ (weight)	Refrigeration
				Fountain solution VOCs $\leq 5\%$ (weight)	Alcohol substitutes
		Nonheatset web facilities that emit ≥ 15 lb per day total emissions	VOCs	Fountain solution VOCs $\leq 5\%$ (weight)	Alcohol substitutes
		Nonheatset sheet facilities that emit ≥ 15 lb per day total emissions	VOCs	Fountain solution VOCs $\leq 5\%$ (weight)	
				Fountain solution VOCs $\leq 8.5\%$ (weight)	Refrigeration
				Cleaning solution VOCs $\leq 5\%$ (weight)	Alcohol substitutes
		Newspaper facilities that emit ≥ 15 lb per day total emissions	VOCs	Fountain solution VOCs $\leq 5\%$ (weight)	Alcohol substitutes
		Cleaning solution at any facilities that emit ≥ 15 lb per day total emissions	VOCs	VOCs $\leq 30\%$ (weight)	
				Vapor pressure ≤ 10 mm Hg at 20°C	

^a EPA, 1978.^b EPA, 1980.^c Emit over 10 tpy of any one HAP or over 25 tpy total of two or more HAPs.^d EPA, 1994a.^e Recommended for nonattainment areas.

3

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATION METHODOLOGIES

A number of methodologies are available for estimating emissions from the graphic arts industry. The method used is dependent upon the degree of accuracy required in the estimate, the available data, and the available resources.

This section discusses the methods available for estimating emissions from area sources in the graphic arts industry and identifies the preferred method. A discussion of the data elements needed for each method is also provided. All methods must take into account point source facilities of graphic arts operations and their emissions.

3.2 AVAILABLE METHODOLOGIES

3.2.1 VOLATILE ORGANIC COMPOUNDS

The VOCs released into the air by graphic arts operations are from the evaporation of the VOCs contained in the raw materials such as inks, fountain solution (offset lithographic printing only), and cleaning solutions used in the printing processes. There are three approaches to estimating the amount of VOCs emitted from this source category:

- Facility Survey Method;
- Ink Sales Emission Factor Method; and
- Per Capita Emission Factor Method.

The Facility Survey Method, the preferred method, and Ink Sales Emission Factor Method, the first alternative method, take into account the variations in VOC emissions between each printing type and in the type of emission controls for each type. With the Facility Survey Method, the amount of VOCs recycled can also be addressed. However, for offset lithographic printing processes, the Facility Survey Method requires incorporating assumptions about the amount of VOCs in the inks that are retained in the substrate and not released during printing. The emissions estimate for offset lithographic printing facilities will not be a simple mass balance calculation (because some ink solvent VOCs are retained in the

substrate). Therefore, an emissions estimate from facility surveys for offset lithography will be more uncertain than for other than printing processes where all the solvent used is emitted.

The Per Capita Emission Factor Method assumes a correlation between population size and graphic arts emissions, which is probably a very weak assumption. Emissions estimated using the Per Capita Emission Factor Method will not reflect variability between regions and, depending on the emission factor used, may not reflect the distribution of the different types of printing within the region and the controls that are being used.

3.2.2 HAZARDOUS AIR POLLUTANTS

HAP emissions from graphic arts operations can be estimated using two methods:

- Facility Survey Method; or
- Applying speciation profiles to the VOC emission estimate obtained using the Ink Sales Emission Factor or Per Capita Emission Factor Methods.

The Facility Survey Method is the preferred method because it provides the most accurate information on material usage and HAP content. The effect of VOC controls on HAP emissions can also be obtained when using this method.

Speciation profiles can be used with either the Facility Survey or Ink Sales Emission Factor Methods as alternative approaches when a detailed survey is not practical. The least desirable method is the use of speciation profiles with the Per Capita Emission Factor Method.

The speciation profiles will need to be updated frequently as a result of changes in product use that are now occurring to meet new regulations (Titles I, III, and V of the Clean Air Act Amendments) and/or as better quality profiles are available. Local speciation profiles may also be available.

3.3 DATA NEEDS

3.3.1 DATA ELEMENTS

The data elements used to calculate emission estimates for the graphic arts operations will depend on the methodology used for emission estimation. The following data elements are necessary for emissions calculations and should be obtained for each method.

For the Facility Survey Method (from each facility sampled):

- Type of printing (rotogravure, flexography, etc.);
- Primary business;
- Number of employees, and number of employees involved in printing operations;
- Amount of VOC-containing raw materials by type;
- VOC content of each product type (weight percent);
- Percentage of VOCs contained in the material that is emitted during graphic arts operations that is estimated or obtained from source test measurements;
- HAP content of product or solvent by type (weight percent) for all HAPs in the product and estimated amount of HAPs emitted during printing operations;
- Controls used at facility, control efficiency; and
- Amount of VOCs or HAPs recycled.

For the first alternative method, the Ink Sales Emission Factor Method:

- Ink sales for the state, or data from the U.S. Census Bureau;
- Uncontrolled point source emissions for graphic arts operations; and
- Controls in use in the inventory region.

For the second alternative method, the Per Capita Emission Factor Method:

- Population of the inventory area; and
- Per capita emission factor from a national database or local survey.

3.3.2 DOUBLE COUNTING CONSIDERATIONS

Double counting can occur for this source category either because emission sources are counted as both graphic arts and as industrial surface coating area sources, or because point source emissions are not properly subtracted from estimates of total emissions. In either case, a clear definition of what processes and industries are included in the graphic arts and

industrial surface coating source categories should be made before data collection for either source category begins. In particular, industries with SIC codes that are *not* in the printing and publishing SIC of 27 should be examined for overlap between the two source categories.

3.3.3 APPLICATION OF CONTROLS

Add-on controls may be used to control ink emissions in the graphic arts industry. Material substitution may also be used to control emissions from all aspects of printing that include the use of water-based inks, reduced alcohol and/or alcohol substitutes in fountain solution, and the use of lower-VOC or low-vapor-pressure cleaning solutions. Rule effectiveness (RE) may be less than 100 percent for add-on controls; RE for material substitution can be assumed to be 100 percent.

Rule penetration will depend on the cutoff size or exemptions for the applicable regulations and can be calculated based on the percentage of sources within the category that are affected by the rule. Because a large number of small sources contribute to total emissions for graphic arts operations, many of the regulations will apply to area sources as well as point sources. In some cases, a lower size cutoff that does not correspond with point versus area distinctions may be specified by the regulation.

3.3.4 SPATIAL ALLOCATION

Spatial allocation may be needed in two possible cases: (1) allocation of state or regional activity to a county level, and (2) allocation of county level emission estimates to a modeling grid cell. In each case, a surrogate for activity should be found that can approximate spatial variation for this category, if specific locations cannot be identified. The preferred method of spatial allocation is to use the facility location collected with other survey information under the preferred method.

Most printing operations occur in or near urban areas to be close to the customers, labor force, or transportation centers. Some national companies locate their large printing plants in suburban or rural areas where land is less expensive. Spatial apportioning can be performed with land use data obtained from county planning departments or population distributions available from the U.S. Census Bureau. Using population to allocate estimated emissions or activity by county or within a grid cell is fairly straightforward and is discussed in Chapter 1, *Introduction to Area Source Emission Inventory Development*. Land use data can be used to generalize building type (i.e., commercial versus residential).

Alternatively, printing facility distributions can be used from *County Business Patterns*^a (U.S. Bureau of the Census, Department of Commerce) or the local "Yellow Pages" to allocate some segments of the category, such as lithographers. However, these indicators may not be useful for in-house or captive printing operations. The importance of these smaller sources to the total area source inventory will determine the usefulness of the data.

3.3.5 TEMPORAL RESOLUTION

Seasonal Apportioning

There are no dramatic seasonal fluctuations in production in the graphic arts industry; therefore, it can be assumed that emissions are distributed uniformly throughout the year. To determine seasonal emissions, the fraction of the year that corresponds to the season of interest can be multiplied times annual emissions to obtain seasonal emissions.

Daily Resolution

Based on a review of the National Acid Precipitation Assessment Program (NAPAP) data (EPA, 1990), 75 percent of emissions activity occurs on weekdays, 20 percent on Saturdays, and 5 percent on Sunday. For allocation on a hourly basis, 65 percent of activity occurs between 9 a.m. and 6 p.m., with the remaining 35 percent occurring between 7 p.m. and 12 a.m.

3.3.6 PROJECTING EMISSIONS

The following equation should be applied when the base year emissions are calculated by the emission factor method and the emission factor takes into account the control level for the projection year (EPA, 1993b):

^a See the most recent publication, which can be obtained from the U.S. Bureau of the Census, Department of Commerce, Washington, D.C.

$$\text{EMIS}_{\text{PY}} = \text{ORATE}_{\text{BY}} * \text{EMF}_{\text{PY}} \left[1 - \left(\frac{\text{CE}_{\text{PY}}}{100} * \frac{\text{RE}_{\text{PY}}}{100} * \frac{\text{RP}_{\text{PY}}}{100} \right) \right] * \text{GF} \quad (7.3-1)$$

where:

EMIS_{PY}	=	Projection year emissions: ozone season typical weekday (mass of pollutant/day);
ORATE_{BY}	=	Base year operating rate (activity level);
EMF_{PY}	=	Projection year (postcontrol) emission factor (mass of pollutant/production unit);
CE_{PY}	=	Projection year control efficiency (percent);
RE_{PY}	=	Projection year rule effectiveness (percent);
RP_{PY}	=	Projection year rule penetration (percent); and
GF	=	Growth factor (dimensionless).

Current control projection emissions in this case are calculated if the projection year emission factor and RE values represent current regulatory or permit conditions and/or actual conditions when appropriate.

Tools for the development and use of growth factors are discussed in Chapter 1 of this volume. Forecasts of ink or paper sales from the data sources discussed in Section 5 of this chapter can also be used to estimate future growth in the graphic arts.

4

PREFERRED METHODS FOR ESTIMATING EMISSIONS

The preferred method for calculating emissions from graphic arts is the Facility Survey Method. In this method, graphic arts facilities in the inventory area will need to be identified. Although initially this is a labor-intensive approach, the results can be used to develop an emission factor specific to the inventory region. Subsequent inventories can use this factor with updated activity data to estimate emissions. If it is not possible to inventory all of the graphic arts facilities in the area, then a representative sample of these graphic arts facilities can be surveyed, and the results can then be scaled up for all facilities in the area. Please refer to Volume I of this series, Chapter 5, *Inventory Development*; Chapter 1 of this volume; and Volume VI of this series, *Quality Assurance Procedures*, for more detailed information about using surveys.

4.1 PLANNING

Identify facilities that would be suitable survey recipients, noting those that are point sources. Facilities engaged in graphic arts may be listed as part of a state or local permitting program. Look for facilities that may have graphic arts facilities as part of another, more significant operation. Title V or other operating permits may include information from such facilities. Facilities can also be identified from the local employment office, professional organizations, and entries in local tax records for printing equipment.

Prepare a survey form or forms that collect the information needed for the inventory. At a minimum, the survey should request:

- Name, location, and contact person of the operation;
- Primary activity and type of graphic arts process(es) used at the facility;
- Amount of inks, fountain solution, and cleaning solution used at the facility. If the amount is expressed in gallons, the density of the materials will be needed as well, in order to calculate emissions in weight units such as pounds or kilograms;
- The VOC or the HAP content of each material, in pounds, or as a weight percentage;

- The amount of material that is recovered and recycled, but not reused within the facility; and
- Control equipment and control efficiency.

During the planning phase, a scaling method should be identified and the survey form should request the information needed to scale up the data collected, such as total employment or production workers. If the survey results are to be converted into an area-specific emission factor, the surrogate activity will also need to be collected. Possible surrogate factors would be per unit, per facility, or per employee factors. If practical, use production workers rather than the total number of employees.

4.2 DISTRIBUTION

Survey distribution will be determined by the budget for the category. Surveys can be distributed by mailing, with initial and follow-up telephone calls. Initial calls may be useful to identify the portion of the survey set that does not have graphic arts processes occurring on their premises. These facilities are an important part of the sample because when the survey is scaled up, if that portion of facilities were to have emissions assigned to them, the emission estimates would be too high. Survey distribution issues are discussed in Chapter 1, *Introduction to Area Source Emission Inventory Development*, under Surveys, in Section 6.

4.3 SURVEY COMPILATION AND SCALING

Use the survey results to either develop an emission factor or an areawide emission estimate. If material amounts were reported in gallons, then the gallons need to be converted to weight units:

$$\begin{array}{l} \text{Amount used} \\ \text{in pounds} \end{array} = \left[\begin{array}{l} \text{Amount of} \\ \text{material (gal)} \end{array} \right] \times \left[\begin{array}{l} \text{Density factor} \\ \text{(lb/gal)} \end{array} \right] \quad (7.4-1)$$

Note that the amount of VOCs emitted during printing (volatile fraction) is not always equivalent to the measured or estimated VOC content of the raw material (especially for offset lithographic printing), since all the VOCs contained in the raw material may not be emitted during printing. The data used in the alternative Ink Sales Emission Factor Method to determine the VOC emissions by amount of ink used should be used with the Facility Survey Method if the volatile fraction specific to the process is not available. Refer to the Ink Sales Emission Factor Method description and emission factors in Section 5 of this chapter. For example, although nonheatset lithographic inks may contain some VOCs, only 2 percent of the VOCs are emitted during printing.

Use the equation below to estimate uncontrolled total emissions for each pollutant (P) emitted, from each type of graphic arts operation (i). Point source emissions should be calculated using the same equation and subtracted from the total emissions calculated using Equation 7.4-2.

$$\text{Total Uncontrolled Emissions}_{\text{from Graphic Arts } P} = \sum \left[\left(\frac{\text{Amount Raw Material}_i}{\text{Used}} \right) \left(\frac{\text{Volatile Fraction}_{P,i}}{\text{Fraction}} \right) - \left(\frac{\text{Amount Recycled}_i}{\text{Recycled}} \right) \right] \quad (7.4-2)$$

An area source emission factor can be developed by calculating the area source emissions and dividing the area source emissions by the area source activity rate:

$$\text{Graphic Arts Emission Factor}_{P,i} = \left[\left(\frac{\text{Total Uncontrolled Emissions}_{P,i}}{\text{Emissions}} \right) - \left(\frac{\text{Uncontrolled Point Source Emissions}_{P,i}}{\text{Emissions}} \right) \right] \div \frac{\text{Area Source Activity Rate}_i}{\text{Rate}_i} \quad (7.4-3)$$

When the emission factor is used, control efficiency (CE), rule penetration (RP), and rule effectiveness (RE) need to be included as part of the emissions calculation. Please refer to Section 4.2 in Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development* for more information about developing these factors.

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5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

The alternative methods for calculating emissions from the graphic arts source category are the Ink Sales Emission Factor Method and the Per Capita Emission Factor Method. This section provides an outline for estimating emissions from either ink sales or population data. The procedures follow below.

5.1 INK SALES EMISSION FACTOR METHOD

In the Ink Sales Emission Factor Method, total uncontrolled emissions from all graphic arts operations sources are estimated using national or state ink sales data. This method's advantages are:

- Inks are common to all printers and not used by any other source except printers;
- The VOC content of the inks is fairly consistent and can be estimated on the average; and
- The printing processes are technically consistent within each printing type (i.e., emissions per unit of ink will be approximately the same from one facility to another) for ink with the same VOC content used in the same type of printing process.

If the amount of printing ink that is recycled is expected to be significant in the inventory area, the emission estimate needs to be adjusted accordingly. Use information collected from the point source inventory to determine the rate of recycling at graphic arts facilities.

Uncontrolled point source emissions for each printing type are subtracted from the total uncontrolled emissions calculated using this method to obtain uncontrolled area source emissions. If the uncontrolled point source emissions from graphic arts operations are not available or cannot be estimated, then the Facility Survey Method or the other alternative method should be used.

The total area source emissions from graphic arts operations are estimated from the sum of emissions estimated for each of the six types of printing. If local information on ink sales is

available, it should be used for this method. If local information is not available, the following approach should be used to estimate ink sales in the inventory area:

First, obtain apportioned ink sales by the following steps:

- Obtain the amount of inks produced, in pounds, in the United States for the inventory year, from the Census Bureau's *Census of Manufactures*, Industry Series for SIC Code 289, Miscellaneous Chemical Products.^a
- Apportion the nationwide ink amount produced for the inventory year to the state level by the ratio between state and national employment in printing and publishing (SIC Code 27). The Census Bureau's report, *Statistics for Industry Groups and Industries*, can provide this information.^a The equation to use is:

$$\text{Total Ink Sales for State} = \left[\text{Total Ink Sales for US} \right] \frac{\left[\begin{array}{c} \text{Printing} \\ \text{Employment} \\ \text{in State} \end{array} \right]}{\left[\begin{array}{c} \text{Printing} \\ \text{Employment} \\ \text{in US} \end{array} \right]} \quad (7.5-1)$$

Next, correct the apportioned ink sales amount for point sources in the state. To do this, identify point sources (from the point source inventory) that have graphic arts processes at their facilities. The Aerometric Information Retrieval System (AIRS) Facility Subsystem (AFS) Source Classification Codes (SCCs) in Table 7.5-1 can be used to identify the applicable graphic arts emissions from the point source inventory. For these facilities, the following additional information should be collected:

- Facility location (county or inventory area);
- Amount of ink used by the facility (amount purchased minus amount recycled);
- SIC Code for the facility's primary operation; and

^a See the most recent publication, which can be obtained from the U.S. Bureau of the Census, Department of Commerce, Washington, D.C.

TABLE 7.5-1**AFS SOURCE CLASSIFICATION CODES FOR GRAPHIC ARTS**

Point Source Description	Process Description	SCC	Units
Offset Lithography - All Processes	Dampening Solution with Isopropyl Alcohol	4-05-004-13	Tons Alcohol Used
	Dampening Solution with Alcohol Substitute	4-05-004-15	Tons Substitute Used
	Cleaning Solution - High Solvent Content	4-05-004-16	Tons Pure Solvent Used
	Cleaning Solution - Water-Based	4-05-004-17	Tons Used
Heatset Offset Lithography	Heatset Lithographic Inks	4-05-004-11	Tons Solvent in Ink
	Heatset Lithographic Inks	4-05-004-12	Gallons Ink
	Heatset Lithographic Inks	4-05-004-01	Tons Ink
	Heatset Ink Mixing	4-05-004-21	Tons Solvent in Ink
	Heatset Solvent Storage	4-05-004-22	Tons Solvent Stored
Nonheatset Offset Lithography	Nonheatset Lithographic Inks	4-05-004-31	Tons Ink
	Nonheatset Lithographic Inks	4-05-004-32	Tons Solvent in Ink
	Nonheatset Lithographic Inks	4-05-004-33	Gallons Ink
Letterpress - All Processes	Letterpress Cleaning Solution	4-05-002-15	Tons Solvent Consumed

TABLE 7.5-1

(CONTINUED)

Point Source Description	Process Description	SCC	Units
Heatset Letterpress	Heatset Letterpress Ink	4-05-002-01	Tons Ink
	Heatset Letterpress Ink	4-05-002-11	Tons Solvent in Ink
	Heatset Letterpress Ink	4-05-002-12	Gallons Ink
	Ink Mixing	4-05-006-01	Tons Solvent in Ink
	Storage	4-05-007-01	Tons Solvent Stored
Gravure Printing	Gravure Ink	4-05-005-01	Tons Ink
	Gravure Ink	4-05-005-11	Tons Solvent in Ink
	Gravure Ink - High Solvent Content	4-05-005-13	Gallons Ink
	Gravure Ink - Water-Based	4-05-005-12	Gallons Ink
	Ink Mixing	4-05-006-01	Tons Solvent In Ink
	Solvent Storage	4-05-007-01	Tons Solvent Stored
	Gravure Cleanup Solvent	4-05-005-14	Tons Solvent Consumed
Flexographic Alcohol-Based Inks	Flexographic Ink Use - Alcohol-Based	4-05-003-01	Tons Ink
	Flexographic Ink Use - Alcohol-Based	4-05-003-11	Tons Solvent in Ink
	Flexographic Ink Use - Alcohol-Based	4-05-003-13	Gallons Ink

TABLE 7.5-1

(CONTINUED)

Point Source Description	Process Description	SCC	Units
Flexographic Alcohol-Based Inks (Continued)	Flexographic Ink Use - Alcohol-Based	4-05-003-12	Gallons Ink
	Flexographic-Alcohol Cleanup	4-05-003-14	Tons Solvent Consumed
	Ink Mixing	4-05-003-01	Tons Solvent in Ink
	Solvent Storage	4-05-007-01	Tons Solvent Stored
Flexographic Steam/ Water-Based Ink	Flexographic Ink Use - Steam/Water-Based	4-05-003-15	Tons Ink
	Flexographic Ink Use - Steam/Water-Based	4-05-003-16	Tons Solvent in Ink
	Flexographic Ink Use - Steam/ Water-Based	4-05-003-17	Tons Solvent Stored
	Steam/Water-Based Ink Mixing	4-05-003-18	Tons Solvent Stored
	Steam/Water-Based Ink Storage	4-05-003-19	Tons Solvent Stored
Miscellaneous	Cleaning Rags	4-05-008-01	Tons Solvent Used

- Facility's employment, if the SIC Code is 27, and if it is available.

Subtract the amount of ink (do not include fountain solutions or cleaning solutions) used by all point source facilities in the state from the total amount of ink allocated to the state:

- Determine the number of employees at printing and publishing point source facilities (SIC Code 27) in the state and subtract those employees from the state total. The remaining employee numbers will be used to apportion the area source ink sales numbers.
- If the numbers of employees at the printing and publishing point source facilities is not available from the facilities' permits, point source inventory information, or local employment data, then the employment can be derived from the U.S Bureau of the Census report, *County Business Patterns*.

When employment in *County Business Patterns* is presented as a number of facilities that have employment within a range of values, the total number of employees for all the facilities listed in each range can be estimated using the midpoint of the indicated size range. See Example 7.5-1 for more details.

The remaining amount of ink can be assumed to be responsible for area source emissions. This ink should be apportioned from the state level to the inventory area, using the non-point-source employment in facilities with SIC Codes of 27.

Apportion the statewide ink sales data for each type of printing to the inventory region by the ratio of the printing employment in the inventory region for each printing type (t) to the state printing employment, as follows:

$$\text{Total Ink Sales for Inventory Region} = \left[\text{Total Ink Sales for State} \right] \frac{\left[\begin{array}{c} \text{Printing} \\ \text{Employment} \\ \text{in Inventory} \\ \text{Region} \end{array} \right]}{\left[\begin{array}{c} \text{Printing} \\ \text{Employment} \\ \text{in State} \end{array} \right]} \quad (7.5-2)$$

- Apportion the inventory region ink sales to each type of printing, using the estimated percentage product market share of ink sales for each type of printing in Table 7.2-3.

Example 7.5-1:

If an inventory for the region contains five graphic arts point sources, and the top five graphic arts facilities, by total employment, in the *County Business Patterns* for the region are distributed as follows: three facilities in the 100 to 149 employees per facility size range and two facilities in the 50 to 99 employee per facility size range, then the total number of employees for point sources can be calculated using the midpoint of the employee size ranges, as in the equation below:

$$\text{Total Employees at Point Sources} = \left[3 \frac{(100 + 149)}{2} + 2 \frac{(50 + 99)}{2} \right] = 3(124.5) + 2(74.5) = 523$$

Assume that point sources correspond to the facilities with the highest number of employees. Start with the facilities with the largest number of employees and sum the number of employees at the largest facilities for as many facilities as there are point source graphic arts facilities in the county for the desired SIC.

- Uncontrolled emission factors for ink, fountain solution, and cleaning solution, in terms of pounds of VOCs emitted per pound of ink used, are in Table 7.5-2. The equation to calculate uncontrolled emissions for a single printing type (t) is:

(7.5-3)

$$\text{Uncontrolled VOC Emissions} = \left[\begin{array}{c} \text{Area Source} \\ \text{Ink}_t \text{ Sales} \\ \text{in the} \\ \text{Inventory Region} \end{array} \right] \times \left[\left(\begin{array}{c} \text{Ink Emission} \\ \text{Factor}_t \end{array} \right) + \left(\begin{array}{c} \text{Fountain} \\ \text{Solution} \\ \text{Emission} \\ \text{Factor}_t \end{array} \right) + \left(\begin{array}{c} \text{Cleaning} \\ \text{Solution} \\ \text{Emission} \\ \text{Factor}_t \end{array} \right) \right]$$

See Table 7.2-5 in this chapter for a summary of national rules for the graphic arts industry. Other types of controls and control efficiencies will vary from area to area and more stringent controls may be required, which will need to be identified from local rules or, if necessary, through a survey of a small cross section of area source graphic arts facilities. Please refer to Section 4.2 in Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development* for more information about developing these factors. Alternatively, no controls could be applied to the area source emission estimates, which will result in the most conservative estimate.

TABLE 7.5-2

COMPONENT VOC EMISSION FACTORS FOR GRAPHIC ARTS OPERATIONS

Type of Printing	Component Emission Factors (Pounds of VOC Emitted per Pound of Ink Used)		
	Ink	Fountain Solution	Cleaning Solution
Rotogravure	0.70 ^a	NA ^b	0.03 ^a
Flexography	0.60 ^a	NA	0.04 ^a
Offset Lithography			
Heatset	0.32 ^c	0.90 ^c	0.03 ^c
Nonheatset Web	0.02 ^c	0.53 ^c	0.03 ^c
Nonheatset Sheet	0.02 ^c	1.25 ^c	1.10 ^c
Newspaper	0.02 ^c	0.07 ^c	0.07 ^c
Letterpress	0.24 ^d	NA	^e
Screen	f	NA	f
Planographic	f	NA	f

^a Bay Area SIP (engineering judgement).

^b NA = not applicable.

^c EPA, 1994a.

^d EPA, 1993a.

^e Unknown at this time; use the emission factor for newspaper offset lithography if no other information is available.

^f Unknown at this time. The Facility Survey Method should be used for these sources until information is available if they are expected to be significant area source emissions.

- Calculate controlled area source emissions for each printing type (t) for the inventory region with the following equation:

(7.5-4)

$$\begin{aligned} \text{Controlled Area Source Emissions}_t = & \left[\begin{array}{c} \text{Area Source} \\ \text{Ink}_t \text{ Sales} \\ \text{in the Inventory Region} \end{array} \right] \times \left\{ \left(\text{Ink Emission Factor}_t \right) \times \left[1 - \left(\frac{\text{CE}_I}{100} \times \frac{\text{RE}_I}{100} \times \frac{\text{RP}_I}{100} \right) \right] \right\} \\ & + \left\{ \left(\text{Fountain Solution Emission Factor}_t \right) \times \left[1 - \left(\frac{\text{CE}_{FS}}{100} \times \frac{\text{RE}_{FS}}{100} \times \frac{\text{RP}_{FS}}{100} \right) \right] \right\} \\ & + \left\{ \left(\text{Cleaning Solution Emission Factor}_t \right) \times \left[1 - \left(\frac{\text{CE}_{CS}}{100} \times \frac{\text{RE}_{CS}}{100} \times \frac{\text{RP}_{CS}}{100} \right) \right] \right\} \end{aligned}$$

where:

$(\text{CE}_{I,FS,CS})$ = Control efficiency (percent) for each material used: ink (I), fountain solution (FS), and cleaning solution (CS);

$(\text{RE}_{I,FS,CS})$ = Rule effectiveness (percent); and

$(\text{RP}_{I,FS,CS})$ = Rule penetration (percent).

- Calculate the total area source controlled VOC emissions from graphic arts operations in the inventory region by summing the controlled VOC emissions for each type of printing (t):

$$\begin{array}{c} \text{Total Controlled} \\ \text{Area Source} \\ \text{VOC Emissions in} \\ \text{Inventory Region} \end{array} = \sum \left[\begin{array}{c} \text{Total Controlled} \\ \text{VOC Emissions}_t \text{ in the} \\ \text{Inventory Region} \end{array} \right] \quad (7.5-5)$$

5.2 PER CAPITA EMISSION FACTOR METHOD

This method calculates graphic arts emissions from the inventory area population. The correlation between population and graphic arts activity is not strong and emissions calculated using this method will not reflect local variability in activity, controls, or types of printing taking place.

- Obtain the population of the inventory region from federal, state, or local census data for the current inventory year and the most recent year for which emission estimates derived from survey data are available.
- Estimate the total VOC emissions from graphic arts facilities with less than 100 tons per year VOC emissions, as in the equation below:

$$\begin{array}{l} \text{Total Uncontrolled} \\ \text{Emissions from} \\ \text{Graphic Arts} \\ \text{Facilities with} \\ \text{<100 tpy Emissions} \\ \text{(tons)} \end{array} = \left[\begin{array}{c} \text{Population of} \\ \text{Inventory} \\ \text{Region} \end{array} \right] \left[\begin{array}{c} 0.00065 \\ \text{(tons VOC per capita)} \end{array} \right] \quad (7.5-6)$$

Note: The factor 0.00065 tons VOC per capita is equivalent to 1.3 pounds per person per year (EPA, 1991). This factor was derived for facilities with emissions that are less than 10 tpy, and is independent of the number of facilities with emissions greater than 100 tpy in the inventory area.

- Subtract the emissions from point sources in the inventory region (as defined by the region) with emissions less than 100 tons per year using data from the point source inventory as in the equation below:

$$\begin{array}{l} \text{Total Uncontrolled} \\ \text{Emissions from} \\ \text{Graphic Arts} \\ \text{Area Sources} \end{array} = \left[\begin{array}{c} \text{Total Uncontrolled} \\ \text{Emissions from} \\ \text{Graphic Arts} \\ \text{Facilities with} \\ \text{<100 tpy Emissions} \end{array} \right] - \left[\begin{array}{c} \text{Total Uncontrolled} \\ \text{Emissions from} \\ \text{Graphic Arts} \\ \text{Point Sources with} \\ \text{<100 tpy Emissions} \end{array} \right] \quad (7.5-7)$$

- If information about CE, RE, and RP is available, then the following equation should be used:

$$\text{Total Controlled Emissions from Area Sources} = \left[\begin{array}{c} \text{Total Uncontrolled} \\ \text{Emissions from} \\ \text{Graphic Arts} \\ \text{Area Sources} \end{array} \right] \left[1 - \left(\frac{\text{CE}}{100} \times \frac{\text{RE}}{100} \times \frac{\text{RP}}{100} \right) \right] \quad (7.5-8)$$

If control information is not available, then the more conservative uncontrolled estimate should be used.

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6

QUALITY ASSURANCE/ QUALITY CONTROL (QA/QC)

Data handling for all of the methods do not involve any category-specific issues; refer to the discussion of data handling QA/QC in Volume VI for more information. When using the Facility Survey Method, the survey planning, sample design, and data handling should be planned and documented in the inventory QA/QC plan. Refer to the discussion of survey planning and survey QA/QC in Chapter 1 of this volume.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

The preferred method gives higher quality estimates than the alternative methods, but requires significantly more effort. The level of effort for the Facility Survey Method requires from 100 to 800 hours depending on the size of the inventory region, the number of graphic arts operation facilities, and the level of detail in the survey. The level of effort for the Ink Sales Emission Factor Method requires between 100 and 200 hours depending on the size of the inventory region, the number of graphic arts operation facilities, and the ease in obtaining the appropriate ink sales data. The level of effort required to calculate emissions using the Per Capita Emission Factor Method ranges from 8 to 40 hours.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The DARS scores for each method are summarized in Tables 7.6-1, 7.6-2, and 7.6-3. A range of scores is given for the preferred and first alternative method because the implementation of these methods can vary. All scores assume that good QA/QC measures are performed and that no significant deviations from the prescribed methods have been made. If these assumptions are not met, new DARS scores should be developed according to the guidance in Appendix F of EIIP Volume VI, *Quality Assurance Procedures*.

The preferred method gives a higher DARS score than the alternative methods, with the Facility Survey Method scoring higher than the Ink Sales Emission Factor Method that in turn scored higher than the Per Capita Emission Factor Method. The alternative methods have scores of 0.5 and 0.31, and the preferred method has a score ranging from 0.56 to 0.76. The relatively high score for the Ink Sales Method assumes that ink sales data are available. This method will have a lower score if the data cannot be obtained directly, and national data must be apportioned.

6.1.2 SOURCES OF UNCERTAINTY

Some of the uncertainty of the emissions estimates based on the Facility Survey Method can be quantified using standard statistical methods. A relative and qualitative assessment can be made for other methods. The Facility Survey Method will be the least uncertain, since (in theory) the local mix of process types and sizes will be accounted for. Emissions from printing types in which most of the ink evaporates from the substrate can be estimated by mass balance with a high degree of certainty. The uncertainty in the emissions estimate is highest for material when an estimate of the amount of VOCs retained in the substrate is needed and is comparable in magnitude to that emitted (for heatset offset lithographic printing only). However, the scaling of the survey results will need to be planned with care. The surrogate(s) should reflect the printing activity for each facility including the nonpublishing and printing industries that use graphic arts processes.

The Ink Sales Emission Factor Method's advantage is that the ink sales data and the information used for the apportioning method are readily available and inexpensive. However, the use of surrogate apportioning factors to apportion the national ink usage to the inventory area and national percentages to allocate ink usage to the different types of printing introduces uncertainty. Because the estimated emissions of each type of material used in printing is not expected to vary widely from facility to facility, and because the type of printing is usually known with a high degree of certainty, the emission factors used in the Ink Sales Emission Factor Method will have the same certainty as that used in the Facility Survey Method.

The Per Capita Emission Factor Method will have the highest degree of uncertainty, since a true relationship between population and printing has not been established. Since the per capita emission factor was developed from national data, as the spatial scale is reduced from the national level, the uncertainty of the emissions estimated is greatly increased. Also, because of variation in emissions among the types of printing, population data will likely not reflect the local distribution of printing type, and consequently, emissions.

TABLE 7.6-1**FACILITY SURVEY METHOD DARS SCORES**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5	0.8 - 0.9	0.4 - 0.45
Source Specificity	0.8 - 0.9	0.5 - 0.8	0.4 - 0.72
Spatial	0.9	0.9 - 1.0	0.81 - 0.90
Temporal	0.8 - 1.0	0.8 - 1.0	0.64 - 1.0
Composite Scores	0.83 - 0.90	0.75 - 0.85	0.56 - 0.76

TABLE 7.6-2**INK SALES EMISSION FACTOR METHOD DARS SCORES**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.4 - 0.5	0.6	0.24 - 0.30
Source Specificity	0.8 - 0.9	0.8 - 0.9	0.64 - 0.81
Spatial	0.7 - 0.6	0.7 - 0.6	0.49 - 0.36
Temporal	0.7 - 0.6	0.9	0.63 - 0.54
Composite Scores	0.65	0.75	0.5 - 0.49

TABLE 7.6-3
PER CAPITA METHOD DARS SCORES

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.4	0.8	0.32
Source Specificity	0.5	0.4	0.2
Spatial	0.3	1.0	0.27
Temporal	0.5	1.0	0.45
Composite Scores	0.43	0.75	0.31

7

DATA CODING PROCEDURES

This section describes the codes available to characterize the graphic arts emission estimates. Consistent categorization and coding will result in greater uniformity between inventories. Inventory planning for data collection calculations and inventory presentation should take the data formats presented in this section into account. Available codes and process definitions may impose constraints or requirements on the preparation of emission estimates for this category.

7.1 PROCESS AND CONTROL CODES

The source category process codes for the graphic arts operations are shown in Table 7.7-1. These codes are derived from the EPA's AIRS Area and Mobile Source (AMS) source category codes (EPA, 1994b).

The control device codes shown in Table 7.7-2 may be used in AMS to record the level of control used for this source in the inventory region. Federal, state, and local regulations can be used as guides to estimate the type of control used and the level of efficiency that can be achieved. Be careful to apply only the regulations that specifically include area sources. If a regulation is applicable only to point sources, it should not be assumed that similar controls exist at area sources without a survey. The equations that utilize the control efficiency to calculate area source emissions for the inventory region are discussed in Chapter 1 of this volume.

Other control devices may be used in the graphic arts industry. The "099" code can be used for miscellaneous control devices that do not have a unique control device identification code. The "999" code can be used for a combination of control devices where only the overall control efficiency is known.

TABLE 7.7-1

AIRS AMS CODES FOR THE GRAPHIC ARTS

Category Description	Process Description	AMS Code	Units
Graphics Arts: All Processes	Total: All Solvent Types	24-25-000-000	Tons VOCs Emitted

TABLE 7.7-2

AIRS CONTROL DEVICE CODES

Control Device	Code
Catalytic Afterburner	019
Catalytic Afterburner with Heat Exchanger	020
Direct Flame Afterburner	021
Direct Flame Afterburner with Heat Exchanger	022
Activated Carbon Adsorption	048
Vapor Recovery System	047
Process Change	046
Process Enclosed	054
Miscellaneous Control Device	099
Combined Control Devices	999

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VOLUME III: CHAPTER 8

INDUSTRIAL SURFACE COATING

September 1997



Prepared by:
TRC Environmental Corporation

Prepared for:
Area Sources Committee
Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

This chapter describes the procedures and recommended approaches for estimating emissions from small industrial surface coating operations. Section 2 of this chapter contains a general description of the small industrial surface coating category and an overview of available control technologies. Section 3 provides an overview of available emission estimation methods. Section 4 presents the preferred method for estimating emission from small industrial surface coating, and Section 5 presents the alternative emission estimation techniques. Quality assurance issues and emission estimate quality indicators for the methods presented in this chapter are discussed in Section 6. Data coding procedures are discussed in Section 7. Section 8 contains references used for this chapter.

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SOURCE CATEGORY DESCRIPTION

2.1 CATEGORY DESCRIPTION

Surface coating operations involve applying a thin layer of coating (e.g., paint, lacquer, enamel, varnish, etc.) to an object for decorative or protective purposes. The surface coating products include either a water-based or solvent-based liquid carrier that generally evaporates in the drying or curing process. In 1989, approximately 3.8 billion pounds of organic solvents, roughly one-third of all solvents purchased that year, were used in surface coating operations. These solvents were used both as carriers for coatings and to clean up coating equipment (EPA, 1991).

The use of surface coatings by manufacturing industries and other sectors of the economy is pervasive. Applications include: (1) coatings that are applied during the manufacture of a wide variety of products by Original Equipment Manufacturers (OEMs) including furniture, cans, automobiles, other transportation equipment, machinery, appliances, metal coils, flat wood, wire, and other miscellaneous products, (2) architectural coatings, and (3) special purpose coatings used for applications such as maintenance operations at industrial and other facilities, auto refinishing, traffic paints, marine finishes, and aerosol sprays. For area source purposes, the small industrial surface coating category includes OEM applications, some marine coatings, and maintenance coatings not accounted for by point sources. This category does not include architectural surface coatings, traffic markings, automobile refinishing, or aerosols. These categories are covered in other EIIP area source chapters. Architectural coatings are covered in Chapter 3; graphic arts in Chapter 7; auto refinishing in Chapter 13; traffic markings in Chapter 14; and aerosols in Chapter 5, which covers consumer and commercial solvent use.

Ideally, all industrial surface coating facilities would be inventoried as point sources. Preferred and alternative methods for estimating point source emissions from industrial surface coating operations are given in EIIP Volume II, Chapter 7. That chapter also includes more detailed discussion of surface coatings technology and controls, as well as process descriptions for industries having significant point source emissions. As a practical matter, it is not usually possible to account for all industrial surface coating facilities as point sources. Although the majority of industrial surface coating emissions may be inventoried as point sources, remaining emissions of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) from industrial surface coating operations must be accounted for as area sources. Since the use of surface coatings by manufacturing industries is so widespread, it is extremely difficult to identify all of the industries in which coating materials are consumed. This makes the job of compiling a truly complete and accurate area source inventory for this category a difficult one. The following

tables list Standard Industrial Classification (SIC) codes that are likely to be associated with industrial surface coating operations. Table 8.2-1 lists the SIC codes for which national level data are available to estimate the quantities of coatings consumed. The largest of these industries are shown in Table 8.2-2, which lists those industries accounting for 90 percent of reported OEM coating consumption on a dollar value basis for 1992. Finally, Table 8.2-3 lists other manufacturing SICs known to consume surface coatings, but for which no reliable national data are available to estimate the volume used. All of the SICs listed in Tables 8.2-1 and 8.2-3 may be thought of as possible industries to be considered for inclusion in an area source industrial surface coating inventory. However, there is no assurance that this list is totally inclusive, nor can it be stated that these SICs always represent categories that include area source industrial surface coating operations.

2.2 PROCESS DESCRIPTION AND EMISSION SOURCES

Surface coating is the process by which paints, inks, varnishes, adhesives, or other decorative or functional coatings are applied to a substrate (e.g., paper, metal, plastic) for decoration and/or protection. This can be accomplished by brushing, rolling, spraying, dipping, flow coating, electrocoating, or specialized combinations or variations of these methods. The process by which the coating is applied is determined in part by the product's intended end use, the substrate to which the coating is applied, and the composition of the coating itself.

After the coating has been applied, it is cured or dried either by conventional curing or radiation curing processes. Conventional curing is accomplished through the use of thermal ovens. The heat from these ovens causes the solvents and/or water trapped in the coating to be driven off into the atmosphere. Coatings can also be cured using radiation. The two types of radiation curing processes currently in use are ultraviolet (UV) curing and electron beam (EB) curing.

Emissions result from the evaporation of the paint solvent and any additional solvent used to thin the coating. Emissions also result from the use of solvents in cleaning the surface prior to coating and in cleaning coating equipment after use.

2.3 FACTORS INFLUENCING EMISSIONS

VOC emissions from small industrial surface coating operations are influenced by several factors. Emissions from surface preparation and coating applications are a function of the VOC content of the product used. Emissions are also a function of the coating process used, including the transfer efficiency of the spray equipment. Transfer efficiency is the percentage of coating solids sprayed that actually adhere to the surface being coated. Emissions from cleaning operations are dependent on the type of cleanup and housekeeping practices used.

TABLE 8.2-1

PRINCIPAL INDUSTRIAL SURFACE COATING SIC

SIC Code	SIC Description
2451	Mobile Homes
2452	Prefabricated Wood Buildings and Components
2493	Reconstituted Wood Products
2499	Wood Products, Not Elsewhere Classified
2511	Wood Household Furniture, Except Upholstered
2512	Wood Household Furniture, Upholstered
2514	Metal Household Furniture
2517	Wood Television, Radio, Phonograph, and Sewing Machine Cabinets
2519	Household Furniture, Not Elsewhere Classified
2521	Wood Office Furniture
2522	Office Furniture, Except Wood
2531	Public Building and Related Furniture
2541	Wood Office and Store Fixtures, Partitions, Shelving, and Lockers
2542	Office and Store Fixtures, Partitions, Shelving, and Lockers, Except Wood
2599	Furniture and Fixtures, Not Elsewhere Classified
3411	Metal Cans
3412	Metal Shipping Barrels, Drums, Kegs, and Pails
3441	Fabricated Structural Metal
3443	Fabricated Plate Work (Boiler Shops)
3444	Sheet Metal Work
3446	Architectural and Ornamental Metal Work
3448	Prefabricated Metal Buildings and Components
3449	Miscellaneous Structural Metal Work
3465	Automotive Stampings
3466	Crowns and Closures
3469	Metal Stampings, Not Elsewhere Classified
3471	Electroplating, Plating, Polishing, Anodizing, and Coloring
3479	Coating, Engraving, and Allied Services, Not Elsewhere Classified
3523	Farm Machinery and Equipment
3524	Lawn and Garden Tractors and Home Lawn and Garden Equipment

TABLE 8.2-1

(CONTINUED)

SIC Code	SIC Description
3531	Construction Machinery and Equipment
3532	Mining Machinery and Equipment, Except Oil and Gas Field Machinery and Equipment
3536	Overhead Traveling Cranes, Hoists, and Monorail Systems
3561	Pumps and Pumping Equipment
3563	Air and Gas Compressors
3581	Automatic Vending Machines
3585	Air Conditioning and Warm Air Heating Equipment
3586	Measuring and Dispensing Pumps
3593	Fluid Power Cylinders and Actuators
3594	Fluid Power Pumps and Motors
3612	Power, Distribution, and Specialty Transformers
3613	Switchgear and Switchboard Apparatus
3621	Motors and Generators
3631	Household Cooking Equipment
3632	Household Refrigerators and Home and Farm Freezers
3633	Household Laundry Equipment
3634	Electric Housewares and Fans
3635	Household Vacuum Cleaners
3639	Household Appliances, Not Elsewhere Classified
3711	Motor Vehicles and Passenger Car Bodies
3713	Truck and Bus Bodies
3714	Motor Vehicle Parts and Accessories
3715	Truck Trailers
3716	Motor Homes
3721	Aircraft
3724	Aircraft Engines and Parts
3728	Aircraft Parts and Auxiliary Equipment, Not Elsewhere Classified
3731	Ship Building and Repairing
3732	Boat Building and Repairing

TABLE 8.2-1

(CONTINUED)

SIC Code	SIC Description
3792	Travel Trailers and Campers
3799	Transportation Equipment, Not Elsewhere Classified
3931	Musical Instruments
3949	Sporting and Athletic Goods, Not Elsewhere Classified
3951	Pens, Mechanical Pencils, and Parts
3952	Lead Pencils, Crayons, and Artists' Materials
3953	Marking Devices
3993	Signs and Advertising Specialties
3995	Burial Caskets

TABLE 8.2-2

1992 MANUFACTURING INDUSTRY SURFACE COATING CONSUMPTION^a

SIC Code	Description	Cost of Coatings Consumed (Million \$)
371	Motor Vehicles and Equipment	1770.1
341	Metal Cans and Shipping Containers	328.2
347	Metal Services, Not Elsewhere Classified	321.7
289	Misc. Chemical Products (Printing Ink) ^b	318.2
344	Fabricated Structural Metal Products	218.1
251	Household Furniture	173.3
363	Household Appliances	142.3
254	Partitions and Fixtures	87.7
373	Ship and Boat Building and Repairing	87.7
346	Metal Forgings and Stampings	86.9
352	Farm and Garden Machinery	85.6
249	Miscellaneous Wood Products	82.8
252	Office Furniture	80.2

^a Information has been compiled from: *1992 Census of Manufactures, Geographic Area Series*, U.S. Department of Commerce, Bureau of the Census, Washington, DC.

^b Represents coating materials consumed for printing ink manufacture. Therefore, this SIC should not be included for inventory purposes as an industrial surface coating end use category.

TABLE 8.2-3**OTHER INDUSTRIES THAT MAY CONSUME SURFACE COATINGS**

SIC Code	SIC Description
2436	Softwood Veneer and Plywood
262	Paper Mills
263	Paperboard Mills
265	Paperboard Containers and Boxes
3069	Fabricated Rubber Products, Not Elsewhere Classified
308	Miscellaneous Plastic Products, Not Elsewhere Classified
331	Blast Furnace and Basic Steel Products
3433	Heating Equipment, Except Electric
3494	Valves and Pipe Fittings, Not Elsewhere Classified
3452	Bolts, Nuts, Rivets, and Washers
364	Electric Lighting and Wiring Equipment
366	Communications Equipment
367	Electronic Components and Accessories
3812	Search and Navigation Equipment
382	Measuring and Controlling Devices
384	Medical Instruments and Supplies
3861	Photographic Equipment and Supplies
3942	Dolls and Stuffed Toys
3944	Games, Toys, and Children's Vehicles

2.4 CONTROL TECHNIQUES

The main approaches for reducing VOC emissions from small industrial surface coating operations are (1) use of lower-VOC coatings, (2) use of enclosed cleaning devices, and (3) increased transfer efficiency. Other housekeeping activities can also be used to reduce emissions from small industrial surface coating operations. These activities include using tight-fitting containers, reducing spills, mixing paint to need, providing operator training, maintaining rigid control of inventory, using proper cleanup methods, etc.

Regulations designed to reduce VOC emissions have led to the development of high-solids and powder coatings, as well as increased use of water-based coatings. Although water-based coatings include some organic solvents, water makes up the main carrier component (generally at least 80 percent) in these formulations.

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATION METHODOLOGIES

There are several methodologies available for calculating emissions from small industrial surface coating operations. The selection of a method to use depends on the degree of accuracy required in the estimate, the available data, and the available resources. This section discusses the methods available for estimating emissions from small industrial surface coating operations and identifies the preferred method for this category.

3.1.1 AVAILABLE METHODOLOGIES

Volatile Organic Compounds

Methods available for estimating emissions from small industrial surface coating operations include the following: (1) using SIC-specific, inventory area-specific per employee emission factors; (2) using national default per employee emission factors; and (3) using per capita emission factors. These methods are summarized in Table 8.3-1. Because of the potentially large number of small industrial surface coating operations within an inventory area and the difficulty in identifying candidate industries to be surveyed, conducting surveys to collect activity, product use, and product-specific VOC content data to develop product-specific, site-specific detailed emissions estimates is generally not recommended. A survey methodology is likely to be too resource intensive for both the facilities surveyed and the inventorying agency.

The preferred method for estimating emissions from small industrial surface coating operations involves developing and applying SIC-specific, inventory area-specific per employee emission factors based on reported point source emissions. Other methods for estimating emissions from this category include using national default per employee and per capita emission factors.

Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone, Volume 1 (EPA, 1991) and *AP-42* (EPA, 1995) contain per employee and per capita emission factors for this category.

TABLE 8.3-1

**PREFERRED AND ALTERNATIVE METHODS FOR ESTIMATING
EMISSIONS FROM SMALL INDUSTRIAL SURFACE COATING OPERATIONS**

Methods	Description
Preferred Method - SIC-Specific, Area-Specific Per Employee Factor	<ul style="list-style-type: none"> • Divide total reported point source emissions (by SIC) for inventory area by total point source employment (by SIC) for inventory area to develop SIC-specific, inventory area-specific per employee emissions factor. • Subtract total point source employment from total employment within the SIC to develop total area source SIC employment. • Multiply area source employment by SIC-specific, inventory area-specific employee factor.
Alternative Method 1 - National Default Per Employee Factor	Use national default per employee emission factors and number of employees in SIC to estimate emissions.
Alternative Method 2 - Per Capita Factor	Use per capita emission factor and population in inventory area to estimate emissions.

Hazardous Air Pollutants

HAP emissions from this source are determined by the same methods discussed above for VOC emissions. Again, conducting a survey to gather specific HAP information may be too resource-intensive for the inventorying agency to undertake. Using the preferred method described above assumes that the coatings and HAP contents used in small facilities are similar to those used and reported by large facilities. The agency may want to verify this assumption with local industry experts.

3.1.2 DATA NEEDS

Data Elements

The data elements needed to calculate emission estimates for small industrial surface coating operations depend on the methodology used for data collection. Each methodology requires some measure of activity (or surrogate for activity) and an emission factor. The data elements needed for each emission estimation technique are presented in Table 8.3-2.

TABLE 8.3-2**DATA ELEMENTS NEEDED FOR EACH METHOD**

Data Element	Preferred Method^a	Alternate Method 1^b	Alternate Method 2^c
Point source emissions by SIC	x		
Point source employment by SIC	x	x	
Total employment by SIC	x	x	
Population (inventory area)			x
SIC-specific, area-specific per employee emission factor	x		
National default per employee emission factor		x	
Per capita emission factor			x

^a Preferred method is the SIC-specific, area-specific per employee factor method.

^b Alternative Method 1 is the national default per employee factor method.

^c Alternative Method 2 is the per capita factor method.

Adjustments to Emissions Estimates

Adjustments applied to annual emissions estimates include point source corrections, applications of controls, spatial allocation, and temporal resolution. The type of adjustment is dependent on the type of inventory required. The data needs for point source emission estimate adjustments are dependent in part on the methodology used. Data needs for the adjustments listed below are as follows:

- Point source corrections require point source emissions or point source employment data for inventory area for the specific SIC;
- Application of controls requires information about control efficiency, rule effectiveness; and rule penetration;
- Spatial allocation requires employment, population, facility location, zoning, or business districts location data;

- Temporal resolution requires data for seasonal throughput, operating days per week, and operating hours per day.

Point Source Corrections

If the Preferred Method is used to estimate area source emissions from this category, the point source correction is performed as part of the method itself. If Alternative Method 1 is used, the point source corrections can be performed by one of the following: (1) subtract point source emissions from calculated total emissions, or (2) subtract point source employment in the specific SIC from total employment in that SIC and calculate area source emissions using the remaining employment in the SIC. If Alternative Method 2 is used, the point source corrections can only be performed by subtracting point source emissions from calculated total emissions.

Application of Controls

Section 3.8 of *Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone, Volume I* (EPA, 1991) provides guidance for determining and applying rule effectiveness (RE) for a source category. In addition, the EPA document *Procedures for Estimating and Applying Rule Effectiveness in Post-1987 Base Year Emission Inventories for Ozone and Carbon Monoxide State Implementation Plans* (EPA, 1989) provides more detailed information on RE.

Sections 4.1.1 and 5.4 of the *Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone, Volume I* (EPA, 1991) describe how to account for emissions reductions expected to result from applying a regulation. If a regulation exists for a surface coating operation SIC represented in the inventory areas and the inventorying agency uses a “top down” approach to estimate emissions from this category, the agency should incorporate an estimate of rule penetration.

If an area source is controlled (e.g., VOC content of surface coating products controlled by regulation), the following general equations can be used to calculate emissions:

$$CAE_A = (UAE_A)[1 - (CE)(RP)(RE)] \quad (8.3-1)$$

or

$$CAE_A = (EF_A)(Q)[1 - (CE)(RP)(RE)] \quad (8.3-2)$$

where:

CAE_A	=	controlled area source emissions of pollutant A
UAE_A	=	uncontrolled area source emissions of pollutant A

CE	=	control efficiency/100
RP	=	rule penetration/100
RE	=	rule effectiveness/100
EF _A	=	emission factor for pollutant A
Q	=	activity factor for category

Spatial Allocation

If the emissions estimates are developed using a per employee factor, the spatial allocation of emissions can be performed according to facility location (if known) as with the point source inventory, or with local employment data. The agency should be aware that since location of surface coating operations does not necessarily mirror location of population within a county, using population to spatially allocate emissions might be misleading. The inventorying agency will need to evaluate options for allocating county emissions, such as zoning information, actual location data identified from surveys, industry publications, etc.

Temporal Resolution

Seasonal Apportioning. Small industrial surface coating emissions do not demonstrate differences in activity from season to season (EPA, 1991). The agency may want to evaluate point source data to determine actual seasonal activity within the inventory area. Area source emissions can be seasonally allocated using the most frequently occurring or average seasonal throughput values found in the point source inventory for the specific SIC.

Daily Resolution. Small industrial surface coating facilities typically operate five days per week (EPA, 1991). This value may be used if local survey data or point source records on daily resolution are not available.

3.2 PROJECTING EMISSIONS

The type of surrogate used to project emissions is dependent on the methodology used to develop the initial emissions estimate. In “growing” the emissions estimate, the inventorying agency should use the same activity parameter as was used to develop the initial estimate. For example, if a per employee factor was used to develop the initial estimate, growth in employment should be used to develop the projected emissions estimate. The agency should use SIC-specific growth information, rather than general business growth projections, if available.

The general equation for developing the projected emissions is:

$$EMIS_{PY} = ORATE_{BY,O} * EMF_{PY,pc} * [1 - (\frac{CE_{PY}}{100})(\frac{RP_{PY}}{100})(\frac{RE_{PY}}{100})] * GF \quad (8.3-3)$$

where:

$EMIS_{PY}$	=	projection year emissions: ozone season typical weekday (mass of pollutant/day)
$ORATE_{BY,O}$	=	base year operating rate: ozone season daily activity level
$EMF_{PY,pc}$	=	projection year precontrol emissions factor (mass of pollutant/production unit)
CE_{PY}	=	projection year control efficiency (percent)
RP_{PY}	=	projection year rule penetration (percent)
RE_{PY}	=	projection year rule efficiency (percent)
GF	=	growth factor (dimensionless)

The precontrol emission factor ($EMF_{PY,pc}$) reflects the mass of VOCs per production unit emitted before control (EPA, 1993).

4

PREFERRED METHOD FOR ESTIMATING EMISSIONS

The preferred method for estimating emissions from small industrial surface coating operations uses employment as the activity factor and an inventory area-specific, SIC-specific per employee emission factor. This method essentially scales up point source surface coating emissions by the ratio of total employment to point source employment. This method is most appropriate when most surface coating emissions have been accounted for as point sources. Implicit assumptions are that emissions per employee for area sources are the same as for point sources and that emissions from SICs for which there are no point sources are insignificant. The following procedures should be followed.

- (1) Develop an SIC-specific, inventory area-specific per employee emission factor. The total reported point source emissions for all of the surface coating classification codes (SCCs) reported within an SIC are divided by the point source employment for the SIC. This method may not be practical if emissions, SCCs and SIC codes for each facility are not all available.
 - Point source surface coating emissions are reported under the 402***** SCC. Table 7.2-1 of EIIP Volume II, Chapter 7 gives a full list of applicable point source surface coating SIC codes.
 - Emissions by SCC can be obtained from state emissions databases or the Aerometric Information Retrieval System (AIRS) Facility Subsystem (AFS). AIRS AFS allows reporting of SIC codes for facilities, but they are not required. State databases may be a more complete source of information for this procedure. Database queries should request a list of facilities' emissions that are reported for SCC 402*****, and those facilities' SIC codes. Facilities may list themselves as being in more than one SIC code. Inventory preparers will have to use some judgement to decide which SIC code is the most appropriate match, both for the per employee emission factor, and the point source correction.

- County employment information can be obtained from state or local records, such as state or local commerce departments, or *County Business Patterns*.¹ *County Business Patterns* lists employment by SIC code.

$$\text{SIC-specific, area-specific, per Employee Emission Factor} = \frac{\text{PSE}_{\text{SIC}}}{\text{PEmp}_{\text{SIC}}} \quad (8.4-1)$$

where:

$$\begin{aligned} \text{PSE}_{\text{SIC}} &= \text{total point source SIC emissions for coating SCCs} \\ \text{PEmp}_{\text{SIC}} &= \text{total point source SIC employment} \end{aligned}$$

A variation of the above procedure would be to develop the area-specific, SIC-specific per employee emission factors based on a selected sample of the point source facilities, instead of basing emission factors on all point sources. A suggested approach is to plot a distribution of emissions per employee values for all point sources. Those sources that have values that may be considered “outliers” (extremely high or low compared to other sources) could be excluded from the sample. The justification for the exclusion is that if a large enough sample of point sources exists, and this sample contains sources with excessively large or small emissions per employee factors, these may not be representative of the typically small sources being inventoried as area sources. In theory, this approach might produce more representative emission factors for area sources. By deliberately excluding some point sources from the sample, however, the sample becomes biased. It is a matter of engineering judgement as to whether this bias would cause less inventory error than basing area source emission factors on a sample of all point sources. Excluding some individual point sources from the sample for those SICs for which there are only a very small number of point sources is generally not a good idea, since the sample is too small to establish a representative average value for emissions per employee.

- (2) Subtract total point source employment from total employment for each SIC to calculate total area source employment. (Point source employment may be available from state inventory or permit files, or from industrial directories or commercially available databases. Alternatively, point source employment may be estimated from *County Business Patterns* data using the procedure described later in this section.)

$$\text{AEmp}_{\text{SIC}} = \text{TEmp}_{\text{SIC}} - \text{PEmp}_{\text{SIC}} \quad (8.4-2)$$

¹ *County Business Patterns*, U.S. Department of Commerce, Bureau of the Census, Washington, DC. Annual publication.

where:

$$\begin{aligned} \text{TEmp}_{\text{SIC}} &= \text{total SIC employment} \\ \text{PEmp}_{\text{SIC}} &= \text{total point source SIC employment} \\ \text{AEmp}_{\text{SIC}} &= \text{area source SIC employment} \end{aligned}$$

- (3) Multiply area source employment by per employee emission factor developed in Step 1.

$$\text{ASE}_{\text{SIC}} = \text{AEmp}_{\text{SIC}} * \text{per Employee Emission Factor} \quad (8.4-3)$$

where:

$$\begin{aligned} \text{AEmp}_{\text{SIC}} &= \text{area source SIC employment} \\ \text{ASE}_{\text{SIC}} &= \text{area source SIC emissions} \end{aligned}$$

- (4) Sum area source surface coating emissions.

$$\text{ASE}_{\text{surf}} = \sum_n^1 \text{ASE}_{\text{SIC}_x} \quad (8.4-4)$$

where:

$$\begin{aligned} \text{ASE}_{\text{surf}} &= \text{total small industrial surface coating emissions} \\ \text{ASE}_{\text{SIC}_x} &= \text{area source SIC emissions for SIC } x \end{aligned}$$

The following procedures can be used to determine total point source employment if these data are not available from the point source or permit files.

Using *County Business Patterns*:

- (1) Assume that the point source facilities are the facilities reported in *County Business Patterns* as having at least x employees. The term x may vary by SIC and location, and can be appropriately selected for each SIC.
- (2) Determine the number of point sources reporting from the AFS or state/local records.
- (3) *County Business Patterns* reports the number of facilities by employment class size. These classes are represented by a range (e.g., 20 to 49 employees, 50 to 99 employees, 100 to 249 employees, etc.). Total numbers of employees are given for all facilities in the SIC, except where the information does not meet Bureau of the Census requirements to

prevent disclosure of data for individual facilities. In these instances, assume that the facility is at the midpoint of the range, if you cannot estimate the number of employees from the available data.

- (4) Using the *County Business Patterns* size-class distribution and number of point sources reporting, sum the number of employees, starting with the largest size class and working down until all reporting point sources have been considered.
- (5) Area source SIC employment is then estimated by subtracting estimated point source SIC employment from total SIC employment as given in *County Business Patterns*. Example 8.4-1 presents through a typical calculation.

Example 8.4-1

County X reports 12 point source facilities in SIC yyyy. For County X, the total employment from *County Business Patterns* for SIC yyyy is 3,281 and the distribution of facilities by size class is:

<u>Size Class</u>	<u>No. of Facilities</u>	<u>No. of Employees</u>
1,000 or more	0	--
500 to 999	1	not available
250 to 499	0	--
100 to 249	5	964
50 to 99	6	871
20 to 49	2	not available
10 to 19	1	not available
5 to 9	0	--
1 to 4	0	--
Total		3,281

Point source employment = 750 (one facility in size class 500 to 999, using 750 as the midpoint) + 964 (five facilities in size class 100 to 249, with total employment of 964) + 450 (6 facilities in size class 50 to 99, using midpoint of 75)

= 2,164

Area source employment is then calculated:

Area Source Employment for SICyyyy in County X = 3,281 - 2,164 = 1,117

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5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

5.1 ALTERNATIVE METHOD 1 - DEFAULT PER EMPLOYEE FACTORS

Alternative Method 1 uses the national default per employee emission factors given in the *Procedures* (EPA, 1991). These emission factors are presented in Table 8.5-1. Emissions are estimated by either of the following procedures:

- (1) Determine point source SIC employment as outlined in the preferred method. Subtract point source SIC employment from total SIC employment to determine area source SIC employment. Multiply area source SIC employment by the appropriate default emission factor from Table 8.5-1.
- (2) Multiply total SIC employment by the appropriate default emission factor from Table 8.5-1. Subtract total point source surface coating emissions for the SIC from total emissions. The result is the area source emissions for the SIC. If the result is negative for an SIC, set the area source emissions equal to zero. If many negative results occur, use of procedure 1 may be a better approach.

Note that these two methods may provide slightly different results because the default emission factor may not accurately represent conditions in the inventory area.

The inventorying agency will need to evaluate which procedure is more representative of activity in the inventory area. Information on temporal allocation and seasonal adjustment factors can be found in Chapter 1 of this volume, or the *Procedures*, (EPA, 1991).

TABLE 8.5-1

NATIONAL DEFAULT PER EMPLOYEE EMISSION FACTORS (EPA, 1991)

Category	SIC Code	Per Employee VOC Emission Factor (lb/yr)	Per Employee Coating Usage Factor (gal/yr)
Furniture and Fixtures	25	944	175
Metal Containers	341	6,029	1,218
Automobiles (new)	3711	794	131
Machinery and Equipment	35	77	17
Appliances	363	463	181
Other Transportation Equipment	37, except 3711 and 373	35	14
Sheet, Strip, and Coil	3479	2,877	474
Factory Finished Wood	2426-9, 243-245, 2493, 2499	131	40
Electrical Insulation	3357, 3612	290	114
Other Product Coatings	NA ^a	NA	NA
High-Performance Maintenance Coatings	NA	NA	NA
Marine Coatings	373	308	47
Other Special Purpose Coatings	NA	NA	NA

^a NA = not available, use per capita emission factors from Table 8.5-2.

Example 8.5-1

Assume that point source employment for the SIC is 200, total employment for the SIC is 250, default emission factor is 80 lb/employee, and total surface coating SCC point source emissions for the SIC are 15,000 lb.

Using procedure 1 above, area source emissions would be calculated as follows:

$$\begin{aligned} 250 \text{ employees} - 200 \text{ employees} &= 50 \text{ employees} \\ (50 \text{ employees}) (80 \text{ lb/employee}) &= 4,000 \text{ lb} \end{aligned}$$

Using procedure 2 above, area source emissions would be calculated as follows:

$$\begin{aligned} (250 \text{ employees}) (80 \text{ lb/employee}) &= 20,000 \text{ lb} \\ 20,000 \text{ lb} - 15,000 \text{ lb} &= 5,000 \text{ lb} \end{aligned}$$

5.2 ALTERNATIVE METHOD 2 - PER CAPITA EMISSION FACTOR

In this alternative method, population in the inventory area is used with SIC-specific default per capita VOC emission factors to estimate emissions by SIC:

$$E_{a,SIC} = POP_a * EF_{SIC}$$

where:

$E_{a,SIC}$	=	SIC emissions for area a
POP_a	=	population in area a
EF_{SIC}	=	per capita SIC VOC emission factor

Population data may be obtained from state or local records or from national databases and publications maintained by the U.S. Department of Commerce, Bureau of the Census. The recommended per capita VOC emission factors are shown in Table 8.5-2. As with other emissions estimation methodologies, point source emissions for this category should be subtracted from the total emissions generated using this methodology. Information on temporal allocation and seasonal adjustment factors can be found in Chapter 1 of this volume, or the *Procedures* (EPA, 1991).

TABLE 8.5-2

NATIONAL DEFAULT PER CAPITA VOC EMISSION FACTORS

Category	SIC Codes	Per Capita VOC Emission Factor (lb/yr)	Per Capita Coating Usage Factor (gal/yr)
Furniture and Fixtures	25	2.0	0.37
Metal Containers	341	1.3	0.26
Automobiles (new)	3711	1.1	0.18
Machinery and Equipment	35	0.7	0.15
Appliances	363	0.2	0.10
Other Transportation Equipment	37, except 3711, 373	0.2	0.08
Sheet, Strip, and Coil	3479	0.5	0.08
Factory Finished Wood	2426-9, 243-245, 2493, 2499	0.3	0.08
Electrical Insulation	3357, 3612	0.1	0.06
Other Product Coatings	NA ^a	0.6	0.23
High-Performance Maintenance Coatings	NA	0.8	0.13
Marine Coatings	373	0.2	0.04
Other Special Purpose Coatings	NA	0.8	0.18

^a NA = not available.

6

QUALITY ASSURANCE/ QUALITY CONTROL (QA/QC)

When using any of the methods for estimating emissions from industrial surface coating, data compilation should be planned and documented in the inventory QA/QC plan. When using the preferred method, all assumptions made about facilities that are excluded from the emission factor calculations, and the use of emission factors developed from facilities in one specific SIC being used for a less specific SIC group must be documented and justified. If permit data for facilities in a particular SIC are not available, employment for that SIC should be checked before it is assumed that emissions from the SIC do not need to be calculated. Refer to the discussion of survey planning and survey QA/QC in Chapter 1 of this volume if the preferred method is used.

Data handling for data collected for all of the methods should be planned and documented in the inventory QA/QC plan and does not involve any category-specific issues. Please consult EIIP Volume VI on inventory QA/QC for more information.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

The preferred method results in higher quality estimates than either of the alternative methods, but it requires significantly more effort. The level of effort required to calculate emission estimates using either of the two national default emission factors is estimated to be between 8 and 40 hours. The preferred method will require two to three times as much time. Inventory preparers will need to decide if the use of the preferred method in their areas will result in enough of an increase in quality to justify the use of this more detailed method. Inventory planners may wish to review the number of employees in industrial surface coating-related SICs and the information available through point source reporting for the inventory area to determine if the preferred method can be used. Planners should also investigate potential differences in coating formulations between area source and point source operations.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The DARS scores for each method are summarized in Tables 8.6-1, 8.6-2, and 8.6-3. A range of scores is given for the preferred method to reflect variability in the results of the technique. All scores assume that good QA/QC measures are performed and that no significant deviations from

the prescribed methods have been made. If these assumptions are not correct, new DARS scores should be developed according to the guidance provided in Appendix F of EIIP Volume VI.

The preferred method results in higher DARS scores than either of the alternative methods. The preferred method's DARS scores are between 0.42 and 0.51 and the alternative method DARS scores range between 0.27 and 0.34. The preferred method scores higher on the emission factor-related attributes than the alternative methods. The preferred and first alternative methods use the same activity factor, and thus have the same activity attribute scores. The second alternative method, which uses population as an activity surrogate, has a lower activity source specificity score because there may be a low correlation between population and industrial surface coating activity.

The preferred method compiles existing information from local permits to develop an area source emission factor. This method depends on several assumptions concerning point and area industrial surface coating sources being true:

- That most surface coating emissions have been accounted for as point sources;
- That emissions for area sources are the same as those for point sources (i.e., processes and materials are similar, emissions per employee are similar, and controls in permitted facilities are similar to those in nonpermitted facilities); and
- That emissions are insignificant from SICs for which there are no permit data.

Ranges in the scoring for the emission factor depend on several issues. The measurement of the emission factor, based on permit data, will vary depending on the original data collection effort's data quality objectives and the methods used to measure emissions. Potential measurement methods can be plant-specific material balance, continuous emission monitoring, source sampling, or *AP-42* emission factors.

The score for the source specificity attribute addresses the application of a few point source facilities' emission rates to all of the area sources. Source specificity scores depend on whether the assumptions listed above are true. The source specificity score will be reduced considerably if data collected for one SIC are used for a more general SIC grouping that includes that SIC. The greatest advantage that this method has over the alternatives is that it should address spatial and temporal variability that is problematic for the alternative methods.

Emission factors for the alternative methods are scored lower than the preferred methods because they use national-level emission factors based on 1989 solvent usage for all industrial surface coatings. Such factors do not take into account controls in place, changes in processes and materials since 1989, or differences in climate that may result in different formulations of coatings from region to region. Emissions calculated using these factors need to be corrected for

point source emissions in the inventory area. When using the population-based emission factor, spatial attributes are scored lower because the single factor does not reflect any variation in different types of industry in the inventory area.

6.1.2 SOURCES OF UNCERTAINTY

The statistics needed to quantify the uncertainty of the preferred and alternative methods are incomplete. Because of the number of different processes used in this source category and the use of surface coatings in so many different industries, it is a very difficult emission source to characterize, and area source methods will necessarily carry a heavy load of uncertainty.

Factors that influence the uncertainty for the preferred method depend on variations between large and small operations. Processes, materials, controls, and the number of employees actually engaged in surface coating may be quite different depending on the size of the operation. Also, assuming that area source emissions will be unimportant if there are no permitted facilities could result in a major underestimation for the SIC. Checking the employment for that SIC will reduce the uncertainty of that assumption.

Factors that influence the uncertainty for the two alternative methods are:

- The proportion of coating solvent emitted, as opposed to that assumed from the top-down national material balance estimate;
- Changes in the solvent usage since 1989, when the emission factor was prepared (see the discussion in Section 6.1.1 about changes since 1989);
- Regional variability in the types of coatings used depending on climate-based drying or curing times; and
- The number of employees that are actually involved in the surface coating operation at a facility, as opposed to other operations.

For the per capita factor method (Alternative Method Two) only, one additional factor influences uncertainty: the regional distribution of industries that do surface coating.

TABLE 8.6-1**PREFERRED METHOD DARS SCORES: AREA-SPECIFIC PER EMPLOYEE FACTOR**

Attribute	Scores		
	Factor	Activity	Composite
Measurement	0.3 - 0.5	0.9	0.27 - 0.45
Source Specificity	0.3 - 0.6	0.5	0.15 - 0.3
Spatial	0.7 - 0.7	0.9	0.63 - 0.63
Temporal	0.8 - 0.8	0.8	0.64 - 0.64
Composite Scores	0.53 - 0.65	0.78	0.42 - 0.51

TABLE 8.6-2**ALTERNATIVE METHOD 1 DARS SCORES: NATIONAL DEFAULT PER EMPLOYEE FACTOR**

Attribute	Scores		
	Factor	Activity	Composite
Measurement	0.3	0.9	0.27
Source Specificity	0.5	0.5	0.25
Spatial	0.5	0.9	0.45
Temporal	0.5	0.8	0.4
Composite Scores	0.45	0.78	0.34

TABLE 8.6-3**ALTERNATIVE METHOD 2 DARS SCORES: NATIONAL DEFAULT PER CAPITA FACTOR**

Attribute	Scores		
	Factor	Activity	Composite
Measurement	0.3	0.9	0.27
Source Specificity	0.5	0.3	0.15
Spatial	0.3	0.9	0.27
Temporal	0.5	0.8	0.4
Composite Scores	0.40	0.73	0.27

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7

DATA CODING PROCEDURES

This section presents the codes available to characterize small industrial surface coating emission estimates. Consistent categorization and coding will result in greater uniformity among inventories.

7.1 PROCESS AND CONTROL CODES

The process codes for the industrial surface coating category are shown in Table 8.7-1. These codes are compatible with the AIRS Area and Mobile Source Subsystem (AMS) source category codes (EPA, 1994). The control codes for use with AMS are shown in Table 8.7-2. Federal, state, and local regulations can be used as guides to estimate the type of control used and the level of efficiency that can be achieved. Be careful to apply only the regulations that specifically include area sources. If a regulation is applicable only to point sources, it should not be assumed that similar controls exist at area sources. A survey should be conducted to determine if similar controls exist at area sources. The “099” control code can be used for miscellaneous control devices that do not have a unique identification code. The “999” code can be used for a combination of control devices where only the overall control efficiency is known.

TABLE 8.7-1

AMS CODES FOR THE INDUSTRIAL SURFACE COATING CATEGORY

Category	Process Description	AMS Code	Units
Factory Finished Wood (SIC 2426-2429, 243-245, 2492, and 2499)	Total: All Solvent Types	24-01-015-000	Number of Employees
Wood Furniture (SIC 2511, 2571, 2521, and 2541)	Total: All Solvent Types	24-01-020-000	Number of Employees
Metal Furniture (SIC 2514, 2522)	Total: All Solvent Types	24-01-025-000	Number of Employees
Metal Cans (SIC 341)	Total: All Solvent Types	24-01-040-000	Number of Employees
Miscellaneous Finished Metals (SIC 34, not including 341 and 3498)	Total: All Solvent Types	24-01-050-000	Number of Employees
Machinery and Equipment (SIC 35)	Total: All Solvent Types	24-01-055-000	Number of Employees
Large Appliances (SIC 363)	Total: All Solvent Types	24-01-060-000	Number of Employees
Electronic and Other Electrical (SIC 36, not including 363)	Total: All Solvent Types	24-01-065-000	Number of Employees
Motor Vehicles (SIC 3711, 3713, 3715)	Total: All Solvent Types	24-01-070-000	Number of Employees
Marine (SIC 373)	Total: All Solvent Types	24-01-080-000	Number of Employees
Railroad (SIC 3743)	Total: All Solvent Types	24-01-085-000	Number of Employees
Miscellaneous Manufacturing	Total: All Solvent Types	24-01-090-000	Population of Area
Industrial Maintenance Coatings	Total: All Solvent Types	24-01-100-000	Population of Area
Other Special Purpose Coatings	Total: All Solvent Types	24-01-200-000	Population of Area

TABLE 8.7-2

AIRS CONTROL DEVICE CODES

Control Device	Code
Wet Scrubber - High Efficiency	001
Wet Scrubber - Medium Efficiency	002
Wet Scrubber - Low Efficiency	003
Mist Eliminators - High Velocity	014
Mist Eliminators - Low Velocity	015
Catalytic Afterburners	019
Catalytic Afterburners with Heat Exchangers	020
Direct Flame Afterburners	021
Direct Flame Afterburners with Heat Exchangers	022
Flares	023
Activated Carbon Adsorption	048
Packed-Gas Absorption Column	050
Tray-Type Gas Absorption Column	051
Impingement Plate Scrubber	055
Mat or Panel Filter	058
Dust Suppression by Water Sprays	061
Refrigerated Condenser	073
Barometric Condenser	074
Process Modification - Water-based Coatings	101
Process Modification - Low-Solvent Coatings	102
Process Modification - Powder Coatings	103
Miscellaneous Control Device	099
Combined Control Efficiency	999

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VOLUME III: CHAPTER 9

PESTICIDES - AGRICULTURAL AND NONAGRICULTURAL

Revised Final

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Prepared by:
Eastern Research Group, Inc.

Prepared for:
Area Sources Committee
Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

This chapter is one of a series of documents developed to provide cost-effective, reliable and consistent approaches to estimating emissions for area source inventories. Multiple methods are provided in the chapters to accommodate needs of state agencies with different levels of available resources and skills; and different levels of needs for accuracy and reliability of their estimates. More information about the EIIP program can be found in Volume 1 of the EIIP series, *Introduction and Use of EIIP Guidance for Emissions Inventory Development*.

Throughout this chapter and other EIIP area source methods chapters, we stress that area source categories should be prioritized by the inventory planners so that resources can be spent on the source categories that are the largest emitters, most likely to be subject to regulations or are already subject to regulations, or require special effort because of some policy reason. Prioritization is particularly important for area source inventories, because in some cases, a difficult to characterize source category may contribute very little to overall emissions and attempting a high quality estimate for that source category may not be cost effective.

EIIP chapters are written for the state and local air pollution agencies, with their input and review. EIIP is a response to EPA's understanding that state and local agency personnel have more knowledge about their inventory area's activities, processes, emissions, and availability of information; and require flexible inventory methods to best use their sometimes limited resources. These EIIP area source chapters are written as a set of options presented to inventory professionals capable of using their own experience and judgement to apply the method that best fits their overall needs and constraints.

This chapter describes the procedures and recommended approaches for estimating emissions from pesticide applications. Section 2 of this chapter contains a general description of the pesticide applications category. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation method for pesticide applications, while Section 5 presents alternative emission estimation techniques. Quality assurance/quality control are discussed in Section 6. Data coding procedures are discussed in Section 7, and Section 8 is the reference section.

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2

SOURCE CATEGORY DESCRIPTION

Pesticides are substances used to control nuisance weeds (herbicides), insects (insecticides), fungi (fungicides), and rodents (rodenticides). Pesticides can be broken down into three chemical categories: synthetics, nonsynthetics (petroleum products), and inorganics. Formulations of pesticides are made through the combination of the pest-killing material referred to as the active ingredient, and various solvents (which act as carriers for the pest-killing material) referred to as the inert ingredient. Both types of ingredients contain volatile organic compounds (VOC) that can potentially be emitted to the air either during application or as a result of evaporation. Pesticide applications can be broken down into two user categories: agricultural and nonagricultural (which includes municipal, commercial, and consumer). The criteria pollutant of concern from the application of pesticides is VOC.

Pesticides are used mainly for agricultural applications. Agricultural pesticides are a cost-effective means of controlling weed, insects, and other threats to the quality and yield of food production. Application rates for a particular pesticide may vary from crop to crop and region to region. Application of pesticides can be from the ground or from the air and pesticides can be applied as sprays, dusts, pellets, fogs, or through other dispersion techniques.

Nonagricultural applications are a smaller part of the inventory and include municipal, commercial, and consumer applications. Municipal applications cover state and possibly public institutions such as schools and hospitals, and public recreational areas. Municipal applications can include mosquito control and weed suppression by government agencies, pesticide application at parks, highway department use, utilities maintenance, and pesticide application at railroad right-of-ways. Commercial applications include applications to public and private golf courses and homeowner/business property (yards, dwellings, and buildings) by a commercial exterminator/lawn care service. Consumer applications include homeowner-applied insecticides (*e.g.*, flea and tick sprays, wasp and hornet sprays, lawn and garden insecticides), fungicides and nematocides (*e.g.*, wood preservatives, and mold and mildew retardants), and herbicides (*e.g.*, defoliant herbicides, swimming pool algicides, and aquatic herbicides). As with agricultural applications of pesticides, nonagricultural applications can be from the ground or from the air and pesticides can be applied as sprays, dusts, pellets, fogs, or through other dispersion techniques. Table 9.2-1 provides a summary of municipal usage of pesticides and the suggested organizations to contact for information on usage.

TABLE 9.2-1
MUNICIPAL USAGE OF PESTICIDES

Type of Use	Suggested Organizations to Contact
Publicly-Maintained Golf Courses	Public Parks Department
Public Parks	Public Parks Department
Public Institutions (grounds and gardens)	Public Parks Departments, Institution's Maintenance Departments
Mosquito/Other Pest Control	Public Health Department
Utility Right of Ways	Utility Companies
Roadways	State and Local Highway Departments

2.1 EMISSIONS SOURCES

Approximately 68 to 75 percent of pesticides used in the United States are applied to agricultural lands, both cropland and pasture (Baker and Wilkinson, 1990), (Aspelin *et. al.*, 1991). Of the remaining 25 to 32 percent, 7 to 8 percent are used privately for home and garden pests, and the remaining 18 to 24 percent are used for industrial, commercial, and government purposes.

A wide variety of solvents are used in pesticide formulations. In 1987, according to the Freedonia solvent marketing study, the United States consumed approximately 1,090 million pounds of pesticide formulations. This study estimated that these formulations contained about 570 million pounds of active ingredients and about 520 million pounds of solvents (Freedonia Group, 1989). Both the active ingredient and the solvent emit VOC either during and/or after application.

2.2.1 FACTORS INFLUENCING EMISSIONS

To use pesticides effectively, the most appropriate pesticide formulation, equipment, and application and treatment strategy must be determined. Table 9.2-2 summarizes the different formulations, equipment, and application strategies available. Each of these factors will influence the amount of VOC emitted by the pesticide application being investigated. Limited information is available on the effects of each of these factors on VOC emissions. However, it can be reasoned that solid formulations such as powders, dusts, and pellets will have lower VOC emissions than solutions, concentrates, and aerosols. In addition, pesticides that are applied by equipment that increases the surface area to which the pesticide is applied, such as compressed air sprayers and mist blowers, will have higher VOC emissions per unit of time than small hand dusters and sprayers. Finally, application strategies that increase the area over which the pesticide is applied, such as a broadcast application, will have higher VOC emissions than a strategy that applies the pesticide to a specific part of the plant to be treated, such as in a directed application. Currently there are no federal or state regulations limiting air emissions from pesticide applications.

TABLE 9.2-2

SUMMARY OF FORMULATIONS, EQUIPMENT, AND APPLICATION STRATEGIES

Formulations	<ul style="list-style-type: none"> Emulsifiable Concentrate Solution Flowable Wettable Powder Dry Flowable Soluble Powder Ultra Low Volume Concentrate Low Concentrate Solution Aerosol Invert Emulsion Dust Bait Granule Pellets Micro Encapsulation Water-soluble Packets Impregnates
Equipment	<ul style="list-style-type: none"> Hand Dusters Rotary-type Hand Dusters Knapsack Dusters Power Dusters Compressed Air Sprayers Power Sprayers Hand Sprayers Knapsack Sprayers Mist Blowers
Applications/Treatments	<ul style="list-style-type: none"> Band Basal Broadcast Directed Sequential Serial Spot

3

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATION METHODS

There are several methods available for calculating emissions from pesticide applications. The method chosen is dependent on the type of application (agricultural or nonagricultural), available data, available resources, and the degree of accuracy required for the estimate. Also, selection of the appropriate estimation method depends on the relative significance of emissions from this source in the inventory area and the data quality objectives (DQOs) of the inventory plan. Refer to EIIP Volume VI, *Quality Assurance Procedures*, Sections 2.1 and 2.4 for discussions of inventory categories and DQOs.

This section discusses the methods available for calculating emission estimates from agricultural and nonagricultural pesticide applications and identifies the preferred method of calculation for each category. A discussion of the data elements needed for each method is provided.

3.2 AVAILABLE METHODS

3.2.1 VOLATILE ORGANIC COMPOUNDS

The VOC emitted from agricultural and nonagricultural pesticide applications are from the inert ingredients (*i.e.*, solvent carriers) and the volatile organic constituents of the active ingredients. These VOC are emitted during application and evaporate over time. There are several methods for estimating VOC emissions from both agricultural and nonagricultural application, depending on the data available and the information sought. Table 9.3-1 summarizes these methods. The preferred methods are discussed in Section 4 and alternative methods are discussed in Section 5.

Agricultural Pesticide Applications

Each method (with the exception of the per capita emission factor) requires information on the total area to which the pesticide is applied, the amount of active and inert ingredients in the pesticide, and the application rate. There are several approaches to estimating the amount of VOC emitted from this category, depending on the data available.

TABLE 9.3-1

PREFERRED AND ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS FROM PESTICIDE APPLICATIONS

Methods	Agricultural	Nonagricultural		
		Municipal	Commercial	Consumer
Preferred Method	Gather data from State Agricultural Departments to calculate emissions based on the pesticide applied, the formulation of the pesticide, and the total acres to which the pesticide is applied. The emission factors in this method are based on the vapor pressures of the active ingredients in the pesticides.	Survey State and local government agencies, highway departments, utility companies, and parks offices to gather information on the total acres and the amount of pesticide applied to those acres. The more information on the pesticide that can be found, the more accurate the emission estimate.	Survey commercial pesticide application companies to determine the pesticides used, the formulation of those pesticides, and the amount applied.	Use data from EPA's Consumer Products Survey.
Alternative Method 1	Gather data from State Agricultural Departments to calculate emissions based on the pesticide applied, the formulation of the pesticide, and the total acres to which the pesticide is applied. This method requires data on the VOC content of the active and inert ingredients in the pesticide.	Use a national per capita emission factor. Calculation is for <u>all</u> nonagricultural pesticide applications.	Use a national per capita emission factor. Calculation is for <u>all</u> nonagricultural pesticide applications.	
Alternative Method 2	Gather data from State Agricultural Departments to calculate emissions based on the pesticide applied, the formulation of the pesticide, and the total acres to which the pesticide is applied. This method uses a default for the amount of VOC present in the active ingredient to calculate the total emissions. Use this method if no pesticide-specific data are available.			
Alternative Method 3 (Volatility/Biodegradability)	This method calculates emissions by taking into consideration the volatility and biodegradability of the pesticide. This method can only be used for semi-volatile pesticides and requires detailed information on the formulation of the pesticide. This is the preferred method if this level of information is available from a State Agricultural Department. Emissions are calculated by month.			
Alternative Method 4 (Top-Down Solvent Use)	Apportion national solvents consumption for this source category to counties.			

Nonagricultural Pesticide Applications

For nonagricultural pesticide applications, the methods require information on the total area to which the pesticide is applied, the amount of active and inert ingredients in the pesticide, and the application rate. If no information is available, total nonagricultural emissions can be calculated based on a per capita emission factor. The method used to calculate emissions depends on the type of nonagricultural application method being used (*i.e.*, municipal, commercial, or consumer).

3.2.2 HAZARDOUS AIR POLLUTANTS

Hazardous air pollutant (HAP) emissions from this source are determined by the methods discussed above for VOC emissions. The emissions of each HAP are assumed to be proportional to the amount of HAP used in the pesticide formulation for which the emissions are being calculated.

3.2.3 NATIONAL SOLVENT USE APPORTIONED TO COUNTIES

An alternative method is a material balance top-down approach, starting with total national solvent consumption and apportioning it to counties. This method utilizes national annual solvents consumption for this source category, surrogates for spatial allocation to counties, a method to show growth (if national numbers not for inventory year), knowledge of regulations¹ and recycling and waste management policies.

3.3 DATA NEEDS

3.3.1 DATA ELEMENTS

The data elements needed to calculate emission estimates for pesticide applications depend on the methodology used for data collection and on the methodology used to estimate emissions. The data elements needed for each emission estimation technique are presented in Table 9.3-2.

¹ State any assumptions made to include national/state/local regulations and the exact regulation applied. Clarify any issues related to regulation and control assumptions. The final emissions estimates are **highly** dependent on these assumptions, therefore they must be stated explicitly in all documentation.

TABLE 9.3-2
DATA ELEMENTS NEEDED FOR EACH METHOD

	Agricultural ^a					Nonagricultural ^b			
	Preferred	ALT 1	ALT 2	ALT 3	ALT 4 ^d	Municipal ^c		Commercial ^c	
						Preferred	ALT 1	Preferred	ALT 1
Total acres	x	x	x	x		x			
Pesticide formulation									
Fraction active ingredient	x	x	x			x		x	
Fraction inert ingredient	x	x				x			
Fraction VOC in active ingredient		x				x		x	
Fraction VOC in inert ingredient	x	x				x			
Vapor pressure of active ingredient	x			x					
Amount of pesticide applied per acre	x	x	x	x		x		x	
Average temperature in month of application				x					
Relative humidity during month of application			x						
Water evaporation rate			x						
Vapor pressure of water at average temperature			x						
Area population							x		x
National solvents consumption for this source category					x				

TABLE 9.3-2

(CONTINUED)

	Agricultural ^a				ALT 4 ^d	Nonagricultural ^b			
	Preferred	ALT 1	ALT 2	ALT 3		Municipal ^c		Commercial ^c	
						Preferred	ALT 1	Preferred	ALT 1
Surrogate data for spatial allocation to counties					x				
Growth indicators to adjust activity (if national numbers not for inventory year)					x				
Impact of regulations ^a on emissions					x				
Recycling and waste management					x				
Solvent content factor					x				

^aALT 1 for agricultural applications is the pesticide-specific volatile component of pesticide applied method.

ALT 2 for agricultural applications is the default volatile component of pesticide applied method.

ALT 3 for agricultural applications is the California Air Resources Board method.

^bConsumer pesticide applications should use EPA's 1992 Consumer Products Survey to estimate emissions.

^cALT 1 for municipal applications is the use of national per capita emission factors.

ALT 1 for commercial applications is the use of national per capita emission factors.

^dALT 4 for agricultural applications is the national top-down solvent use method.

Adjustments to Emission Estimates

Adjustments to an emission estimate for pesticide applications may be necessary depending on the type of inventory being prepared. For an annual inventory, adjustments would be made to spatially allocate the emissions to the appropriate counties and any corrections for applicable regulations. Therefore, data will be needed on where the pesticide was used and the appropriate values for rule effectiveness and rule penetration, assuming regulations apply to pesticide applications in the study area. A seasonal inventory will require seasonal corrections as outlined in Section 5.8 of Volume I of *Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone* (EPA-450/4-91-016, May 1991), herein referred to as the *Procedures* document. The correction assumes application through a nine month growing season, six days per week (EPA, 1991). No additional data are required to seasonally adjust an inventory (the default value of 1.3 can be used) unless the pesticide application is not equivalent to the assumptions in the *Procedures* document. Projecting emissions for pesticides requires data on the anticipated changes in the number of acres to which pesticides are being applied in the area of concern.

Information on seasonal activity of the agricultural pesticide usage can also be obtained from agricultural extension offices. Such information may include data on the standard schedules for pesticide and herbicide application and the type of crops grown during the inventory season.

Application of Controls

Historically, control of emissions from pesticide applications have been limited. The use of solid formulations, low volume spray equipment, and direct applications have the potential for reducing the amount of VOC emitted. No states have regulated air emissions from pesticide applications through the controls mentioned, however, these types of regulations are being developed. When considering the effect of these potential rules, both rule effectiveness and rule penetration should be applied to the emission estimate.

3.4 SPATIAL ALLOCATION

The spatial allocation of agricultural pesticide application emissions can be performed by using agricultural data from the State Agricultural Departments. To spatially allocate municipal applications, data should be obtained by surveying various state and local agencies and utility companies that are responsible for applying the pesticide to determine in which county the pesticide was applied. For commercial applications, a survey should be used to pinpoint the county in which the pesticide was used. Finally, for consumer applications, spatial allocation can be accomplished by using local population data.

3.5 TEMPORAL RESOLUTION

3.5.1 SEASONAL APPORTIONING

Emissions from all types of pesticide applications vary from season to season in most areas of the United States. Seasonal throughput or months of application information should be collected so that a seasonal adjustment can be calculated. Section 5.8 of the *Procedures* document contains information and instructions on the methods for calculating a seasonal adjustment factor.

3.5.2 DAILY RESOLUTION

Most agricultural pesticide applications occur either five or six days per week. Municipal and commercial applications also occur five or six days per week. Consumer pesticide applications can take place throughout the entire seven day week. Most pesticide applications, both agricultural and nonagricultural, occur during daylight hours.

3.6 PROJECTING EMISSIONS

Projecting emissions from agricultural and nonagricultural pesticide applications requires information on anticipated changes in the number of acres to which pesticides are applied. However, if no information is available, the inventorying agency can assume no changes to the number of acres treated.

4

PREFERRED METHOD FOR ESTIMATING EMISSIONS

4.1 AGRICULTURAL APPLICATIONS

The preferred method for estimating emissions from agricultural applications of pesticides uses the vapor pressure of the active ingredient to determine the appropriate emission factor, the amount of pesticide applied to an area, and the percent of the active ingredient in the pesticide applied. This method takes into consideration the method by which the pesticide is applied, the type of formulation, and the fact that volatilization is essentially complete within 30 days of application (EPA, 1996).

This method cannot be used for aerial applications. A major factor in losses by aerial application is drift, and neither equations nor experimental data are currently available to permit predictions of these losses or the development of emission factors.

The following procedures should be applied for non-aerial applications:

- (1) Contact State Agricultural Departments to collect data on:
 - The pesticides applied;
 - The amount of pesticide applied by county/nonattainment area;
 - Method of application;
 - The active ingredient(s) in the pesticide applied;
 - The vapor pressure of the active ingredient(s);
 - The type of formulation;
 - The percentage of inert ingredients in the pesticide applied; and
 - The percentage of VOC in the inert ingredients.

Data on the formulations can be found in publications such as the *Farm Chemicals Handbook*² or from the National Agricultural Statistics Service, U.S. Department of Agriculture, Washington, DC (USDA, 1992). If specific data can not be obtained from the state, Tables 9.4-1 through 9.4-4 provide active ingredients for many pesticides, vapor pressures for typical active ingredients, and average VOC content for the inert portion by formulation type.

- (2) Calculate the emissions from the active ingredient of the pesticide applied.

$$E_1 = R \times A \times PA \times EF \quad (9.4-1)$$

where:

E_1	=	emissions from the active ingredient
R	=	pounds of pesticide applied per year per harvested acre
A	=	total harvested acres
PA	=	fraction active ingredient in the pesticide applied
EF	=	emission factor from Table 9.4-4 based on vapor pressure of active ingredient

- 3) Calculate emissions from the inert ingredients in the pesticide applied.

$$E_2 = R \times A \times PI \times PVI \quad (9.4-2)$$

where:

E_2	=	emissions from inert ingredients
R	=	pounds of pesticide applied per year per harvested acre
A	=	total harvested acres
PI	=	fraction inert ingredient in the pesticide applied
PVI	=	fraction VOC in the formulation from Table 9.4-3

² The *Farm Chemicals Handbook* is published annually by Meister Publishing Company, Willoughby, OH.

TABLE 9.4-1

TRADE NAMES FOR SELECTED ACTIVE INGREDIENTS^a

Trade Name ^b	Active Ingredient ^c
Insecticides	
AC 8911	Phorate
Acephate-met	Methamidophos
Alkron [®]	Ethyl Parathion
Alleron [®]	Ethyl Parathion
Aphamite [®]	Ethyl Parathion
Bay 17147	Azinphos-methyl
Bay 19639	Disulfoton
Bay 70143	Carbofuran
Bay 71628	Methamidophos
Benzoepin	Endosulfan
Beosit [®]	Endosulfan
Brodan [®]	Chlorpyrifos
BugMaster [®]	Carbaryl
BW-21-Z	Permethryn
Carbamine [®]	Carbaryl
Carfene [®]	Azinphos-methyl
Cekubaryl [®]	Carbaryl
Cekudifol [®]	Dicofol
Cekuthoate [®]	Dimethoate
CGA-15324	Profenofos
Chlorpyrifos 99%	Chlorpyrifos
Chlorthiepin [®]	Endosulfan

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
Comite [®]	Propargite
Corothion [®]	Ethyl Parathion
Crisulfan [®]	Endosulfan
Crunch [®]	Carbaryl
Curacron	Profenofos
Curaterr [®]	Carbofuran
Cyclodan [®]	Endosulfan
Cygon 400 [®]	Dimethoate
D1221	Carbofuran
Daphene [®]	Dimethoate
Dazzel [®]	Diazinon
Denapon [®]	Carbaryl
Devicarb [®]	Carbaryl
Devigon [®]	Dimethoate
Devisulphan [®]	Endosulfan
Devithion [®]	Methyl Parathion
Diagran [®]	Diazinon
Dianon [®]	Diazinon
Diaterr-Fos [®]	Diazinon
Diazajet [®]	Diazinon
Diazatol [®]	Diazinon
Diazide [®]	Diazinon
Dicarbam [®]	Carbaryl
Dicomite [®]	Dicofol

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
Dimethogen [®]	Dimethoate
Dimet [®]	Dimethoate
Dizinon [®]	Diazinon
DPX 1410	Oxamyl
Dyzol [®]	Diazinon
E-605	Ethyl Parathion
Ectiban [®]	Permethryn
Endocide [®]	Endosulfan
Endosol [®]	Endosulfan
ENT 27226	Propargite
ENT27164	Carbofuran
Eradex [®]	Chlorpyrifos
Ethoprop	Ethoprop
Ethoprophos	Ethoprop
Ethylthiodemeton	Disulfoton
Etilon [®]	Ethyl Parathion
Fezudin	Diazinon
FMC-5462	Endosulfan
FMC-33297	Permethryn
Fonofos	Dyfonate
Force [®]	Tefluthrin
Fosfamid	Dimethoate
Furacarb [®]	Carbofuran
G-24480	Diazinon

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
Gardentox [®]	Diazinon
Gearphos [®]	Methyl Parathion
Golden Leaf Tobacco Spray [®]	Endosulfan
Hexavin [®]	Carbaryl
Hoe 2671	Endosulfan
Indothrin [®]	Permethryn
Insectophene [®]	Endosulfan
Insyst-D [®]	Disulfoton
Karbaspray [®]	Carbaryl
Kayazinon [®]	Diazinon
Kayazol [®]	Diazinon
Kryocide [®]	Cryolite
Lannate [®] LV	Methomyl
Larvin [®]	Thiodicarb
Metafos	Methyl Parathion
Metaphos [®]	Methyl Parathion
Methomex [®]	Methomyl
Methyl	Methyl Parathion
Metiltriazotion	Azinphos-methyl
Nipsan [®]	Diazinon
Niran [®]	Ethyl Parathion
Nivral [®]	Thiodicarb
NRDC 143	Permethryn
Ortho 124120	Acephate

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
Orthophos [®]	Ethyl Parathion
Panthion [®]	Ethyl Parathion
Paramar [®]	Ethyl Parathion
Paraphos [®]	Ethyl Parathion
Parathene [®]	Ethyl Parathion
Parathion	Methyl Parathion
Parathion	Ethyl Parathion
Parawet [®]	Ethyl Parathion
Partron M [®]	Methyl Parathion
Penncap-M [®]	Methyl Parathion
Phoskil [®]	Ethyl Parathion
Piridane [®]	Chlorpyrifos
Polycron [®]	Profenofos
PP 557	Permethryn
Pramex [®]	Permethryn
Prokil [®]	Cryolite
PT265 [®]	Diazinon
Qamlin [®]	Permethryn
Rampart [®]	Phorate
Rhodiatox [®]	Ethyl Parathion
S276	Disulfoton
SD 8530	Trimethacarb
Septene [®]	Carbaryl
Sevin 5 Pellets [®]	Carbaryl

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
Soprathion [®]	Ethyl Parathion
Spectracide [®]	Diazinon
SRA 5172	Methamidophos
Stathion [®]	Ethyl Parathion
Tekwaisa [®]	Methyl Parathion
Temik [®]	Aldicarb
Tercyl [®]	Carbaryl
Thimul [®]	Endosulfan
Thiodan	Endosulfan
Thiofor [®]	Endosulfan
Thiophos	Ethyl Parathion
Tricarnam [®]	Carbaryl
Trimetion [®]	Dimethoate
UC 51762	Thiodicarb
UC 27867	Trimethacarb
Uniroyal D014	Propargite
Yaltox [®]	Carbofuran
None listed	Dicrotophos
None listed	Terbufos
Herbicides	
A-4D	2,4-D
AC 92553	Pendimethalin
Acclaim	Fenoxaprop-ethyl
Acme MCPA Amine 4 [®]	MCPA

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
Aljaden [®]	Sethoxydim
Amiben [®]	Chloramben
Amilon [®] -WP	Chloramben
Amine [®]	MCPA
Aqua-Kleen [®]	2,4-D
Arrhenal [®]	DSMA
Arsinyl [®]	DSMA
Assure [®]	Quizalofop-ethyl
Avadex [®] BW	Triallate
Banlene Plus [®]	MCPA
Banvel [®]	Dicamba
Barrage [®]	2,4-D
Basagran	Bentazon
Bay 30130	Propanil
Bay DIC 1468	Metribuzin
Bay 94337	Metribuzin
Benefex [®]	Benefin
Benfluralin	Benefin
Bentazon	Bentazon
Bethrodine	Benefin
BH [®] MCPA	MCPA
Bioxone [®]	Methazole
Blazer [®]	Acifluorfen
Bolero [®]	Thiobencarb

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
Border-Master [®]	MCPA
Brominex [®]	Bromoxynil
C-2059	Fluometuron
Cekuiron [®]	Diuron
Cekuquat [®]	Paraquat
Cekusima [®]	Simazine
CGA-24705	Metolachlor
Checkmate [®]	Sethoxydim
Chloroxone [®]	2,4-D
Classic [®]	Chlorimuron-ethyl
Clomazone	Clomazone
Command [®]	Clomazone
CP50144	Alachlor
Crisuron [®]	Diuron
Croprider [®]	2,4-D
Dacthal [®]	DCPA
Dailon [®]	Diuron
Depon [®]	Fenoxaprop-ethyl
Dextrone [®]	Paraquat
Di-Tac [®]	DSMA
Diater [®]	Diuron
DMA	DSMA
DMA-100 [®]	DSMA
DPA	Propanil

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
DPX-Y6202	Quizalofop-ethyl
EL-110	Benefin
EL-161	Ethalfluralin
Emulsamine [®]	2,4-D
Esgram [®]	Paraquat
Excel [®]	Fenoxaprop-ethyl
EXP-3864	Quizalofop-ethyl
Expand [®]	Sethoxydim
Far-Go [®]	Triallate
Farmco Diuron [®]	Diuron
Farmco Atrazine Gesaprim [®]	Atrazine
Fervinal [®]	Sethoxydim
Ferxone [®]	2,4-D
Furore [®]	Fenoxaprop-ethyl
Fusilade 2000	Fluazifop-p-butyl
G-30027	Atrazine
G-34161	Prometryn
G-34162	Ametryn
Gamit [®]	Clomazone
Genate Plus [®]	Butylate
Glyphosate Isopropylamine Salt	Glyphosate
Goldquat [®] 276	Paraquat
Grasidim [®]	Sethoxydim
HerbAll [®]	MSMA

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
Herbaxon [®]	Paraquat
Herbixol [®]	Diuron
Higalcoton [®]	Fluometuron
Hoe 002810	Linuron
Hoe-023408	Diclofop-methyl
Hoe-Grass [®]	Diclofop-methyl
Hoelon [®]	Diclofop-methyl
Illoxan [®]	Diclofop-methyl
Kilsem [®]	MCPA
Lasso [®]	Alachlor
Lazo [®]	Alachlor
Legumex Extra [®]	MCPA
Lexone [®] 4L	Metribuzin
Lexone [®] DF [®]	Metribuzin
Linorox [®]	Linuron
LS 801213	Acifluorfen
M.T.F. [®]	Trifluralin
Magister [®]	Clomazone
Mephanac [®]	MCPA
Merge 823 [®]	MSMA
Methar [®] 30	DSMA
Mezopur [®]	Methazole
Monosodium methane arsenate	MSMA
Nabu [®]	Sethoxydim

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
Option [®]	Fenoxaprop-ethyl
Oxydiazol	Methazole
Paxilon [®]	Methazole
Pillarquat [®]	Paraquat
Pillarxone [®]	Paraquat
Pillarzo [®]	Alachlor
Pilot [®]	Quizalofop-ethyl
Plantgard [®]	2,4-D
Pledge [®]	Bentazon
PP 005	Fluazifop-p-butyl
Primatol Q [®]	Prometryn
Probe	Methazole
Prop-Job [®]	Propanil
Propachlor	Propachlor
Prowl [®]	Pendimethalin
Rattler [®]	Glyphosate
RH-6201	Acifluofen
Rodeo [®]	Glyphosate
Roundup [®]	Glyphosate
S 10145	Propanil
Sarclex [®]	Linuron
Saturno [®]	Thiobencarb
Saturn [®]	Thiobencarb
Scepter [®]	Imazaquin

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
SD 15418	Cyanazine
Sencor [®] 4	Metribuzin
Sencor [®] DF	Metribuzin
Shamrox [®]	MCPA
Sodar [®]	DSMA
Sonalan [®]	Ethalfuralin
Squadron [®]	Imazaquin
Squadron [®]	Pendimethalin
Strel [®]	Propanil
Surpass [®]	Vernolate
Targa [®]	Quizalofop-ethyl
Target MSMA [®]	MSMA
Telok [®]	Norflurazon
Tigrex [®]	Diuron
Total [®]	Paraquat
Toxer [®]	Paraquat
Trans-Vert [®]	MSMA
Tri-4 [®]	Trifluralin
Tri-Scept [®]	Imazaquin
Tributon [®]	2,4-D
Trifluralina 600 [®]	Trifluralin
Trinatox D [®]	Ametryn
Tritex-Extra [®]	Sethoxydim
Tunic [®]	Methazole

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
Unidron [®]	Diuron
VCS 438	Methazole
Vegiben [®]	Chloramben
Vernam 10G	Vernolate
Vernam 7E	Vernolate
Vonduron [®]	Diuron
Weed-Rhap [®]	MCPA
Weed-B-Gon [®]	2,4-D
Weedatul [®]	2,4-D
Weedtrine-II [®]	2,4-D
Whip [®]	Fenoxaprop-ethyl
WL 19805	Cyanazine
Zeaphos [®]	Atrazine
Zelan [®]	MCPA
None listed	EPTC
None listed	Fomesafen
None listed	Molinate
None listed	Tridiphane
Other Active Ingredients	
A7 Vapam [®]	Metam Sodium
Aquacide [®]	Diquat
Avicol [®]	PCNB
Carbam (MAF)	Metam Sodium
Clortocaf Ramato [®]	Chlorothalonil

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
Clortosip [®]	Chlorothalonil
Cotton Aide HC [®]	Cacodylic
De-Green [®]	Tribufos
DEF [®]	Tribufos
Deiquat	Diquat
Dextrone [®]	Diquat
E-Z-Off D [®]	Tribufos
Earthcide [®]	PCNB
Exotherm Termil [®]	Chlorothalonil
Folex [®]	Tribufos
Folosan [®]	PCNB
Fos-Fall A [®]	Tribufos
Karbation [®]	Metam Sodium
Kobutol [®]	PCNB
Kobu [®]	PCNB
Kypman [®] 80	Maneb
M-Diphar [®]	Maneb
Mancozin [®]	Mancozeb
Maneba [®]	Maneb
Manebe	Maneb
Manzate [®] 200	Mancozeb
Manzeb	Mancozeb
Manzin [®]	Mancozeb
Maposol [®]	Metam Sodium

TABLE 9.4-1 (CONTINUED)

Trade Name ^b	Active Ingredient ^c
Metam for the Acid	Metam Sodium
Moncide [®]	Cacodylic
Montar [®]	Cacodylic
Nemisor [®]	Mancozeb
Pentagen [®]	PCNB
Quintozone	PCNB
Rad-E-Cate [®] 25	Cacodylic
Reglon	Diquat
Riozeb [®]	Mancozeb
RTU [®] PCNB	PCNB
Sectagon [®] II	Metam Sodium
SMDC	Metam Sodium
Soil-Prep [®]	Metam Sodium
Sopranebe [®]	Maneb
Superman [®] Maneb F	Maneb
Terrazan [®]	PCNB
Tersan 1991 [®]	Benomyl
TriPCNB [®]	PCNB
Tubothane [®]	Maneb
Weedtrine-D [®]	Diquat
Ziman-Dithane [®]	Mancozeb
None listed	Dimethipin
None listed	Ethephon
None listed	Thiadiazuron

^a From *Farm Chemicals Handbook*. See the USDA publication on Agricultural Chemical Usage (USDA, 1992) for selected pesticides used on major field crops.

^b From *Farm Chemicals Handbook*.

^c Common names. See *Farm Chemicals Handbook* for chemical names.

TABLE 9.4-2
VAPOR PRESSURES OF SELECTED ACTIVE INGREDIENTS^a

Active Ingredient	Vapor Pressure (mm Hg at 20 to 25 °C)
1,3-Dichloropropene	29
2,4-D acid	8.0×10^{-6}
Acephate	1.7×10^{-6}
Alachlor	1.4×10^{-5}
Aldicarb	3.0×10^{-5}
Aldoxycarb	9×10^{-5}
Amitraz	2.6×10^{-6}
Amitrole (aminotriazole)	4.4×10^{-7}
Atrazine	2.9×10^{-7}
Azinphos-methyl	2.0×10^{-7}
Benefin (benfluralin)	6.6×10^{-5}
Benomyl	$< 1.0 \times 10^{-10}$
Bifenox	2.4×10^{-6}
Bromacil acid	3.1×10^{-7}
Bromoxynil butyrate ester	1.0×10^{-4}
Butylate	1.3×10^{-2}
Captan	8.0×10^{-8}
Carbaryl	1.2×10^{-6}
Carbofuran	6.0×10^{-7}
Chlorobenzilate	6.8×10^{-6}
Chloroneb	3.0×10^{-3}
Chloropicrin	18
Chlorothalonil	1.0×10^{-3} (estimated)
Chlorpyrifos	1.7×10^{-5}
Clomazone (dimethazone)	1.4×10^{-4}
Cyanazine	1.6×10^{-9}
Cyromazine	3.4×10^{-9}

TABLE 9.4-2 (CONTINUED)

Active Ingredient	Vapor Pressure (mm Hg at 20 to 25° C)
DCNA (dicloran)	1.3×10^{-6}
DCPA (chlorthal-dimethyl; Dacthal®)	2.5×10^{-6}
Diazinon	6.0×10^{-5}
Dichlobenil	1.0×10^{-3}
Dicofol	4.0×10^{-7}
Dicrotofos	1.6×10^{-4}
Dimethoate	2.5×10^{-5}
Dinocap	4.0×10^{-8}
Disulfoton	1.5×10^{-4}
Diuron	6.9×10^{-8}
Endosulfan	1.7×10^{-7}
EPTC	3.4×10^{-2}
Ethalfluralin	8.8×10^{-5}
Ethion	2.4×10^{-6}
Ethoprop (ethoprophos)	3.8×10^{-4}
Fenamiphos	1.0×10^{-6}
Fenthion	2.8×10^{-6}
Fluometuron	9.4×10^{-7}
Fonofos	3.4×10^{-4}
Isofenphos	3.0×10^{-6}
Lindane	3.3×10^{-5}
Linuron	1.7×10^{-5}
Malathion	8.0×10^{-6}
Methamidophos	8.0×10^{-4}
Methazole	1.0×10^{-6}
Methiocarb (mercaptodimethur)	1.2×10^{-4}
Methomyl	5.0×10^{-5}

TABLE 9.4-2 (CONTINUED)

Active Ingredient	Vapor Pressure (mm Hg at 20 to 25 °C)
Methyl parathion	1.5×10^{-5}
Metolachlor	3.1×10^{-5}
Metribuzin	$< 1.0 \times 10^{-5}$
Mevinphos	1.3×10^{-4}
Molinate	5.6×10^{-3}
Naled	2.0×10^{-4}
Norflurazon	2.0×10^{-8}
Oxamyl	2.3×10^{-4}
Oxyfluorfen	2.0×10^{-7}
Parathion (ethyl parathion)	5.0×10^{-6}
PCNB	1.1×10^{-4}
Pendimethalin	9.4×10^{-6}
Permethrin	1.3×10^{-8}
Phorate	6.4×10^{-4}
Phosmet	4.9×10^{-7}
Profenofos	9.0×10^{-7}
Prometon	7.7×10^{-6}
Prometryn	1.2×10^{-6}
Propachlor	2.3×10^{-4}
Propanil	4.0×10^{-5}
Propargite	3.0×10^{-3}
Propazine	1.3×10^{-7}
Propoxur	9.7×10^{-6}
Siduron	4.0×10^{-9}
Simazine	2.2×10^{-8}
Tebuthiuron	2.0×10^{-6}
Terbacil	3.1×10^{-7}
Terbufos	3.2×10^{-4}

TABLE 9.4-2 (CONTINUED)

Active Ingredient	Vapor Pressure (mm Hg at 20 to 25 °C)
Thiobencarb	2.2×10^{-5}
Thiodicarb	1.0×10^{-7}
Toxaphene	4.0×10^{-6}
Triallate	1.1×10^{-4}
Tribufos	1.6×10^{-6}
Trichlorfon	2.0×10^{-6}
Trifluralin	1.1×10^{-4}
Triforine	2.0×10^{-7}

^a From Wauchope, *et al.*, 1992. Vapor pressures of other pesticide active ingredients can also be found there.

TABLE 9.4-3

**AVERAGE VOC CONTENT OF PESTICIDE INERT INGREDIENT
PORTION, BY FORMULATION TYPE^a**

Formulation Type	Average VOC Content Of Inert Portion (wt. %)
Oils	66
Solution/liquid (ready to use)	20
Emulsifiable concentrate	56
Aqueous concentrate	21
Gel, paste, cream	40
Pressurized gas	29
Flowable (aqueous) concentrate	21
Microencapsulated	23
Pressurized liquid/sprays/foggers	39
Soluble powder	12
Impregnated material	38
Pellet/tablet/cake/briquette	27

TABLE 9.4-3 (CONTINUED)

Formulation Type	Average VOC Content Of Inert Portion (wt. %)
Wettable powder	25
Dust/powder	21
Dry flowable	28
Granule/flake	25
Suspension	15
Paint/coatings	64

^a Written communication from California Environmental Protection Agency, Department of Pesticide Regulation, Sacramento, CA, to D. Safriet, U.S. Environmental Protection Agency, Research Triangle Park, NC. December 6, 1993.

TABLE 9.4-4
UNCONTROLLED EMISSION FACTORS FOR
PESTICIDE ACTIVE INGREDIENTS^a
(METRIC AND ENGLISH UNITS)

EMISSION FACTOR RATING: E

Vapor Pressure Range (mm Hg at 20° to 25°C) ^b	Emission Factor ^c	
	kg/Mg	lb/ton
Surface application (SCC 24-61-800-001)		
1 x 10 ⁻⁴ to 1 x 10 ⁻⁶	350	700
>1 x 10 ⁻⁴	580	1,160
Soil incorporation (SCC 24-61-800-002)		
<1 x 10 ⁻⁶	2.7	5.4
1 x 10 ⁻⁴ to 1 x 10 ⁻⁶	21	42
>1 x 10 ⁻⁴	52	104

^a Factors are functions of application method and vapor pressure. SCC = Source Classification Code.

^b See Wauchope *et al.*, 1992 for vapor pressures of specific active ingredients.

^c Based on Jury, *et al.*, 1983a, Jury, *et al.*, 1983b, Jury, *et al.*, 1984a, Jury, *et al.*, 1984b, and Midwest Research Institute, 1994. Expressed as equivalent weight of active ingredients volatilized/unit weight of active ingredients applied.

(4) Calculate the total emissions

$$E = E_1 + E_2 \quad (9.4-3)$$

where:

E = total emissions from pesticide applied during the 30 day period
 E_1 = emissions from active ingredient
 E_2 = emissions from inert ingredients

The 30-day period was chosen because (1) most pesticides volatilize within 30 days of application and (2) there are very few data available on pesticide volatilization based on field application studies with sampling times greater than 30 days.

Example 9.4-1 Farmco Atrazine Gesaprim[®] is surface applied to the soil surrounding corn at an annual rate of 3.5 lbs/year/acre. There are 15,000 acres of corn in the area.

From Table 9.4-1, Gesaprim[®]'s active ingredient is atrazine, with a vapor pressure (from Table 9.4-2) of 2.9×10^{-7} mm Hg at 20° to 25°C. The pesticide is an emulsifiable concentrate that is 52 percent active ingredient and 48 percent inert ingredient. From Table 9.4-4, the emission factor is 700 lb/ton and from Table 9.4-3, the VOC content of the inert portion of emulsifiable concentrates is 56 percent.

$$E_1 = 3.5 \text{ lbs/year/acre} \times 15,000 \text{ acres} \times 1 \text{ ton}/2000 \text{ lbs} \times 0.52 \times 700 \text{ lb/ton} = 9,555 \text{ lbs/year}$$

$$E_2 = 3.5 \text{ lbs} \times 15,000 \text{ acres} \times 0.48 \times 0.56 = 14,112 \text{ lbs/year}$$

4.2 NONAGRICULTURAL APPLICATIONS

4.2.1 MUNICIPAL

The preferred method for estimating emissions from municipal applications of pesticides involves using a survey to collect data on the pesticide use and total acreage. The following procedures should be followed:

- (1) Survey state and local government agencies, state and local highway departments, local utility companies, and state and local park offices to determine:
 - The amount of pesticides applied per acre;
 - Total acres (parks, right-of-ways, etc.);
 - The pesticides applied to those acres;
 - The percent active and inert ingredients in the pesticides applied;
 - The VOC content of the active and inert ingredients; and
 - Times of year in which the pesticide was applied.
- (2) Calculate a pesticide-specific VOC content for each pesticide that is applied in the study area.

$$PVP = (PA \times PVA) + (PI \times PVI) \quad (9.4-4)$$

where:

PVP	=	pounds VOC per pound of pesticide applied
PA	=	fraction active ingredient in the pesticide applied
PVA	=	fraction VOC in the active ingredient of the pesticide applied
PI	=	fraction inert ingredient in the pesticide applied
PVI	=	fraction VOC in the inert ingredient of the pesticide applied

- (3) Using the pesticide-specific VOC content developed with equation 9.4-4, calculate the total emissions.

$$\text{Total emissions} = PVP \times R \times A \times ER \quad (9.4-5)$$

where:

PVP	=	pounds VOC per pound of pesticide applied
R	=	pounds of pesticide applied per year per acre
A	=	total acres
ER	=	evaporation rate (typically 0.9) (Wiens, 1977)

The seasonal adjustment factor should be calculated based on the information in Section 5.8 of the *Procedures* document.

Example 9.4-2 Assume County X has 1,000 acres of park land and 300 acres of other municipal land. Pesticide A is applied to 1,100 acres (900 acres of park land plus 200 acres of municipal land), and is 47 percent active ingredient (90 percent VOC) and 53 percent inert ingredient (60 percent VOC). Pesticide A is applied at 1.5 lbs per acre per year. Using Equations 9.4-4 and 9.4-5, emissions for County X are calculated as follows:

$$\text{PVP} = (0.47 \times 0.90) + (0.53 \times 0.60) = 0.741 \text{ lbs VOC per lb Pesticide A}$$

$$\text{Total emissions} = 0.741 \text{ lb VOC/lb Pesticide A} \times 1.5 \text{ lbs Pesticide A/acre/yr} \times 1,100 \text{ acres} \times 0.9$$

$$\text{Total emissions} = 1,100 \text{ lb VOC/yr} = 0.55 \text{ tons VOC/yr}$$

The *Procedures* document assumes that the inert ingredient (solvent carrier) in the pesticide is 1.45 times the active ingredient (the amount of which can be found for most pesticides). Therefore, 2.45 times the active ingredient has the potential to be emitted as a VOC. The method in the *Procedures* document also assumes that 2 to 5 pounds of pesticide are applied per year per acre (average of 3.5 pounds of pesticide per year per acre). This range was derived from national pesticide use data, and can be used as a default or a check for the specific application rate, if necessary. Therefore, where the survey does not provide enough detail, the defaults of 2.45 pounds of VOC per pound of active ingredient and an average of 3.5 pounds of pesticide per year per acre can be used. However, at a minimum, the survey must provide information on the amount of active ingredients in the pesticides applied. Equation 9.4-6 shows the calculation used in this approach.

$$\text{Total emissions} = R \times \text{PA} \times \text{PVP} \times A \times \text{ER} \quad (9.4-6)$$

where:

- R = pounds of pesticide applied per year per acre (in this approach, R = 3.5 pounds of pesticide per year, per acre)
- PA = fraction active ingredient in the pesticide
- PVP = pounds VOC per pound of active ingredient (in the approach, PVP = 2.45 pounds of VOC per pound of active ingredient)
- A = total acres
- ER = evaporation rate (typically 0.9) (Wiens, 1977)

Example 9.4-3 Again, assume County X has 1,100 acres of park and municipal land. However, while the survey did not provide any information on the application rate, it did indicate that 41 percent of the pesticide is active ingredient. Using default assumptions (2.45 pounds VOC per pound active ingredient and 3.5 pounds pesticide applied per year per acre), the calculation of total emissions is as follows:

$$\text{Total emissions} = 3.5 \text{ lb pesticide/yr/acre} \times 0.41 \text{ lbs active ingredient/lb pesticide} \times 2.45 \text{ lb VOC/lb active ingredient} \times 1,100 \text{ acres} \times 0.9$$

$$\text{Total emissions} = 3,481 \text{ lb VOC/yr} = 1.74 \text{ tons VOC/yr}$$

4.2.2 COMMERCIAL

The preferred method for estimating emissions from commercial applications of pesticides is to conduct a survey to gather information on each commercial pesticide application company. The following procedure should be used:

- (1) Survey commercial pesticide application companies (exterminators and lawn care services) to determine the pesticides used, the formulation of the pesticides (indicating the active and inert ingredients), and the total amount applied in a given period.
- (2) Calculate total emissions based on the information gathered in Step (1).

$$\text{Total emissions} = R \times PA \times PVA \times ER \quad (9.4-7)$$

where:

- R = pounds of pesticide applied per year
- PA = fraction active ingredient in the pesticide applied
- PVA = fraction VOC in the active ingredient or 2.45 pounds VOC per pound of active ingredient
- ER = evaporation rate (typically 0.9) (Wiens, 1977)

If R is given in gallons, it will be necessary to convert to pounds by multiplying by the density of the pesticide. The density of the pesticide should be available from the manufacturer.

Example 9.4-4 An area surveys commercial pesticide application companies and determines that 1,500 gallons of pesticide X are used to eliminate fleas and ticks and 10,000 pounds of pesticide Y are used for lawn weed control. Pesticide X is 50 percent active ingredient. Pesticide Y is 45 percent active ingredient. Pesticide X has a density of 7.2 pounds per gallon. Using the Equation 9.4-7, total emissions are calculated as follows:

Total emissions of X = $1,500 \text{ gal/yr} \times 7.2 \text{ lbs/gal} \times 0.5 \text{ lbs active ingredient/lb pesticide} \times 2.45 \text{ lbs VOC/lb active ingredient} \times 0.9$

Total emissions of X = $11,907 \text{ lbs VOC/yr} = 5.95 \text{ tons VOC/yr}$

Total emissions of Y = $10,000 \text{ lbs/yr} \times 0.45 \text{ lbs active ingredient/lb pesticide} \times 2.45 \text{ lbs VOC/lb active ingredient} \times 0.9$

Total emissions of Y = $9,923 \text{ lbs VOC/yr} = 4.96 \text{ tons VOC/yr}$

Total emissions for area = $11,907 \text{ lbs VOC/yr} + 9,923 \text{ lbs VOC/yr} = 21,830 \text{ lbs VOC/yr} = 10.9 \text{ tons VOC/yr}$

4.2.3 CONSUMER

Limited information is available on consumer use of pesticides. In 1992, EPA conducted a consumer/commercial products survey to determine the number of products, the sales of those products, and the VOC content of the products. From these data, EPA calculated estimates of emissions for specific product categories in pounds per 10,000 people and in tons for nonattainment areas. Chapter 5 of this volume titled *Consumer and Commercial Solvent Use* includes per capita emission factors for pesticide application. However, these per capita factors are based on a wide range of uses including consumer, municipal, and commercial. Multiplying the emission factor by the population yields total pesticides applied. Subtracting municipal and commercial use (using any of the methods described in this chapter) yields estimates of consumer usage.

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5

ALTERNATE METHODS FOR ESTIMATING EMISSIONS

5.1 AGRICULTURAL APPLICATIONS

5.1.1 PESTICIDE-SPECIFIC VOLATILE COMPONENT OF PESTICIDE APPLIED

This alternative method for estimating emissions from agricultural applications of pesticides uses a pesticide-specific volatile component of the pesticide, total acreage, and application rate. The following procedures should be followed:

- (1) Collect data on:
 - The total harvested acreage by crop in the study area;
 - The pesticides used for each crop;
 - The time of year when the pesticide is typically applied to the crop. If the application time is not during the inventory season, it may not be necessary to estimate emissions for that pesticide;
 - The application rate of each pesticide for each crop; and
 - The percent active and inert ingredients and the VOC contents of each ingredient for each pesticide used.

Some states may gather this information periodically, mainly on an annual basis. In addition, many states publish an annual handbook which contains suggested pesticides for a particular crop and suggested application rates. When this information is not already compiled, it can be collected from other sources. Acreage by crop data can be found in the following sources:

- The Department of Commerce Bureau of Census publication *Census of Agriculture*² includes county level harvested acres by crop and other data that can be helpful in estimating emissions. However, the *Census of Agriculture* is published at 5 year intervals for years ending in “2” and “7” and may not be available for the inventory year. Inventory preparers will need to decide whether the data in this publication is suitable for their inventory area.
- The United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS)³ maintains county statistics on production for major crops and farm acreage.
- State agricultural departments and state commerce departments may also compile the acreage of major crops in each county.

Although detailed information about the type of pesticide used, the time of application and the pesticide-specific application rate for each county’s crops may not be available, reasonable estimates can be made based on local recommended practices. It is best to identify crops that have either high rates of pesticide use or are the most significant crops in the area, so that inventory personnel can focus their efforts on crops that are the most significant sources of emissions in their area. Local agricultural extension agents can discuss the typical pesticide treatment, application time, and application rate. Agricultural chemical suppliers can discuss the recommended practices for the major crops in an area. State universities with agricultural schools also can be contacted for recommended pesticide usage practices. When several counties in an inventory area have similar crops, only one contact may be necessary to collect data on all of the crops and pesticides.

Agricultural extension agents, agricultural chemical suppliers, and agricultural university experts may also be sources of information about total VOC content of the pesticides used in the area.

- (2) Calculate the pesticide-specific VOC content of the pesticide applied.

$$PVP = (PA \times PVA) + (PI \times PVI) \quad (9.5-1)$$

² The *Census of Agriculture* is published every 5 years by the U.S. Department of Commerce, Bureau of Census, Washington, D.C. Information about the Census can also be found on the Bureau of Census Website at: <http://www.census.gov/>.

³ At the time of this writing, NASS maintains a World Wide Web site at: <http://www.usda.gov.nass/>. Links are available to state offices. NASS can also be contacted through the NASS Information Hotline at: 1-800-727-9540.

where:

PVP = pounds VOC per pound of pesticide applied
 PA = fraction active ingredient in the pesticide applied
 PVA = fraction VOC in the active ingredient in the pesticide applied
 PI = fraction inert ingredient in the pesticide applied
 PVI = fraction VOC in the inert ingredient in the pesticide applied

- (3) Using the pesticide-specific VOC content developed in Step (2), calculate the total emissions.

$$\text{Total emissions} = \text{PVP} \times \text{R} \times \text{A} \times \text{ER} \quad (9.5-2)$$

where:

PVP = pounds VOC per pound of pesticide applied
 R = pounds of pesticide applied per year per harvested acre
 A = total harvested acres
 ER = evaporation rate (typically 0.9) (Wiens, 1977)

This procedure would be followed for each pesticide and each crop for which it is used.

Example 9. 5-1 Pesticide A is applied to corn at an annual rate of 3.8 lbs/year/acre. There are 2,100 acres of corn in the area. Pesticide A is 47 percent active ingredient (90 percent VOC) and 53 percent inert ingredient (60 percent VOC).

Using the above equations, total emissions from Pesticide A applied to corn in this area are calculated as follows:

$$\text{PVP} = (0.47 \times 0.90) + (0.53 \times 0.60) = 0.741 \text{ lbs VOC/lb Pesticide A applied}$$

$$\text{Total emissions} = 0.741 \text{ lbs VOC/lb Pesticide A} \times 3.8 \text{ lbs Pesticide A/yr/acre} \times 2,100 \text{ acres} \times 0.9$$

$$\text{Total emissions} = 5,322 \text{ lbs VOC/yr} = 2.7 \text{ tons VOC/yr}$$

5.1.2 DEFAULT VOLATILE ORGANIC COMPONENT OF PESTICIDE APPLIED

Another alternative method for estimating emissions is to use a default for the VOC content of the pesticide. This method also requires the use of total acreage and application rate. The following procedures should be followed:

- (1) Contact State Agricultural Departments to collect data on:
 - The total harvested acreage by crop in the county/nonattainment area;
 - The pesticides used for each crop;
 - The application rate of each pesticide for each crop; and
 - The percent active ingredient for each pesticide used.
- (2) Calculate the total emissions using the information gathered in Step (1). The *Procedures* document assumes that the inert ingredient (solvent carrier) in the pesticide is 1.45 times the active ingredient (the amount of which can be found for most pesticides) (EPA, 1991). Therefore, 2.45 times the active ingredient has the potential to be emitted as a VOC. The following equation is the same as the equation for the preferred method; however, a default VOC content of 2.45 pounds VOC per pound active ingredient is assumed in place of the pesticide-specific VOC content (PVP).

$$\text{Total emissions} = A \times R \times I \times ER \times 2.45 \text{ pounds VOC/pound active ingredient} \quad (9.5-3)$$

where:

A	=	total harvested acres
R	=	pounds of pesticide applied per year per harvested acre
I	=	pounds of active ingredient per pound of pesticide
ER	=	evaporation rate (typically 0.9) (Wiens, 1977)

Again, this procedure would be followed for each pesticide and each crop for which it is used.

Example 9.5-2 Assume an area has 800,000 acres of corn and 2.9 lbs of pesticide are applied per year per harvested acre. The pesticide contains 0.8 lbs of active ingredient (AI) per lb of pesticide (P).

Using the equation above, total emissions are calculated as follows:

Total emissions = $800,000 \text{ acres} \times 2.9 \text{ lbs P/acre} \times 0.8 \text{ lbs AI/lb P} \times 2.45 \text{ lbs VOC/lb AI} \times 0.9$

Total emissions = $4,092,480 \text{ lbs VOC/yr} = 2,046 \text{ tons VOC/yr}$

The method in the *Procedures* document assumes that 2 to 5 lbs of pesticide are applied per year per harvested acre (average of 3.5 lbs of pesticide per year per harvested acre). This range was derived from national pesticide use data, and can be used as a default or a check for the specific application rate, if necessary.

5.1.3 VOLATILITY/BIODEGRADABILITY METHOD

The final alternative method for calculating emissions takes into consideration the volatility and the biodegradability of the pesticide (CARB, 1991). The data that are used in the methodology are available through the California Department of Food and Agriculture's Pesticide Use Report. The methodology classifies pesticides into the following four categories:

- Very low volatility pesticides;
- High volatility pesticides;
- Semi-volatile pesticides that are highly absorbed; and
- Semi-volatile pesticides that are highly biodegradable.

Table 9.5-1 provides a list of highly absorbed and highly biodegradable semi-volatile pesticides. For those pesticides with very low volatility (vapor pressure less than 10^{-7} mm Hg), the pesticide is assumed not to volatilize and therefore has no emissions associated with its application (Li, 1981). For those pesticides that are highly volatile (vapor pressure greater than 0.3 mm Hg), the amount of pesticide that is applied is assumed to equal the total emissions from that pesticide because it will completely evaporate within a month of the application (Seiber, *et al.*, 1983).

TABLE 9.5-1
SEMI-VOLATILE PESTICIDES^a

Highly Adsorbed Pesticides ^b		
Azinphosmethyl	Fenac	Picloram
Chlordane	Fluchloralin	Tebuthiuron
Chloroxuron	Heptachlor	
Dichlobenil	Nitralin	
Highly Biodegradable Pesticides ^c		
Alachlor	Bentazon	IPC (Propham)
Amitrole	Bromoxynil Octanoate	Monocrotophos
Ammonium Ethyl Carbamoylphosphonate	Dalapon	Propanil
Barban	Eptam	2-4-D

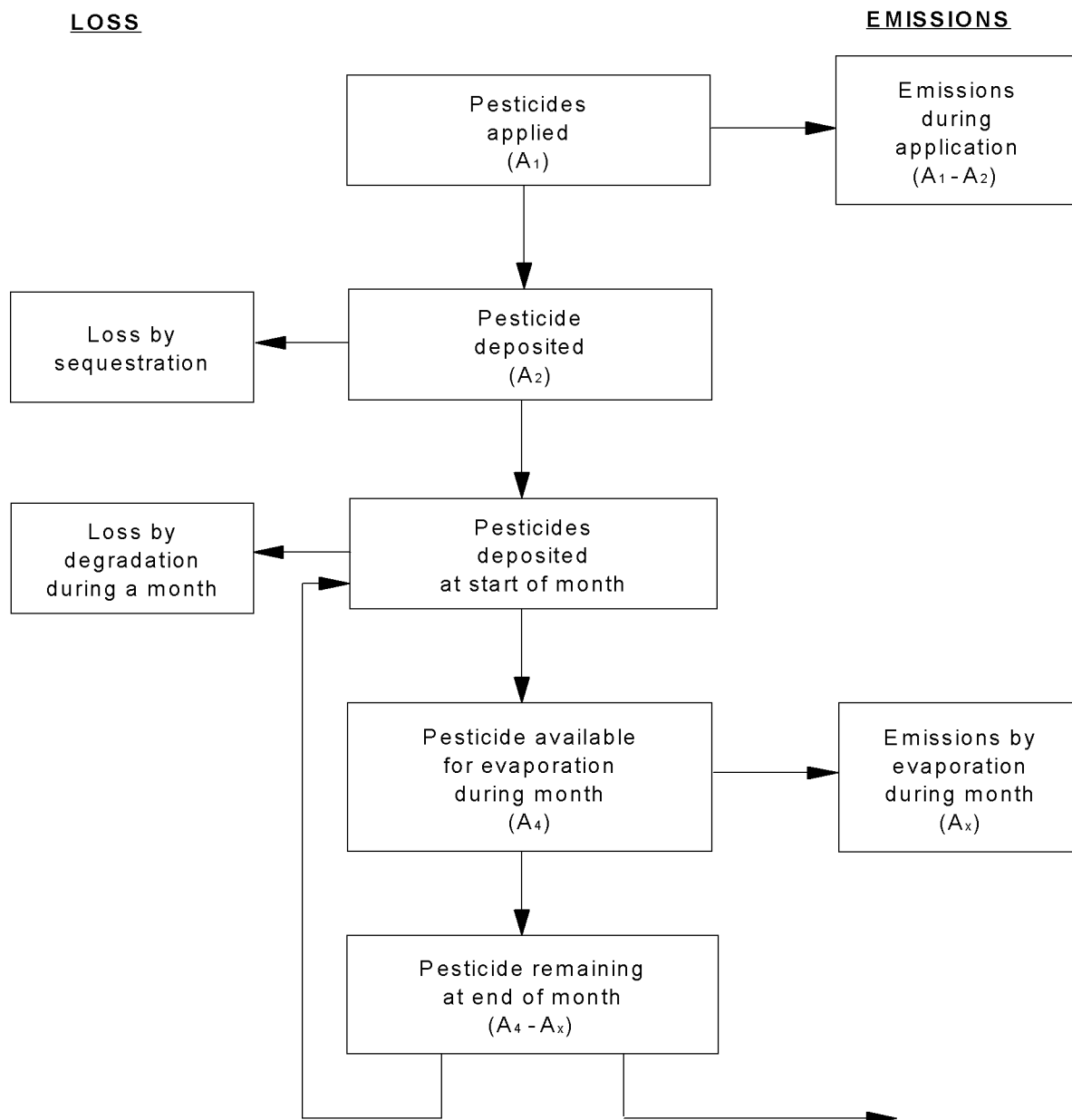
^a Data in this table has been drawn from Matsumura and Murti, 1982; Wangern, 1983; Verschueren, 1983; Weed Science Society of America, 1979; and Worthing, 1979.

^b Pesticides that persist for one year or more and are not considered to undergo biological degradation.

^c Pesticides that undergo complete biodegradation within 30 days and are not considered subject to sequestration. Assume loss due to biodegradation will be 30 percent per month.

Special calculation procedures were developed for the semi-volatile pesticides. Figure 9.5-1 is a flow chart of the process. Due to pesticide applications being reported in acres as well as other units (such as gallons), equations exist for each type of application units (this does not affect the process as outlined in Figure 9.5-1).

$$\text{For acreage applications, emissions during application} = A_1 - A_2 \quad (9.5-4)$$



ERG_001_PRE_JES

FIGURE 9.5-1**FLOWCHART OF EMISSIONS ESTIMATION METHOD FOR SEMI-VOLATILE PESTICIDES**

where:

A_1 = total pesticide applied per acre
 A_2 = total pesticide deposited per acre

To calculate A_2 , use the following equation:

$$A_2 = A_1 \times (1 - [4.625 \times (\log P_i + 7) \times (0.0024 \times T^2) \times 0.01]) \quad (9.5-5)$$

where:

P_i = vapor pressure of pesticide i (mm Hg at 20°C)
 T = average temperature in the month of application (°C)

It is assumed that 2 percent of the amount of pesticide deposited is lost by sequestration and that an additional 4 percent of the remaining amount of pesticide (after sequestration) is lost by biodegradation. Therefore, the calculation of those losses is as follows:

$$A_3 = (1 - 0.02) \times A_2 \quad (9.5-6)$$

where:

A_3 = remaining pesticide per acre after sequestration
 A_2 = total pesticide deposited per acre

$$A_4 = (1 - 0.04) \times A_3 \quad (9.5-7)$$

where:

A_4 = remaining pesticide per acre after loss by biodegradation
 A_3 = remaining pesticide per acre after sequestration

In order to calculate the emissions on a monthly basis, the maximum monthly evaporation rate must be calculated. The Hartley Equation is used to calculate the maximum monthly evaporation rate as follows (Hartley, 1969):

$$E_p = [E_A / (1 - RH)] \times [(P_i \times M_i^{0.5}) / (P_w \times M_w^{0.5})] \quad (9.5-8)$$

where:

E_p	=	the maximum evaporation rate of compound i in lbs/acre during the month p (E_p is calculated for each month)
E_A	=	adjusted water evaporation rate in lbs/acre
RH	=	average relative humidity during the month p (in percent)
P_i	=	vapor pressure of compound i at cited temperature (mm Hg)
M_i	=	molecular weight of compound i
P_w	=	vapor pressure of water at cited temperature (mm Hg)
M_w	=	molecular weight of water

E_A is equal to $0.73 \times E$, $0.40 \times E$, and $0.70 \times E$ for applications to vegetated land, soil surfaces, and water surfaces, respectively. E is equal to the inches of water evaporated times 226,600 pounds per inch of water on one acre.

The monthly emissions from the deposited pesticide are calculated by the following equation:

$$k \times t = 2.303 \times \log[A_4/(A_4 - A_x)] \quad (9.5-9)$$

where:

k	=	rate constant
t	=	time in days
A_4	=	remaining pesticide after loss by biodegradation in lbs per acre
A_x	=	pounds of pesticide evaporated per acre in any month for time t

This is an iterative process starting with $t=1$ and solving for k . The calculation of monthly emissions would continue by calculating the losses and following the steps outlined above until A_x is less than 0.1 pounds per acre or 12 months have passed since the application. The calculation is best illustrated with an example (see Example 9.5-3).

5.2 NONAGRICULTURAL APPLICATIONS

The alternative method for estimating emissions is through the use of national per capita emission factors for nonagricultural pesticide uses provided in Chapter 5 of this volume, titled "Consumer and Commercial Solvent Use."

Example 9.5-3 Assume that an area applies mineral oil as an insecticide to nectarines. The vapor pressure of mineral oil is 7.4×10^{-6} mm Hg, and its molecular weight is 327. Assume that 182 pounds of the insecticide are applied in February on 23 acres of nectarines. The average temperature in February is 10.28°C , with a relative humidity of 75 percent and a water evaporation rate of 2.46 inches. The vapor pressure of water is 17.535 mm Hg, and its molecular weight is 18.

Emissions during application

$$A_2 = 182/23 \times (1 - [(4.625) \times (\log 7.4\text{E}^{-6} + 7) \times (0.0024) \times (10.28^2) \times (0.01)]) \quad (9.5-5)$$

$$A_2 = 7.74 \text{ lbs/acre deposited}$$

$$A_1 - A_2 = 182/23 - 178/23 = 0.17 \text{ lbs/acre emitted during application} \quad (9.5-4)$$

Loss by sequestration

$$A_3 = (1 - 0.02)(7.74) = 7.6 \text{ lbs/acre deposited after sequestration} \quad (9.5-6)$$

Loss by biodegradation

$$A_4 = (1 - 0.04)(7.6) = 7.3 \text{ lbs remaining after loss by biodegradation} \quad (9.5-7)$$

Maximum evaporation rate

$$E_p = [(0.73 \times 2.46 \times 226,600)/(1-0.75)] \times [(7.4 \times 10^{-6} \times 327^{0.5})/(17.535 \times 18^{0.5})] \quad (9.5-8)$$

$$E_p = 2.93 \text{ lbs/acre}$$

Monthly emissions

solve for k at t = 1 day

$$A_4 = 7.3 \text{ lbs/acre}$$

$$A_x = 2.93 \text{ lbs/acre/30 days} = 0.0976667$$

$$k \times 1 = 2.303 \log [7.3/(7.3 - 0.0976667)] \quad (9.5-9)$$

$$k = 0.0134717$$

then solve for A_x

$$0.0134717 \times 30 = 2.303 \log [7.3/(7.3 - A_x)]$$

$$7.3/(7.3 - A_x) = \text{antilog } (0.1754889)$$

$$A_x = 2.426 \text{ lbs/acre during the month}$$

Therefore the total emissions in February are:

$$\text{Total emissions} = (A_1 - A_2) + A_x \times \text{acres}$$

$$\text{Total emissions} = 4 + 2.426 \times 23 = 59.8 \text{ lbs}$$

To determine whether to continue the calculation of monthly emissions, determine the remaining pesticide that is available for the next month as follows:

$A_4 - A_x = 7.3 - 2.426 = 4.874 \text{ lbs/acre}$, which is greater than 0.1 lbs/acre, therefore the calculation is continued for the month of March following the same procedure as outlined above.

5.3 METHOD FOR ALL USERS: TOP-DOWN SOLVENT USE METHOD

Another alternative type of methodology involves the estimation of national solvents consumption, spatial allocation of consumption to counties, and application of local control regulations. Estimation of national consumption is based on a material balance approach, since this is the best way of ensuring that the inventory covers all solvents emissions. A detailed description and application of this method with emission calculations can be found in (*reference project report*). The steps required for this method are:

- Estimate solvents consumption for this source category at the national level. These data can be obtained from solvents industries studies (*reference project report*).
 - Apply growth indicator, if national solvent consumption data from industry studies are not available for the target inventory year:
 - Use national solvent consumption projections for the target inventory year from industry studies, or extrapolate between past and future years that span the target inventory year, using data obtained from the same national solvent consumption data from industry studies.
 - Use BEA estimates of future employment and Census projections of population to project solvent use from national solvent consumption data from industry studies for previous years.
- Estimate county-level solvents consumption (S) from national data in the same proportions as employment for this source category. The following equation is used to allocate national consumption to counties:

$$S_{\text{cty}} = S_{\text{nat}} * F_{\text{nat}, \text{cty}} \quad (9.5.10)$$

where:

S_{cty} = County solvent consumption

S_{nat} = National solvent consumption

$F_{\text{nat}, \text{cty}}$ = Spatial allocation factor for the county: the ratio of employment in the county to nationwide employment

Note: Employment data at a county level are available in the County Business Patterns database (U.S. DOC).

- Incorporate the effects of national, state, and local regulations¹ into spatial allocation to counties. On the state/local level, stricter controls in some states/counties than in others has the effect of moving some of the solvent emission from the more highly controlled counties/states into other counties/states. (*Reference project report*).
- Estimate the extent of recycling and waste management practices in the source category.
- Subtract out point source solvent use, using the method described in Section 3.2.2. Point sources should be accounted for, and subtracted out from, the solvent consumption that is allocated to the county level. Point source solvent consumption for the category may be determined from the emission factor(s) used or from other underlying consumption data if available. Otherwise, the point source activity (solvent consumption) may be assumed equal to point source (uncontrolled) emissions, and that proportion subtracted from the total county solvent consumption.
- The emission factor used in converting solvents to VOC² emissions is complete conversion of consumption to emission (2000 lbs solvent/ton VOC) adjusted for controls/regulations,¹ recycling and waste management, and processes that consume solvents with no emissions. For activity data in terms of product/coating consumption, emission factors account for the amount of solvent in the product/coating by including a solvent content factor.

¹ State any assumptions made to include national/state/local regulations and the exact regulation applied. Clarify any issues related to regulation and control assumptions. The final emissions estimates are **highly** dependent on these assumptions, therefore they must be stated explicitly in all documentation.

² The solvents consumption information is identified by solvent chemical and type of source. Some of the solvents chemicals are HAPs, and one could follow a similar process as the above method (which estimates VOC not individual chemicals to obtain estimates for some HAPs).

6

QUALITY ASSURANCE/ QUALITY CONTROL

Data collection and handling for this source category should be planned and documented in the Quality Assurance Plan. When using survey methods, the survey planning and data handling should also be documented. Refer to the discussion of survey planning and survey QA/QC in Chapter 1, *Introduction to Area Source Emission Inventory Development*, of this volume, and Volume VI, *Quality Assurance Procedures*, of the Emission Inventory Improvement Program (EIIP) series. Potential pitfalls when developing emission estimates by using a survey for this category are data gaps due to surveys not returned; unanswered or misunderstood survey questions; inappropriate assumptions used to compensate for missing information or scaling up the survey sample; errors in compiling the returned survey information; and calculation errors, which can include unit conversion errors, and data handling errors.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

The Data Attribute Rating System (DARS) has been developed as a tool to rate emission inventories. A description of the system and the EIIP recommendations for its use can be found in Appendix F of EIIP Volume VI, *Quality Assurance Procedures*. The following discussion uses the DARS rating system as a way to compare the estimation approaches presented in this chapter and analyze their strengths and weaknesses.

For agricultural pesticide emission estimates, the third alternative method gives higher Data Attribute Rating System (DARS) scores, but requires more effort than the other methods. The preferred method for agricultural pesticide gives the next highest DARS scores.

The lowest potential DARS score assigned to any of the methods is assigned to the preferred method for consumer pesticide use. The method recommends using the pesticide use portion of the emission factor from Chapter 5 of this volume, *Consumer and Commercial Solvent Use*, for consumer pesticide use. However, this factor has been developed for consumer and commercial (which includes municipal) users and must be corrected by subtracting the estimated municipal and commercial emissions in order to estimate consumer pesticide use only. The alternative method for municipal, commercial, and consumer pesticide use recommends using the unadjusted pesticide use emission factor from Chapter 5 of this volume to estimate emissions for all of these users. It is more suitable in this case, and has a higher DARS score. Another

advantage of using this alternative method is that it is a straightforward and economical approach.

6.1.2 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The DARS scores for each method are summarized in Tables 9.6-1 through 9.6-7. A range of scores is provided for the methods because the implementation of these methods can vary. The higher scores assume that reliable data were collected specifically for the inventory area and time period, and few, if any, assumptions or generalizations have been made in the data gathered. All scores assume that satisfactory QA/QC measures are performed and no significant deviations from good inventory practices have been made. If these assumptions are not met, new DARS scores should be developed according to the guidance provided in Appendix F of EIIP Volume VI.

The preferred method for agricultural pesticide use is to collect detailed data on pesticide usage and type, and estimate emissions based on the pesticide formulation vapor pressure and application method. DARS scoring for this method is shown in Table 9.6-1. The preferred method for municipal and commercial pesticide use and the first alternative method for agricultural pesticide use collect information on the amount of active and inert ingredients and assume a standard emission rate. DARS scores for these sources are shown in Tables 9.6-2 and 9.6-3. The second alternative method for agricultural pesticide use is similar to the first alternative method, but uses a default proportion of active to inert ingredients. DARS scores for the second alternative method for agricultural pesticides are shown in Table 9.6-4. In each of these methods, the approach is similar, but the method of calculating emissions becomes more generalized and consequently, DARS scores for the emission factor become lower. The third alternative method for agricultural pesticide use collects detailed data on pesticide usage and type, and estimates emissions based on the pesticide formulation vapor pressure, local temperatures, and reductions from sequestration and biodegradation. The DARS scores for this method are shown in Table 9.6-5.

The preferred method for consumer pesticide use calculates emissions from the per capita pesticide usage factor provided in Chapter 5 of this volume for all municipal, commercial, and consumer pesticide use, and then subtracts the estimated emissions from commercial and municipal users collected by survey. Because the preferred method for municipal and commercial pesticide use is based on local survey data, it will provide an estimate that reflects local usage. If these emission estimates are significantly different from the national average (which is inherent in the pesticide usage factor in Chapter 5), then using the surveyed estimates for municipal and commercial pesticide use to adjust the consumer estimate will skew the estimate for consumer pesticide use in a manner that is opposite from the most likely local consumption level.

TABLE 9.6-1**PREFERRED: AGRICULTURAL PESTICIDE USE**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5 - 0.5	0.3 - 0.9	0.15 - 0.45
Source Specificity	0.6 - 0.8	0.4 - 0.9	0.24 - 0.72
Spatial Congruity	0.7 - 0.8	0.7 - 1	0.49 - 0.8
Temporal Congruity	0.5 - 0.8	0.7 - 0.9	0.35 - 0.72
Composite Scores	0.58 - 0.73	0.53 - 0.93	0.31 - 0.67

TABLE 9.6-2**PREFERRED: MUNICIPAL AND COMMERCIAL PESTICIDE USE**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.3 - 0.4	0.3 - 0.6	0.09 - 0.24
Source Specificity	0.5 - 0.7	0.3 - 0.6	0.15 - 0.42
Spatial Congruity	0.6 - 0.7	0.6 - 0.9	0.36 - 0.63
Temporal Congruity	0.5 - 0.5	0.7 - 0.9	0.35 - 0.45
Composite Scores	0.48 - 0.58	0.48 - 0.75	0.24 - 0.44

TABLE 9.6-3

ALTERNATIVE 1: AGRICULTURAL PESTICIDE USE

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.3 - 0.4	0.3 - 0.6	0.09 - 0.24
Source Specificity	0.5 - 0.7	0.3 - 0.6	0.15 - 0.42
Spatial Congruity	0.6 - 0.6	0.6 - 0.9	0.36 - 0.54
Temporal Congruity	0.5 - 0.5	0.7 - 0.9	0.35 - 0.45
Composite Scores	0.48 - 0.55	0.48 - 0.75	0.24 - 0.41

TABLE 9.6-4

ALTERNATIVE 2: AGRICULTURAL PESTICIDE USE

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.3	0.3 - 0.6	0.09 - 0.18
Source Specificity	0.5	0.5 - 0.7	0.25 - 0.35
Spatial Congruity	0.6	0.6 - 0.9	0.36 - 0.54
Temporal Congruity	0.5	0.7 - 0.9	0.35 - 0.45
Composite Scores	0.48	0.53 - 0.78	0.26 - 0.38

TABLE 9.6-5**ALTERNATIVE 3: AGRICULTURAL PESTICIDE USE**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5 - 0.5	0.3 - 0.9	0.15 - 0.45
Source Specificity	0.7 - 0.8	0.7 - 0.9	0.49 - 0.72
Spatial Congruity	0.7 - 0.8	0.7 - 1	0.49 - 0.8
Temporal Congruity	0.8 - 0.8	0.7 - 0.9	0.56 - 0.72
Composite Scores	0.68 - 0.73	0.6 - 0.93	0.42 - 0.67

TABLE 9.6-6**PREFERRED: CONSUMER PESTICIDE USE**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.3	0.6	0.18
Source Specificity	0.5	0.5	0.25
Spatial Congruity	0.5	0.5	0.25
Temporal Congruity	0.6	0.9	0.54
Composite Scores	0.48	0.63	0.31

TABLE 9.6-7**ALTERNATIVE 1: MUNICIPAL, COMMERCIAL, AND CONSUMER PESTICIDE USE**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.3	0.6	0.18
Source Specificity	0.7	0.5	0.35
Spatial Congruity	0.6	0.9	0.54
Temporal Congruity	0.6	0.9	0.54
Composite Scores	0.55	0.73	0.40

The unadjusted per capita emission factor is also recommended as the first alternative method for municipal, commercial and consumer pesticide use. A discussion of QA/QC for the per capita method can be found in Chapter 5 of this volume, but the DARS scores for the use of the per capita pesticide factor have been compiled for the preferred consumer method and the first alternative municipal, commercial, and consumer method, and are shown in Tables 9.6-6 and 9.6-7.

Scores for these methods are presented as ranges to allow for variability in data collection and the use of assumptions. The upper range of scores can be used as long as survey responses are complete and few assumptions have been made. However, assumptions about the pesticides used in an area, the volatility of a pesticide, or the proportion of volatile organic compounds (VOC) to the amount of active ingredients will result in lower scores. Temporal congruity DARS scores may need to be lowered if emissions are estimated for a longer or shorter time period than the inventory time period, and the estimates are apportioned to the inventory time period without adjustment for variations in usage or temperature. When using these methods, inventory preparers are cautioned to consider the feasibility of the methods and the detail necessary to develop an estimate that merits the higher score.

DARS scoring attributes were originally developed for rating emission factor-based methods (EIIP Volume VI, Appendix F). When applying DARS scores to methods that use more than emission and activity factors in the calculation, it is useful to review which DARS attribute covers which part of the emission estimation method. For the methods described in this chapter, the DARS attributes reflect the following qualities:

- Measurement -- The quality and reliability of the data used as variables in the emission estimation equation. For this source category, this attribute is used to show how well the method (material balance) takes all the potential variables affecting emission rates into account;
- Source Specificity -- The specificity of the equation to the actual emission process, the choices of variables used or not used in the emission estimation equation, or the use of surrogate variables in the equation;
- Spatial Congruity -- The variability in emissions that may be introduced by local climate, terrain, or other environmental factors, and the scaling of data used in the emission estimation equations for the inventory area; and
- Temporal Congruity -- The specificity of the method and the data used in the method to the temporal scale of the inventory.

6.1.3 SOURCES OF UNCERTAINTY

Another way to evaluate the emission estimates is to examine the associated uncertainty. For estimates derived from survey data, the uncertainty can be quantified (see Chapter 4 of Volume VI of the EIIP series). Statistics needed to quantify the uncertainty of emissions derived by the per capita emission factor method are incomplete. Please refer to Chapter 5 of this volume, *Consumer and Commercial Solvent Use*, for further discussion of the uncertainties associated with the use of these emission factors.

There are a number of sources of uncertainty in estimating emissions from this source category. Emissions from pesticide use depend on variables such as the amounts and types of pesticides used, application method, the timing of the application relative to the inventory period, and meteorology. Data collection alone for this number of variables is likely to be a source of uncertainty. The preferred method for consumer pesticide use, which adjusts a national average per capita emission factor with the estimated emissions from municipal and commercial use surveys, is affected by the associated uncertainty of both the emission factor and the surveys of commercial and municipal pesticide usage.

The preferred emission estimation methods for agricultural, municipal, and commercial pesticide emissions, and the third alternative method for agricultural pesticide emissions are based on the actual amount and types of pesticides used, and include more of the potential variables in their respective emission estimation equations. These methods can be viewed as being the least uncertain of the methods presented here. The remaining alternative methods have increasingly uncertain results as more and more assumptions are made.

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7

DATA CODING PROCEDURES

The inventory preparer should check the EPA website (<http://www.epa.gov/ttn/chief/>) for the latest information (codes) available to characterize emission estimates from agricultural and non-agricultural pesticides. A complete list of Source Classification Codes (SCC) can be retrieved at <http://www.epa.gov/ttn/chief/codes/>. Table 9.7-1 lists the applicable SCCs for agricultural and non-agricultural pesticides.

Available codes and process definitions influence and help guide the preparation of emission estimates for this category. Data transfer formats should be taken into account when an inventory preparer plans for data collection, calculation, and inventory presentation. Consistent categorization and coding will result in greater continuity between emission inventories for use in regional and national scale analyses.

7.1 NECESSARY DATA ELEMENTS

If the category emissions data will be transferred to EPA for incorporation into the national criteria and toxics air pollutant inventory, specific data transfer formats are acceptable. The acceptable data transfer format(s) are described and available for download at <http://www.epa.gov/ttn/chief/net/>. The acceptable data transfer formats contain the data elements necessary to complete the data set for use in regional or national air quality and human exposure modeling. The inventory preparer should review the area source portion of the acceptable file format(s) to understand the necessary data elements. The EPA describes its use and processing of the data for purposes of completing the national inventory, in its Data Incorporation Plan, also located at <http://www.epa.gov/ttn/chief/net/>.

TABLE 9.7-1

**AREA AND MOBILE SOURCE CATEGORY CODES
FOR AGRICULTURAL AND NONAGRICULTURAL
PESTICIDES APPLICATIONS**

Process Description	Source Category Code
Pesticide Application: Herbicides - Corn	24-61-850-001
Pesticide Application: Herbicides - Apples	24-61-850-002
Pesticide Application: Herbicides - Grapes	24-61-850-003
Pesticide Application: Herbicides - Potatoes	24-61-850-004
Pesticide Application: Herbicides - Soybeans	24-61-850-005
Pesticide Application: Herbicides - Hay and Grain	24-61-850-006
Pesticide Application: Herbicides - Misc. Agricultural Use	24-61-850-009
Pesticide Application: Other Pesticides - Corn	24-61-850-051
Pesticide Application: Other Pesticides - Apples	24-61-850-052
Pesticide Application: Other Pesticides - Grapes	24-61-850-053
Pesticide Application: Other Pesticides - Potatoes	24-61-850-054
Pesticide Application: Other Pesticides - Soybeans	24-61-850-055
Pesticide Application: Other Pesticides - Hay and Grain	24-61-850-056
Pesticide Application: Other Pesticides - Misc. Agricultural Use	24-61-850-099
Pesticide Application: Nonagricultural Use	24-61-870-999

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VOLUME III: CHAPTER 11

GASOLINE MARKETING (STAGE I AND STAGE II)

**Revised Final
January 2001**



Prepared by:
Eastern Research Group, Inc.

Prepared for:
Area Sources Committee
Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

This chapter is one of a series of documents developed to provide cost-effective, reliable and consistent approaches to estimating emissions for area source inventories. Multiple methods are provided in the chapters to accommodate needs of state agencies with different levels of available resources and skills; and different levels of needs for accuracy and reliability of their estimates. More information about the EIIP program can be found in Volume 1 of the EIIP series, *Introduction and Use of EIIP Guidance for Emissions Inventory Development*.

Throughout this chapter and other EIIP area source methods chapters, we stress that area source categories should be prioritized by the inventory planners so that resources can be spent on the source categories that are the largest emitters, most likely to be subject to regulations or are already subject to regulations, or require special effort because of some policy reason. Prioritization is particularly important for area source inventories, because in some cases, a difficult to characterize source category may contribute very little to overall emissions and attempting a high quality estimate for that source category may not be cost effective.

EIIP chapters are written for the state and local air pollution agencies, with their input and review. EIIP is a response to EPA's understanding that state and local agency personnel have more knowledge about their inventory area's activities, processes, emissions, and availability of information; and require flexible inventory methods to best use their sometimes limited resources. These EIIP area source chapters are written as a set of options presented to inventory professionals capable of using their own experience and judgement to apply the method that best fits their overall needs and constraints.

This chapter describes the procedures and recommended approaches for estimating emissions from gasoline tank trucks in transit and at retail gasoline marketing outlets. Section 2 of this chapter contains a general description of the gasoline distribution industry category and an overview of available control technologies. Section 3 provides an overview of available emission estimation methods. Section 4 presents the preferred method for estimating emissions, and Section 5 presents the alternative emission estimation techniques. Quality assurance issues and emission estimate quality indicators for the methods presented in this chapter are discussed in Section 6. Data coding procedures are discussed in Section 7. Section 8 contains references used for this chapter.

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2

SOURCE CATEGORY DESCRIPTION

2.1 CATEGORY DESCRIPTION

Motor gasoline is produced by domestic petroleum refineries or in some cases imported to the United States, and then transported through a distribution network to customers. The distribution network is a complex system that includes many wholesale and retail outlets. The network includes a variety of storage and transfer facilities. Gasoline may be transported by tanker ships and barges, through pipelines, or by rail tank cars or tank trucks. This chapter covers most of those sections of the distribution network where evaporative emissions are usually considered to be area sources. Stage I and Stage II emissions (occurring during the transfer of gasoline from tank trucks to storage tanks at service stations, and subsequent transfer to the vehicle gasoline tank, respectively) are covered, as well as emissions from delivery trucks in transit, gasoline station storage tanks, and spillage. Additional information about this category can be found in *AP-42* (Section 4.4) (EPA, 1995), and the *AIRS Area and Mobile Source Category Codes* (EPA, 2000).

Figure 11.2-1 shows a typical path by which gasoline may be transported from producer to consumer. This path includes operations that are not addressed in this chapter. Marine vessel loading and unloading operations are covered in Chapter 12. Bulk terminals and gasoline bulk plants, which are intermediate distribution points between refineries and outlets, are usually inventoried as point sources. Loading and unloading of railroad tank cars and pipeline transmission losses could be significant area source categories in some areas, but have not been included in this chapter.

2.2 PROCESS DESCRIPTION AND EMISSION SOURCES

The area sources of evaporative VOC emissions from the distribution of gasoline that are covered in this chapter include the following:

- Trucks in transit: evaporation of gasoline vapor (1) from loaded tank trucks during transportation of gasoline from the bulk plant/terminal to the service station or other dispensing outlet, and (2) from empty tank trucks returning from service stations to bulk plant/terminals.

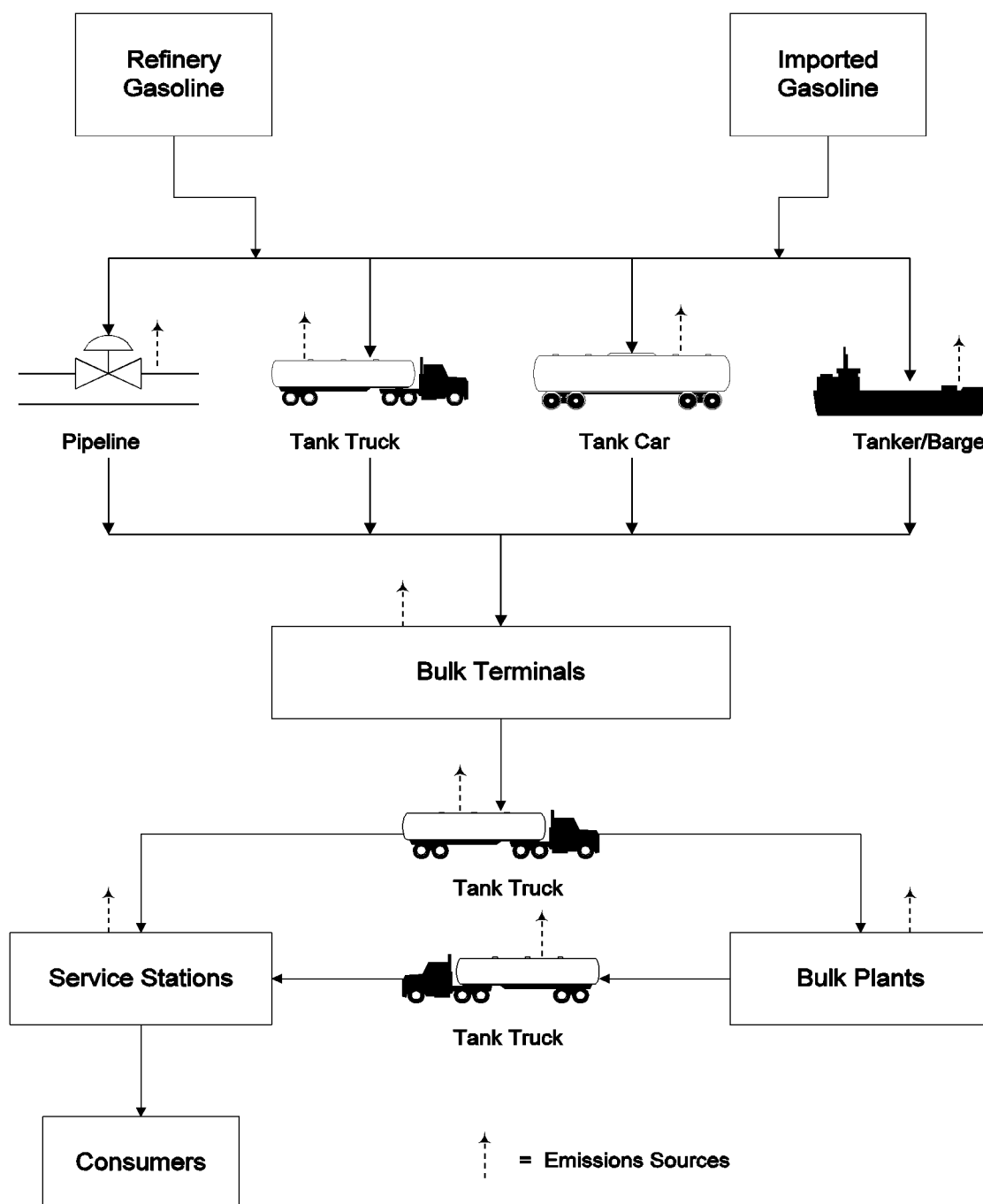


Figure 11.2-1
Gasoline Marketing Operations and Emission Sources

- Stage I: displacement of gasoline vapors from the storage tanks during the transfer of gasoline from tank trucks to storage tanks at the service station
- Stage II: displacement of gasoline vapors from vehicle gasoline tanks during vehicle refueling. This category also may include spillage of gasoline (and subsequent evaporation) during either delivery activity above. This loss includes prefill and postfill nozzle drip and spitback and overflow from the filler pipe of the vehicle's fuel tank during filling.
- Storage tank working losses: evaporation of gasoline vapors from the storage tank and from the lines going to the pumps during transfer of gasoline.

Service stations (Standard Industrial Classification code 5541) traditionally have been the primary retail distributors for gasoline. Gasoline can be purchased from other types of businesses, such as auto repair garages, parking garages, and convenience stores. Gasoline may also be distributed to vehicles through various nonretail outlets, such as government motor pools and other vehicle fleet servicing operations. Gasoline is stored in underground and aboveground storage tanks at service stations and other dispensing facilities. Evaporative emissions occur during tank filling and vehicle refueling.

2.3 FACTORS INFLUENCING EMISSIONS

VOC emissions from gasoline marketing activities are influenced by several factors. Fuel volatility (measured as Reid vapor pressure, or RVP) affects the evaporation rate of gasoline. The technology for loading tank trucks and tanks (splash loading, submerged loading, vapor balance, etc.) affects the release of displacement emissions. Tank characteristics (color and design) affect working losses from aboveground storage tanks.

2.4 CONTROL TECHNIQUES

Emissions from underground tank filling operations at service stations (Stage I emissions) can be reduced by the use of a vapor balance system, which consists of a hose that returns gasoline vapors displaced from the underground tanks during filling back to the tank truck, as well as measures to ensure tightness of the truck. The control efficiency of the balance system can range from 93 to 100 percent (EPA, 1995). Emissions from vehicle refueling (Stage II emissions) also can be reduced by a vapor balance system. During refueling, the vapors displaced from the vehicle fuel tanks are returned to the underground tanks through the use of a special nozzle (EPA, 1995). Stage I controls have been implemented in some areas, both attainment and nonattainment. Stage II controls are currently not widely implemented, but are required in some ozone nonattainment areas as defined by the 1990 Clean Air Act (CAA) (EPA, 1991).

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3

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATION METHODOLOGIES

The following activities of the gasoline distribution industry are generally area sources of air pollution: (1) gasoline trucks in transit; (2) fuel delivery to outlets (Stage I); (3) vehicle refueling (Stage II); and (4) storage tank breathing. The emissions estimation methodologies for the subcategories of gasoline distribution identified in Section 2 have a common, simple form:

$$\text{Emissions} = \text{Emission Factor} \times \text{Activity Level} \quad (11.3-1)$$

The methodologies for adjusting the emission factors and activity levels vary somewhat among the subcategories. Accordingly, methodologies for developing emission factors and activity levels are presented separately for each subcategory.

3.2 AVAILABLE METHODOLOGIES

Selection of the appropriate estimation method depends on the relative significance of emissions from this source in the inventory area and the data quality objectives (DQOs) of the inventory plan. Refer to EIIP Volume VI, *Quality Assurance Procedures*, Sections 2.1 and 2.4 for discussions of inventory categories and DQOs.

Methods for estimating emissions from the gasoline marketing system generally involve employing an emission factor (provided by EPA or generated with EPA's MOBILE model) relating emissions to the volume of gasoline distributed. Gasoline distribution within the study area may be determined by area-specific tax records or survey data. Unfortunately, gasoline sales tax data are not always available at the county or city level, and performing a valid survey may not be feasible due to resource limitations. Alternately, state-level gasoline sales may be allocated to the study area based on economic data (dollars of total sales, available in U.S. Bureau of the Census publications).

Emission factors for gasoline trucks in transit, fuel delivery to outlets, and storage tank breathing are all provided by EPA. No methodologies have been identified to replace the use of these emission factors. Emission factors for vehicle refueling should be developed through the use of

EPA's MOBILE model. This software uses local data (e.g., temperature, fuel volatility) to generate a custom VOC emission factor.

In selecting preferred methodologies identified for gasoline marketing subcategories, preference has been given to methodologies that maximize use of survey data or other data collected or reported at the county or city level.

3.1.1 EMISSION FACTORS

Gasoline Trucks in Transit

EPA has published emission factors for gasoline tank trucks in transit. The emission factors are included in Table 11.3-1.

TABLE 11.3-1

VOC EMISSION FACTORS FOR GASOLINE MARKETING ACTIVITIES^a

Emission Source	mg/Liter Throughput	lb/1000 gal Throughput
Gasoline Tank Trucks in Transit		
Vapor-filled Tank Trucks ^b	6.5	0.055
Gas-filled Tank Trucks ^c	0.5	0.005
Filling Underground Tank (Stage I)		
Submerged Filling	880	7.3
Splash Filling	1,380	11.5
Balanced Submerged Filling	40	0.3
Underground Tank Breathing and Emptying ^d	120	1.0

^a Source: AP-42 Tables 5.2-5, 5.2-7.

^b Midpoint of typical range provided in AP-42. Under extreme conditions, the upper end of the range is 0.37 lb/1000 gal (44.0 mg/L).

^c Midpoint of typical range provided in AP-42. Under extreme conditions, the upper end of the range is 0.08 lb/1000 gal (9.0 mg/L).

^d Includes any vapor less between tank and gas pump.

Emission factors can be supplemented by using the HAP speciation profiles provided in the NTI area source category, Gasoline Distribution Stage II. The NTI documentation provides profiles that can be applied to the VOC estimates for baseline, reformulated, and winter-oxygenated gasolines. The reformulated and winter-oxygenated gasolines are then subdivided depending on the additive contents, which include methyl tertiary butyl ether (MTBE) or ethanol. Table 11.3-2 displays the HAP speciation profiles that should be applied to the VOC emissions.

TABLE 11.3-2**HAP PERCENT OF VOC EMISSIONS**

HAP	Gasoline Type				
	Baseline	Reformulated		Winter-Oxygenated	
		w/ MTBE	w/ Ethanol	w/ MTBE	w/ Ethanol
2,2,4-Trimethylpentane	0.8	0.7	0.7	0.7	0.7
Benzene	0.9	0.4	0.4	0.7	0.7
Ethylbenzene	0.1	0.1	0.1	0.1	0.1
Hexane	1.6	1.4	1.4	1.4	1.4
MTBE	0	8.7	0	11.9	0
POM as 16-PAH	0.05	0.05	0.05	0.05	0.05
Toluene	1.3	1.1	1.1	1.1	1.1
Xylene	0.5	0.4	0.4	0.4	0.4

Source: EPA, 1999

Fuel Delivery to Outlets

EPA has published emission factors for filling underground storage tanks (Stage I). The emission factors are included in Table 11.3-1.

Vehicle Refueling

EPA recommends that the MOBILE model be used to generate refueling (Stage II) emission factors for highway vehicle emission inventories (EPA, 1992b). The model, designed to support the evaluation of air pollution from gasoline- and diesel-fueled vehicles, generates emission

factors for tailpipe emissions and refueling activities. A detailed discussion of using this model is available from EPA (EPA, 1994).

The MOBILE model allows the user to select whether refueling emission factors are presented in grams per gallon (g/gal) of dispensed fuel or in grams per mile (g/mi). The preferred approach is to use the g/gal refueling emission factor that reflects any applicable Stage II controls, then multiply the emission factor by total gasoline sales (TGD). Using the g/gal emission factor will capture refueling emissions from gasoline purchased in the study area but consumed outside the study area. Conversely, the g/mi emission factor will assign to the study area emissions for vehicles refueled outside the study area but driven within the study area. It should be noted that MOBILE makes use of improved predictive equations to calculate refueling emission factors, including sensitivity to temperature and Reid vapor pressure (RVP), and these have not yet been incorporated into published *AP-42* factors for refueling. Additionally, the user may provide information on local Stage II emission controls to develop an emission factor for controlled emissions.

Refueling emissions have two mechanisms of introducing emissions to the environment: (1) vapor displacement from the vehicle fuel tank during refilling; and (2) gasoline spillage during refueling. The MOBILE user may request either a single emission factor that combines the two mechanisms or separate emission factors for displacement and spillage. Because both mechanisms should be taken into account when estimating refueling emissions, the preferred approach is to request the combined emission factor.

Storage Tank Breathing

EPA has published emission factors for storage tank breathing. The emission factors are included in Table 11.3-1.

3.1.2 ACTIVITY LEVELS

All of the preferred methodologies discussed in this document use total gasoline distribution as activity levels. The most useful source of existing data for estimating total gasoline distributed (TGD) in the inventory area is any existing collection of highway fuel sales data. The preferred approach to estimating TGD is to use these data. If available, these data should be collected, assessed, and processed to ensure that only highway vehicle gasoline dispensed in the area of concern is included in the total to be used as TGD. According to a recent EPA study, only 10 states actually collect and publish this type of data: Alabama, Arizona, Florida, Hawaii, Mississippi, Nevada, New Mexico, New York, Washington and, Wyoming. Most of the states with significant nonattainment problems are absent from this list. In addition, the reliability of these statistics as measures of gasoline distributed at the county level is unknown; significant errors in allocation may occur if statistics are based on locations of distributors and not all of this

fuel supply remains in the area of concern, or if substantial quantities of fuel come from distributors outside the area.

Where adequate data are not routinely collected, the only other alternatives for developing county-level data are (1) to collect sales tax data from the state taxing agency, if these data are available at sufficient disaggregation, or (2) to generate original data by collecting gasoline sales data from fuel distributors and retailers. State taxing agencies typically cannot provide the level of geographic detail necessary for inventory application; fuel taxes are usually collected from distributors rather than retailers, and these data are often considered proprietary information. Any tax-based estimates should be cross-checked with data from associations of service station owners, distributors, and other local sources. The large number of retailers and ongoing changes in retailer locations and ownership can make an original survey costly and difficult, although a small area might find this a reasonable approach. Scaling survey results to account for outlets not surveyed and/or nonresponders is also problematic; however, this could be accomplished using employment data for SIC Code 5541 or data on the total numbers of outlets in the area. One advantage of this approach is that information on the amount of gasoline distributed under different types of emission control scenarios can be directly estimated.

Another alternative for estimating gasoline consumption is to use data from various national publications. The Federal Highway Administration (FHWA) annually publishes *Highway Statistics*, which contains gasoline consumption data for each state.¹ Countywide estimates can be made by apportioning these statewide totals by the percentage of state gasoline station sales occurring within each county. Countywide service station gasoline sales data (dollars of sales, not gasoline volume) are available from the Bureau of the Census's *Census of Retail Trade*.² (Note: Data in the *Census of Retail Trade* are usually too old to use directly in estimating countywide sales; however, they are useful in allocating other data to the county level.) Other apportioning variables, such as registered vehicles or vehicle miles traveled (VMT), can be used if the local agency feels that their use results in more accurate distributions of state totals to the county level. Even if the agency uses local sales data in the area source inventory, this approach should be used as a cross-check of the local consumption estimates. One distinct advantage of using data in *Highway Statistics* is that sales are tabulated by month which facilitates a seasonal adjustment of the gasoline station emission totals.

¹ *Highway Statistics*. U.S. Department of Transportation. Federal Highway Administration, Washington, D.C. (Annual publication. Check USDOT/FHWA Web site for latest version, <http://www.fhwa.dot.gov>).

² *Census of Retail Trade: Geographic Area Series*. Bureau of the Census, U.S. Department of Commerce, Washington, D.C. (Available on hard copy by contracting the Census Bureau at 1-800-541-8345 or see the Census Bureau Web site, <http://www.census.gov>. Alternatively, check <http://sasquatch.kerr.orst.edu/econ-stateis.html>).

Another method of estimating gasoline sales is to use VMT data available from the ongoing transportation planning process. This alternative is not generally recommended for several reasons. First, it requires local information on both the percentage of VMT attributable to diesel versus gasoline fuel and the average miles-per-gallon fuel efficiency of the gasoline-powered motor fleet. None of these data may be available locally, and using nationwide averages may introduce errors in certain applications. Moreover, highway travel will not account for all gasoline sold at various off-highway applications. For these reasons, fuel sales is the preferred method for determining fuel use.

Note: Using state or local air pollution permit files for inventorying gasoline dispensing outlets is not likely to be an effective alternative. Permit information is not usually collected because of the large number of stations and because each station's emissions are much lower than traditional point source cutoff levels. Registration systems are being attempted in some states where major retail chains are required to compile and submit service station lists. Such a detailed approach is not usually warranted when gasoline distribution data will yield adequate emissions estimates.

Gasoline Trucks in Transit

The activity level for estimating emissions from gasoline trucks in transit is fuel transported through the study area. In order of preference, the available methods for estimating fuel throughput include: (1) obtaining (if available) existing gasoline sales data for the study area; and (2) apportioning state gasoline sales data to the study area level using surrogate allocation variables such as gasoline sales, vehicle registration, or economic activity data.

Gasoline distributed in an inventory area may be transported once (from bulk terminals outside the study area to retail outlets) or twice (distribution to gasoline bulk plants, then subsequent distribution to retail outlets). Recent industry trends favor more direct delivery to outlets, bypassing bulk plants.

The following equation can be used to develop an adjusted gasoline transportation activity factor for trucks in transit to account for gasoline transported twice within the inventory region:

$$GTA = \frac{TGD + TGT}{TGD} \quad (11.3-2)$$

where:

GTA	=	Gasoline transportation adjustment factor
TGD	=	Total gasoline dispensed in the inventory region (1,000 gallons)
TGT	=	Amount of gasoline transported twice within the inventory region (1,000 gallons)

A default value of 1.25 for GTA can be used if the information needed to calculate GTA is not available. This default value is based on an estimated overall historical national ratio of bulk plant throughput to total gasoline consumption and should be used only as a last resort since it will not reflect temporal or regional variations from this national historical average.

Depending on the location of nearby gasoline terminals and routes used to deliver product to remote bulk plants or outlets, there may be some inventory areas with heavy tank truck traffic on local interstates consisting of gasoline being transported through the area but not loaded or unloaded locally. There are currently no adjustment factors for this specific type of activity. However, it may be possible to obtain data on this type of traffic from weigh stations on interstate highways and add this throughput to the estimate of TGD in the area to obtain an upper-limit estimate for total emissions for trucks in transit including transport through the area (assuming that the factors for full and empty trucks are appropriate in this case). Inventory preparers may want to make a gross estimate of the contribution to overall emissions that these trucks may make before investing significant resources in this effort. (Typical round-trip emissions for each truck are probably less than 1 pound of VOCs.)

Total gasoline tank truck emissions (TTE) in the inventory region can be estimated with the following equation:

$$TTE = \frac{(TGD \times LEF \times GTA) + (TGD \times UEF \times GTA)}{2000} \quad (11.3-3)$$

where:

- TTE = Total gasoline emissions from tank trucks in transit (tons)
- LEF = Loaded tank truck in-transit emission factor from Table 11.3-1 (pounds per 1,000 gallons)
- UEF = Unloaded tank truck in-transit emission factor from Table 11.3-1 (pounds per 1,000 gallons)

Fuel Delivery to Outlets

In order to use the emission factors for fuel delivery to outlets included in Table 11.3-1, it may be necessary to make estimates of the amounts of fuel delivered by each delivery technology (submerged filling, splash filling, balanced submerged filling). The first step is to determine what rules are in place for Stage I tank filling. If a rule requires a certain type of control or filling method, then the inventory preparer need only determine a rule penetration factor. Otherwise, estimates of or surrogates for the volumes of fuel delivered via each filling method are required. Potential methodologies for making these estimates include:

Method 1 - Obtain estimates of gasoline delivery volumes: Obtain data on throughput of area gasoline outlets from state/local regulators or industry and trade groups (the national Petroleum Marketing Association, located in Arlington, Virginia, or state/local associations of gasoline dealers and repair shops). This is the preferred method.

Method 2 - Use estimated fractions of service stations using each filling method: Obtain the number of gasoline outlets that use each of the three types of tank filling methods from state and local regulators or industry and trade groups. Distribute gasoline delivery volumes according to these results.

Method 3 - Survey of outlets by filling method: Perform a survey of all or a representative sample of gasoline dispensing outlets in the inventory region to determine the type of tank filling method. Distribute gasoline delivery volumes according to these results. A survey design must ensure that the sample selected is representative. It is likely that smaller stations may use different controls or filling methods than larger ones. A sample should be stratified to ensure that all types of outlets are included. The survey needs to collect gasoline throughput data and other data that may be used to scale survey results to study area totals. Potential surrogates may be number of employees, number of pumps, or storage tank capacities.

The activity levels for each of the three fuel delivery technologies is then calculated as follows:

$$A_i = F_i \times TGD \quad (11.3-4)$$

where:

- A_i = Adjusted activity rate for fill type I (1,000 gallons)
- F_i = Fraction of area total for fill type I (based on either throughput or number of stations)
- TGD = Total gasoline dispensed in the inventory region (1,000 gallons)
- I = 1-3 representing the three filling methods

Vehicle Refueling

The activity factor for vehicle refueling can be either the total amount of gasoline distributed in the area or vehicle miles of travel (VMT). The preferred approach is to use estimates of local gasoline sales if these data are available.

- Obtain information on the amount of gasoline dispensed in the inventory region (TGD) using the methods described previously in this section. Use the best locally available estimate of TGD as the activity factor for vehicle refueling.

- If no local sources of information are available for estimating TGD, the agency may wish to use VMT as an alternative. Estimates of VMT should be obtained from the local transportation or planning agency who is responsible for preparing the highway vehicle emissions inventory. The disadvantage of using VMT is that it is a measure of vehicle activity in the area not a measure of the fuel dispensed in the inventory area. VMT produced by vehicles simply passing through the area, that did not refuel in the inventory region would tend to overstate the vehicle refueling activity level.

Storage Tank Breathing

The activity level for estimating emissions from storage tank breathing is total gallons delivered (TGD) in the inventory area. The methodology for estimating TGD for vehicle refueling is also recommended for this subcategory.

3.1.3 SPECIAL EMISSION CALCULATION ISSUES

Estimation of month-specific emissions from gasoline distribution can be based on activity apportionment factors developed from monthly state fuel use statistics available in *Highway Statistics*. Projections for fuel use can also be based on historic fuel use and vehicle miles traveled data from *Highway Statistics*, historic records from the sources from which current year area fuel usage was obtained, and/or area-specific VMT from Highway Performance Monitoring System (HPMS) (from Federal Highway Administration, Washington, DC) or local transportation agencies.

3.1.4 METHODOLOGY SUMMARIES

The methodologies proposed in this document are summarized in Table 11.3-3 below. Preferred and alternate methodologies are presented for each of the subcategories.

3.3 DATA NEEDS

3.3.1 DATA ELEMENTS

The data elements needed to calculate emission estimates for the gasoline distribution system depend on the methodology used for data collection. Each methodology requires some measure of activity (or surrogate for activity) and an emission factor. The data elements needed for each emission estimation technique are presented in Table 11.3-4.

TABLE 11.3-3

**PREFERRED AND ALTERNATE METHODS FOR ESTIMATING EMISSIONS
FROM GASOLINE DISTRIBUTION SUBCATEGORIES**

Sub-category	Method	Description
Gasoline Trucks in Transit	Preferred Method - Use detail or survey data	<i>Emission Factors</i> - from Table 3-1. <i>Activity Level</i> - Obtain fuel sales from tax records or survey data. Develop adjustment factor based on survey or highway-weight station data.
	Alternate Method 1 - Use combination of default and detailed data	<i>Emission Factor</i> - from Table 3-1. <i>Activity Level</i> - Same as preferred method, substituting default GTA.
	Alternate Method 2 - Use default GTA and allocated fuel sales data	<i>Emission Factor</i> - from Table 3-1. <i>Activity Level</i> - Same as preferred method, substituting default GTA, allocate state fuel sales to study area based on gasoline station sales.
Fuel Delivery to Outlets	Preferred Method - Use detail or survey data	<i>Emission Factor</i> - from Table 3-1. <i>Activity Level</i> - Obtain fuel sales from tax records or survey data. Use survey data to determine filling technologies.
	Alternate Method 1 - Use allocated fuel sales data, survey filling data	<i>Emission Factor</i> - from Table 3-1. <i>Activity Level</i> - Same as preferred method, using allocated fuel sales estimates instead of actual data. Use survey data to determine filling technologies' usage.
	Alternate Method 2 - Use allocated fuel sales data, local knowledge of filling technology	<i>Emission Factor</i> - from Table 3-1. <i>Activity Level</i> - Same as preferred method, using allocated fuel sales estimates instead of actual data. Use trade association or local knowledge to determine filling technologies' usage.
Vehicle Refuel-ing	Preferred Method - Use MOBILE emission factor and detail or survey data	<i>Emission Factor</i> - use MOBILE emission factor. <i>Activity Level</i> - Obtain fuel sales from tax records or survey data.
	Alternate Method 1 - Use MOBILE emission factor, allocated fuel sales	<i>Emission Factor</i> - use MOBILE emission factor. <i>Activity Level</i> - use allocated fuel sales estimates instead of actual data.
	Alternate Method 2 - Use MOBILE emission factor, vehicle miles traveled (VMT) data	<i>Emission Factor</i> - use MOBILE emission factor to get emission factor in dimensions grams per mile traveled. <i>Activity Level</i> - Get VMT data from highway planners.
Storage Tank Breath-ing	Preferred Method - Use EPA emission factor and detail or survey data	<i>Emission Factor</i> - see Table 3-1. <i>Activity Level</i> - Obtain fuel sales from tax records or survey data.
	Alternate Method 1 - Use EPA emission factor, allocated fuel sales	<i>Emission Factor</i> - see Table 3-1. <i>Activity Level</i> - Use allocated fuel sales estimates instead of actual data.

TABLE 11.3-4**DATA ELEMENTS NEEDED FOR EACH METHOD**

Subcategory	Data Element	Preferred Method	Alternate Method 1	Alternate Method 2
Gasoline Trucks in Transit	County-level fuel sales tax/survey data	X	X	
	Highway/weigh-station data	X		
	State fuel sales			X
	Gasoline station sales			X
Fuel Delivery to Outlets	County-level fuel sales tax/survey data	X		
	Filling technology survey data	X	X	
	Filling technology summary from local/state regulators or trade groups			X
	State fuel sales		X	X
	Gasoline station sales		X	X
Vehicle Refueling	MOBILE model inputs (see Reference 8)	X	X	X
	County-level fuel sales tax/survey data	X		
	State fuel sales		X	
	Gasoline station sales		X	
	VMT data			X
Tank Breathing	County-level fuel sales Tax/survey data	X		
	State fuel sales		X	
	Gasoline station sales		X	

3.3.2 ADJUSTMENTS TO EMISSIONS ESTIMATES

Adjustments applied to annual emissions estimates include point source corrections, applications of controls, spatial allocation, and temporal resolution. The type of adjustment is dependent on the type of inventory required. The data needs for point source emission estimate adjustments are dependent in part on the methodology used. Data needs for the adjustments listed below are as follows:

- | | |
|----------------------------|---|
| • Point source corrections | point source emissions or point source employment for inventory area for the specific SIC |
| • Application of controls | control efficiency, rule effectiveness, rule penetration |
| • Spatial allocation | employment, population, facility location, zoning or business districts location |
| • Temporal resolution | seasonal throughput, operating days per week, operating hours per day |

3.3.3 POINT SOURCE CORRECTIONS

If the preferred method is used to estimate area source emissions from this category, the point source correction is performed as part of the method itself. If Alternate Method 1 is used, the point source corrections can be performed by one of the following: (1) subtract point source emissions from calculated total emissions, or (2) subtract point source employment in the specific SIC from total employment in that SIC and calculate area source emissions using the remaining employment in the SIC. If Alternate Method 2 is used, the point source corrections are performed by subtracting point source emissions from calculated total emissions.

3.3.4 APPLICATION OF CONTROLS

Section 3.8 of *Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone, Volume I*, (EPA, 1991) provides guidance for determining and applying rule effectiveness (RE) for a source category. In addition, the EPA document *Procedures for Estimating and Applying Rule Effectiveness in Post-1987 Base Year Emission Inventories for Ozone and Carbon Monoxide State Implementation Plans* (EPA, 1989) provides more detailed information on RE.

Controlled area source emissions may be calculated with either of the following equations:

$$CAE_A = (EF_A)(Q)[1 - (CE)(RP)(RE)] \quad (11.3-5)$$

or

$$CAE_A = (UAE_A)[1 - (CE)(RP)(RE)]$$

where: CAE_A = controlled area source emissions of pollutant A
 EF_A = emission factor for pollutant A
 Q = activity factor for category
 CE = control efficiency/100
 RP = rule penetration/100
 RE = rule effectiveness/100
 UAE_A = uncontrolled area source emissions of pollutant A

3.3.5 SPATIAL ALLOCATION

If the emissions estimates are developed using a per employee factor, the spatial allocation of emissions can be performed according to facility location (if known) as with the point source inventory, or with local employment data. The agency should be aware that since location of gasoline marketing does not necessarily mirror location of population within a county, using population to spatially allocate emissions might be misleading. The inventorying agency will need to evaluate options for allocating county emissions, such as zoning information, actual location data identified from surveys, industry publications, etc.

3.3.6 TEMPORAL RESOLUTION

Seasonal Apportioning

Because emissions from these subcategories are generally directly proportional to fuel sales and fuel sales have well-documented seasonal trends, annual gasoline distribution emissions should be apportioned monthly based on fuel sales data. Fuel sales tax revenues are usually available from state departments of revenue and should be used to allocate emissions.

Daily/Hourly Resolution

As with all issues, the inventory agency should use local data if available. If no data are available, inventory agencies may use the Table 11.3-5 as default values:

TABLE 11.3-5
DAILY AND HOURLY ALLOCATION OF
GASOLINE DISTRIBUTION SYSTEM EMISSIONS

Subcategory	Daily Allocation (days per week)	Hourly Allocation (hours per day)
Trucks in Transit	6	24
Fuel Delivery to Outlets	6	24
Vehicle Refueling	7	24
Storage Tank Breathing	7	24

3.4 PROJECTING EMISSIONS

The type of surrogate used to project emissions is dependent on the methodology used to develop the initial emissions estimate. In “growing” the emissions estimate, the inventorying agency should use the same activity parameter as was used to develop the initial estimate. For example, if a per gallon factor was used to develop the initial estimate, growth in gasoline sales should be used to develop the projected emissions estimate.

The EIIP Projections Committee has developed a series of guidance documents containing information on options for forecasting future emissions. You can refer to these documents at <http://www.epa.gov/ttn/chief/eiip/project.htm>.

4

PREFERRED METHODS FOR ESTIMATING EMISSIONS

The following procedures should be used for estimating emissions from the gasoline distribution subcategories. See Section 3 for additional guidance for the application of these methods.

4.1 GASOLINE TRUCKS IN TRANSIT

- (1) Consult state gasoline sales tax records or data collected through a survey of fuel distributors and retailers to determine the gasoline consumption in the study area.
- (2) Obtain highway weigh-station data to estimate the amount of fuel transported through the area. Calculate GTA, the factor accounting for twice-transported fuel:

$$GTA = \frac{TGD + TGT}{TGD} \quad (11.4-1)$$

where:

GTA = Gasoline transportation adjustment factor
TGD = Total gasoline dispensed in the inventory region (1,000 gallons)
TGT = Amount of gasoline transported twice within the inventory region (1,000 gallons)

- (3) Calculate emissions:

$$TTE = \frac{(TGD \times LEF \times GTA) + (TGD \times UEF \times GTA)}{2000} \quad (11.4-2)$$

where:

TTE = Total gasoline emissions from tank trucks in transit (tons)
LEF = Loaded tank truck in-transit emission factor from Table 11.3-1 (pounds per 1,000 gallons)
UEF = Unloaded tank truck in-transit emission factor from Table 11.3-1 (pounds per 1,000 gallons)

4.2 FUEL DELIVERY TO OUTLETS

- (1) Consult gasoline sales tax records or survey data to determine the gasoline consumption in the study area.
- (2) Use survey data to determine penetration of each filling technology.
- (3) Multiply total fuel sales in the study area by the fraction of stations using each filling technology to estimate the fuel dispensed by each technology.
- (4) Use technology-specific emission factors to estimate emissions from submerged filling, splash filling, and vapor-balanced submerged filling activities.
- (5) Sum emissions from each technology to estimate total emissions.

4.3 VEHICLE REFUELING

- (1) Consult gasoline sales tax records or survey data to determine the total amount of gasoline dispensed in the study area.
- (2) From the local control agency or survey data, determine the level of local Stage II refueling controls.
- (3) Run the MOBILE model to determine the emission rate on a mass per volume throughput (grams per gallon, converted to pounds per gallon) basis. (In MOBILE5b, this is accomplished by setting HCFLAG = 3). Based on the results of step 2, determine whether Stage II refueling controls need to be considered. If local stage II controls are in place, enter the appropriate data in the MOBILE one-time data section per MOBILE model requirements (EPA, 1994). (In MOBILE5b, set RLFLAG = 1 if there are no local Stage II controls, or set RLFLAG = 2 to calculate an emission factor that includes local Stage II controls. Note that MOBILE5b will factor in the effects of the national on-board vapor recovery system requirements for either value of RLFLAG.) MOBILE6 is due for release in 2000. The reader should check the OTAQ Website for updated information on MOBILE6 (www.epa.gov/oms/m6.htm).
- (4) Multiply the emission factor (lb/gallon of fuel) times the estimated gasoline volume (gallons of gasoline) to estimate emissions from vehicle refueling.

4.4 STORAGE TANK BREATHING

- (1) Consult gasoline sales tax records or survey data to determine the gasoline consumption in the study area.
- (2) Multiply gasoline sales (gallons) times the emission factor to estimate emissions from storage tank breathing.

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5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

Frequently, local county-level sales tax data for gasoline sales or other local data needed to adjust these values are not available. Also, the collection of local gasoline sales data through surveys of distributors and retailers may be impractical or too expensive. Under these circumstances, use of one of the following alternative methods is appropriate.

5.1 ALTERNATIVE METHOD 1

5.1.1 GASOLINE TRUCKS IN TRANSIT

This method is the same as the preferred method, except that a default factor is used to estimate the adjustment factor for gasoline transported twice in the inventory area.

- (1) Consult gasoline sales tax records or survey data to determine the gasoline consumption in the study area.
- (2) Use 1.25, a national default rate, as GTA (gasoline transportation adjustment factor).
- (3) Calculate emissions:

$$\text{TTE} = \frac{(\text{TGD} \times \text{LEF} \times \text{GTA}) + (\text{TGD} \times \text{UEF} \times \text{GTA})}{2000} \quad (11.5-1)$$

where:

TTE	=	Total gasoline emissions from tank trucks in transit (tons)
LEF	=	Loaded tank truck in-transit emission factor from Table 11.3-1 (pounds per 1,000 gallons)
UEF	=	Unloaded tank truck in-transit emission factor from Table 11.3-1 (pounds per 1,000 gallons)

5.1.2 FUEL DELIVERY TO OUTLETS

This method apportions state-level data to counties instead of using local sales tax or survey data.

- (1) Assume that gasoline consumption is proportional to gasoline station sales, reported in the Bureau of the Census's *Census of Retail Trade*. Allocate state gasoline consumption data from *Highway Statistics* to the study area according to the dollar sales figures reported in the *Census of Retail Trade*.
- (2) Use survey data to determine penetration of each filling technology.
- (3) Multiply total fuel sales in the study area by the fraction of stations using each filling technology to estimate the fuel dispensed by each technology.
- (4) Use technology-specific emission factors to estimate emissions from submerged filling, splash filling, and vapor-balanced submerged filling activities.
- (5) Sum emissions from each technology to estimate total emissions.

5.1.3 VEHICLE REFUELING

- (1) Allocate state gasoline consumption from *Highway Statistics* to the study area. Assume that gasoline consumption is proportional to gasoline station sales, reported in the Bureau of the Census's *Census of Retail Trade*.
- (2) From the local control agency or survey data, determine the level of local Stage II refueling controls.
- (3) Run the MOBILE model to determine the emission rate on a mass per volume throughput (grams per gallon, converted to pounds per gallon) basis. (In MOBILE5b, this is accomplished by setting HCFLAG = 3). Based on the results of Step 2, determine whether Stage II refueling controls need to be considered. If local Stage II controls are in place, enter the appropriate data in the MOBILE one-time data section per MOBILE model requirements (EPA, 1994). (In MOBILE5b, set RLFLAG = 1 if there are no local Stage II controls, or set RLFLAG = 2 to calculate an emission factor that includes local Stage II controls. Note that MOBILE5b will factor in the effects of the national on-board vapor recovery system requirements for either value of RLFLAG.) MOBILE6 is due for release in 2000. The reader should check the OTAQ Website for updated information on MOBILE6 (www.epa.gov/oms/m6.htm).

- (4) Multiply the emission factor (lb/gallon of fuel) times the estimated gasoline volume (gallons of gasoline) to estimate emissions from vehicle refueling.

5.1.4 STORAGE TANK BREATHING

- (1) Allocate state gasoline consumption from *Highway Statistics* to the study area. Assume that gasoline consumption is proportional to gasoline station sales, reported in the Bureau of the Census's *Census of Retail Trade*.
- (2) Multiply gasoline sales (gallons) times the Table 11.3-1 emission factor to estimate emissions from storage tank breathing.

5.2 ALTERNATIVE METHOD 2

5.2.1 GASOLINE TRUCKS IN TRANSIT

- (1) Allocate state gasoline consumption from *Highway Statistics* to the study area. Assume that gasoline consumption is proportional to gasoline station sales, reported in the Bureau of the Census's *Census of Retail Trade*.
- (2) Use 1.25, a national default rate, as GTA.
- (3) Calculate emissions:

$$\text{TTE} = \frac{(\text{TGD} \times \text{LEF} \times \text{GTA}) + (\text{TGD} \times \text{UEF} \times \text{GTA})}{2000} \quad (11.5-2)$$

where:

TTE	=	Total gasoline emissions from tank trucks in transit (tons)
LEF	=	Loaded tank truck in-transit emission factor from Table 11.3-1 (pounds per 1,000 gallons)
UEF	=	Unloaded tank truck in-transit emission factor from Table 11.3-1 (pounds per 1,000 gallons)

5.2.2 FUEL DELIVERY TO OUTLETS

- (1) Allocate state gasoline consumption from *Highway Statistics* to the study area. Assume that gasoline consumption is proportional to gasoline station sales, reported in the Bureau of the Census's *Census of Retail Trade*.

- (2) Use advice of local trade groups, industry representatives, or regulators to determine penetration of each filling technology.
- (3) Multiply total fuel sales in the study area by the fraction of stations using each filling technology to estimate the fuel dispensed by each technology.
- (4) Use technology-specific emission factors to estimate emissions from submerged filling, splash filling, and vapor-balanced submerged filling activities.
- (5) Sum emissions from each technology to estimate total emissions.

5.2.3 VEHICLE REFUELING

- (1) Consult state or local transportation planners to obtain VMT data for the study area.
- (2) From the local control agency or survey data, determine the level of local Stage II refueling controls.
- (3) Run the MOBILE model to determine the emission rate on a mass per vehicle-mile (grams per vehicle mile traveled, converted to pounds per mile) basis. (In MOBILE5b, this is accomplished by setting HCFLAG = 2). Based on the results of Step 2, determine whether Stage II refueling controls need to be considered. If local Stage II controls are in place, enter the appropriate data in the MOBILE one-time data section per MOBILE model requirements (EPA, 1994). (In MOBILE5b, set RLFLAG = 1 if there are no local Stage II controls, or set RLFLAG = 2 to calculate an emission factor that includes local Stage II controls. Note that MOBILE5b will factor in the effects of the national on-board vapor recovery system requirements for either value of RLFLAG.) MOBILE6 is due for release in 2000. The reader should check the OTAQ Website for updated information on MOBILE6 (www.epa.gov/oms/m6.htm).
- (4) Multiply the emission factor times the VMT estimates to estimate emissions from vehicle refueling.

5.2.4 STORAGE TANK BREATHING

Only one alternate methodology is provided for this category.

6

QUALITY ASSURANCE/ QUALITY CONTROL

Data collection and handling for the gasoline marketing source category should be planned and documented in the Quality Assurance Plan. When using survey methods, the survey planning and data handling should also be documented. Refer to the discussion of survey planning and survey QA/QC in Chapter 1, *Introduction to Area Source Emission Inventory Development*, of this volume, and the QA volume (VI) of the Emission Inventory Improvement Program (EIIP) series. Potential pitfalls to avoid when developing emission estimates by using a survey for this category are data gaps due to survey nonreturns or unidentified operations, unanswered or misunderstood survey questions, inappropriate assumptions used to compensate for missing information or scaling up the survey sample, and errors in compiling the returned survey information. Potential errors that are common to many area source methods are calculation errors, which can include unit conversion errors and data transfer errors.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

In this chapter, four subcategories of emission sources are discussed. Emission estimation for all of the subcategories requires the amount of gasoline sold in the inventory area as the activity level. The preferred methods call for detailed gasoline sales data that may not be available at the county or study area level. While using the most accurate fuel distribution data available is important, if the data are not immediately available, conducting a survey to determine actual gasoline distribution data is difficult, expensive, and time consuming. Allocating fuel distribution to the county level using gasoline station sales is estimated to require from 20 to 30 hours of technical effort, while performing a survey would probably take several months and possibly 1,000 to 2,000 hours of technical effort.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The Data Attribute Rating System (DARS) has been developed as a tool to rate emission inventories. A description of the system and the EIIP recommendations for its use can be found in Appendix F of EIIP Volume VI, *Quality Assurance Procedures*. The following discussion uses the DARS rating system as a way to compare the estimation approaches presented in this chapter and analyze their strengths and weaknesses.

The DARS scores for methods for tank trucks in transit are summarized in Tables 11.6-1 through 11.6-3; for fuel delivery to outlets, in Tables 11.6-4 through 11.6-6; for vehicle refueling, in Tables 11.6-7 through 11.6-9; and for storage tank breathing, in Tables 11.6-10 and 11.6-11. A range of scores is provided for activity attributes when the recommended method for activity data collection uses either local tax data or survey results scaled to the inventory area. The higher scores are assigned to the local tax data because local tax data are the most direct measure of local data for the inventory period. Survey data require a scaling step, which introduces potential over- or underestimation. All scores assume that satisfactory QA/QC measures are performed and no significant deviations from good inventory practice have been made. If these assumptions are not met, new DARS scores should be developed according to the guidance provided in the QA volume.

TABLE 11.6-1

**PREFERRED METHOD DARS SCORES: TANK TRUCKS IN TRANSIT;
LOCAL GASOLINE SALES, ADJUSTMENT FACTOR
FROM HIGHWAY WEIGH-STATION DATA**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.7	0.6 - 0.9	0.42 - 0.63
Source Specificity	0.6	0.4 - 0.5	0.24 - 0.30
Spatial Congruity	0.7	0.7 - 1	0.49 - 0.70
Temporal Congruity	0.5	0.7 - 0.8	0.35 - 0.40
Composite Scores	0.63	0.60 - 0.80	0.37 - 0.51

TABLE 11.6-2**ALTERNATIVE METHOD 1 DARS SCORES: TANK TRUCKS IN TRANSIT;
LOCAL GASOLINE SALES, DEFAULT ADJUSTMENT FACTOR**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.7	0.6 - 0.9	0.42 - 0.63
Source Specificity	0.6	0.7 - 0.9	0.42 - 0.54
Spatial Congruity	0.7	0.5 - 0.8	0.37 - 0.53
Temporal Congruity	0.5	0.5 - 0.6	0.26 - 0.30
Composite Scores	0.63	0.59 - 0.79	0.37 - 0.50

TABLE 11.6-3**ALTERNATIVE METHOD 2 DARS SCORES: TANK TRUCKS IN TRANSIT;
SCALED STATE-LEVEL GASOLINE SALES, DEFAULT ADJUSTMENT FACTOR**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.7	0.6	0.42
Source Specificity	0.6	0.7	0.42
Spatial Congruity	0.7	0.5	0.37
Temporal Congruity	0.5	0.5	0.26
Composite Scores	0.63	0.59	0.37

TABLE 11.6-4

**PREFERRED METHOD DARS SCORES: FUEL DELIVERY TO OUTLETS;
LOCAL GASOLINE SALES, FILLING METHOD FROM SURVEY**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.7	0.4 - 0.5	0.29 - 0.38
Source Specificity	0.7	0.4 - 0.5	0.24 - 0.32
Spatial Congruity	0.7	0.7 - 1	0.49 - 0.70
Temporal Congruity	0.5	0.7 - 0.8	0.35 - 0.40
Composite Scores	0.65	0.54 - 0.70	0.34 - 0.45

TABLE 11.6-5

**ALTERNATIVE METHOD 1 DARS SCORES: FUEL DELIVERY TO OUTLETS;
SCALED STATE-LEVEL GASOLINE SALES, FILLING METHOD FROM SURVEY**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.7	0.4	0.29
Source Specificity	0.7	0.4	0.24
Spatial Congruity	0.7	0.6	0.42
Temporal Congruity	0.5	0.7	0.35
Composite Scores	0.65	0.52	0.33

TABLE 11.6-6**ALTERNATIVE METHOD 2 DARS SCORES: FUEL DELIVERY TO OUTLETS;
SCALED STATE-LEVEL GASOLINE SALES, FILLING METHOD FROM TRADE GROUPS**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.7	0.4	0.29
Source Specificity	0.7	0.4	0.29
Spatial Congruity	0.7	0.6	0.42
Temporal Congruity	0.5	0.7	0.35
Composite Scores	0.65	0.54	0.34

TABLE 11.6-7**PREFERRED METHOD DARS SCORES: VEHICLE REFUELING;
LOCAL GASOLINE SALES, FILLING METHOD FROM REGULATORS**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.8	0.4 - 0.7	0.32 - 0.56
Source Specificity	0.8	0.6 - 0.8	0.48 - 0.64
Spatial Congruity	1	0.7 - 1	0.70 - 1.00
Temporal Congruity	0.9	0.7 - 0.8	0.63 - 0.72
Composite Scores	0.88	0.60 - 0.83	0.53 - 0.73

TABLE 11.6-8

**ALTERNATIVE METHOD 1 DARS SCORES: VEHICLE REFUELING;
SCALED STATE-LEVEL GASOLINE SALES, FILLING METHOD FROM SURVEY**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.7	0.4	0.28
Source Specificity	0.8	0.6	0.48
Spatial Congruity	1	0.6	0.60
Temporal Congruity	0.9	0.7	0.63
Composite Scores	0.85	0.58	0.50

TABLE 11.6-9

**ALTERNATIVE METHOD 2 DARS SCORES: VEHICLE REFUELING;
GASOLINE USE FROM VMT, FILLING METHOD FROM SURVEY**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.7	0.4	0.28
Source Specificity	0.8	0.4	0.32
Spatial Congruity	1	0.7	0.70
Temporal Congruity	0.9	0.7	0.63
Composite Scores	0.85	0.55	0.48

TABLE 11.6-10**PREFERRED METHOD DARS SCORES: STORAGE TANK BREATHING;
LOCAL GASOLINE SALES**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.7	0.6 - 0.9	0.42 - 0.63
Source Specificity	0.7	0.7 - 0.9	0.49 - 0.63
Spatial Congruity	0.7	0.7 - 1	0.49 - 0.70
Temporal Congruity	0.5	0.7 - 0.8	0.35 - 0.40
Composite Scores	0.65	0.68 - 0.90	0.44 - 0.59

TABLE 11.6-11**ALTERNATIVE METHOD 1 DARS SCORES: STORAGE TANK BREATHING;
SCALED STATE-LEVEL GASOLINE SALES**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.7	0.6	0.42
Source Specificity	0.7	0.7	0.49
Spatial Congruity	0.7	0.6	0.42
Temporal Congruity	0.5	0.7	0.35
Composite Scores	0.65	0.65	0.42

All of the emission calculation methods for tank trucks in transit, fuel delivery to outlets, and storage tank breathing use emission factors from *AP-42*. Important points to consider when scoring the emission factor component of these methods are that the factors are based on studies published in 1982 and that local temperature variations and gasoline Reid vapor pressure (RVP) are not factored into the emission calculation. The age of the emission data means that any changes in gasoline formulation and improvements in vapor control technology since 1982 will not be reflected in the emission factors. DARS scoring for all of the *AP-42* emission factors are the same except for the tank trucks in-transit subcategory. The scores for emission factor source specificity for tank trucks in transit are lower than for other subcategories because the factors provided in this chapter are averages of ranges provided in *AP-42*.

The emission factor recommended for the vehicle refueling subcategory was developed using the MOBILE model, and is a factor that expresses refueling emissions as a function of fuel RVP, temperature of dispensed fuel, and the difference in the temperature between the dispensed fuel and the residual tank fuel. The effects of emission controls may also be included in this factor. These more locally specific and up-to-date emission factors are scored higher than the *AP-42* factors.

The most significant difference between the preferred and the first and second alternative methods for this source category is how the activity-level data are collected. The preferred methods for activity data collection use either local gasoline sales data collected by a state or local tax authority, or survey data obtained from gasoline retailers in the area. Using local gasoline sales tax data results in the highest DARS scores for activity attributes. The other preferred method for collecting activity data, a survey of gasoline retailers, will require a scaling step. That scaling step could introduce the same level of variability to the estimate that is introduced in Alternative Method 2, in which state-level gasoline sales are scaled down to the inventory area. DARS scores assigned to the survey approach and the scaled state-level data approach reflect this similarity.

A component of the DARS scoring for gasoline trucks in transit, fuel delivery to outlets, and vehicle refueling is the apportioning of the activity. For trucks in transit, the amount of gasoline sold in the area must be adjusted up to account for gasoline that is transported twice within the inventory area and gasoline that is transported through, but not delivered in, the area. The preferred approach for this adjustment, using weigh-station data, will not capture all of the activity. Activity scores for the preferred method are reduced because of this adjustment approach. The alternative approach is a national default factor, which reduces the spatial congruity score because it will not reflect variability at the local level. The activity temporal congruity score for tank trucks in transit is also lowered since the adjustment factor is based on

a 1978 report on gasoline marketing (EPA, 1991) and does not reflect any recent changes in transport practices. Adjustments for fuel delivery to outlets and vehicle refueling activities must be made to define uncontrolled or controlled portions for the emission estimate. In each case, the apportioning procedure reduces the rating of activity measurement and source specificity from what they might have been if the activity level had been more directly measured and assumptions about the application of controls were more specific to gasoline sales. These adjustments may result in an over- or underestimation of emissions if the assumptions are not valid in the inventory area.

6.1.2 SOURCES OF UNCERTAINTY

Another way to assess the emission estimates is to examine the associated uncertainty. For activity estimates derived from survey data, the uncertainty can be quantified (see Chapter 4 of Volume VI of the EIIP series). Statistics needed to quantify the uncertainty for other methods of activity-level data collection are incomplete.

Sources of uncertainty in estimating emissions from gasoline marketing include the difficulty of collecting information for adjustment and apportioning factors, and the use of assumptions when using that information. Of particular concern is the assumption that activity data for fuel delivery to outlets can be apportioned to different types of controls by a count of gasoline stations with no consideration of the differences in throughput that may exist between a larger and possibly controlled station and a smaller uncontrolled station.

The emission factors provided in *AP-42* also carry a degree of uncertainty in that any single emission factor for gasoline marketing processes will not necessarily reflect the local gasoline formulation or temperatures, or the equipment and handling practices in the area for the inventory time period. The emission factors calculated by the MOBILE model should reduce the uncertainty for the vehicle refueling subcategory emission estimates.

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7

DATA CODING PROCEDURES

The inventory preparer should check the EPA website (<http://www.epa.gov/ttn/chief/>) for the latest information (codes) available to characterize emission estimates from gasoline marketing. A complete list of Source Classification Codes (SCC) can be retrieved at <http://www.epa.gov/ttn/chief/codes/>. Table 11.7-1 lists the applicable SCCs for gasoline marketing.

Available codes and process definitions influence and help guide the preparation of emission estimates for this category. Data transfer formats should be taken into account when an inventory preparer plans for data collection, calculation, and inventory presentation. Consistent categorization and coding will result in greater continuity between emission inventories for use in regional and national scale analyses.

7.1 NECESSARY DATA ELEMENTS

If the category emissions data will be transferred to EPA for incorporation into the national criteria and toxics air pollutant inventory, specific data transfer formats are acceptable. The acceptable data transfer format(s) are described and available for download at <http://www.epa.gov/ttn/chief/net/>. The acceptable data transfer formats contain the data elements necessary to complete the data set for use in regional or national air quality and human exposure modeling. The inventory preparer should review the area source portion of the acceptable file format(s) to understand the necessary data elements. The EPA describes its use and processing of the data for purposes of completing the national inventory, in its Data Incorporation Plan, also located at <http://www.epa.gov/ttn/chief/net/>.

TABLE 11.7-1
AREA AND MOBILE SOURCE CATEGORY CODES
FOR GASOLINE MARKETING

Process Description	Source Category Codes
Petroleum Product Transit: Truck - Gasoline	25-01-030-120
Petroleum Product: Underground Tank Filling-Submerged	25-01-060-051
Storage - Gasoline Service Stations: Underground Tank Filling-Splash	25-01-060-052
Storage - Gasoline Service Stations: Underground Tank Filling-Balanced Submerged	25-01-060-053
Storage - Gasoline Service Stations: Vehicle Fueling-Uncontrolled Displacement Loss	25-01-060-101
Storage - Gasoline Service Stations: Vehicle Fueling-Controlled Displacement Loss	25-01-060-102
Storage - Gasoline Service Stations: Vehicle Fueling-Spillage	25-01-060-103
Storage - Gasoline Service Stations: Underground Tank-Breathing and Emptying	25-01-060-201
Storage - Gasoline Service Stations: Total All Processes	25-01-060-000

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VOLUME III: CHAPTER 12

MARINE VESSEL LOADING, BALLASTING, AND TRANSIT

Revised Final

January 2001



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Prepared for:
Area Sources Committee
Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

This chapter is one of a series of documents developed to provide cost-effective, reliable and consistent approaches to estimating emissions for area source inventories. Multiple methods are provided in the chapters to accommodate needs of state agencies with different levels of available resources and skills; and different levels of needs for accuracy and reliability of their estimates. More information about the EIIP program can be found in Volume 1 of the EIIP series, *Introduction and Use of EIIP Guidance for Emissions Inventory Development*.

This chapter describes the procedures and recommended approaches for estimating emissions from marine vessel loading, ballasting, and transit. Section 2 of this chapter contains a general description of marine vessel loading, ballasting, and transit and an overview of available control technologies. Section 3 provides an overview of available emission estimation methods. Section 4 presents the preferred method for estimating emissions from these processes, and Section 5 of this series of documents usually presents alternative emission estimation techniques. For this source category, no alternative methods are known to exist, and Section 5 presents a brief discussion of this issue. Quality assurance issues and emission estimate quality indicators for the methods presented in this chapter are discussed in Section 6. Data coding procedures are discussed in Section 7. Section 8 is the reference section.

Throughout this chapter and other EIIP area source methods chapters, we stress that area source categories should be prioritized by the inventory planners so that resources can be spent on the source categories that are the largest emitters, most likely to be subject to regulations or are already subject to regulations, or require special effort because of some policy reason. Prioritization is particularly important for area source inventories, because in some cases, a difficult to characterize source category may contribute very little to overall emissions and attempting a high quality estimate for that source category may not be cost effective.

EIIP chapters are written for the state and local air pollution agencies, with their input and review. EIIP is a response to EPA's understanding that state and local agency personnel have more knowledge about their inventory area's activities, processes, emissions, and availability of information; and require flexible inventory methods to best use their sometimes limited resources. These EIIP area source chapters are written as a set of options presented to inventory professionals capable of using their own experience and judgement to apply the method that best fits their overall needs and constraints.

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2

SOURCE CATEGORY DESCRIPTION

2.1 CATEGORY DESCRIPTION

Petroleum liquids are transported via ships and barges, and on-land transportation. The procedures discussed below relate to evaporative VOC emissions from marine transport of petroleum liquids. This category does not include exhaust emissions from fuel consumed by vessels while in transit or in port. Additional information about petroleum vessels can be found in *AP-42* (EPA, 1995), *AIRS Area and Mobile Source Category Codes* (EPA, 1999), and *Methodologies for Estimating Air Emissions from Three Non-Traditional Source Categories* (EPA, 1993).

2.2 PROCESS DESCRIPTION AND EMISSION SOURCES

In general, “petroleum liquids” include both crude oil and any refined petroleum product. Refined petroleum products conveyed to fuel marketing terminals and petrochemical industries via ships and barges include gasoline, kerosene, distillate oil, residual oil, jet fuel, and other petroleum-derived chemicals such as naphtha, mineral spirits, and asphalt.

For the purposes of this document, petroleum liquids are classified into groups which are represented by crude oil, gasoline, jet naphtha, distillate oil/kerosene, or residual oil. Evaporative emissions from marine vessel operations result from three processes: loading, ballasting, and transit. These processes are described in more detail below and in *Methodologies for Estimating Air Emissions from Three Non-Traditional Source Categories*. Although there may be certain ports where loading large marine tankers results in emissions greater than 100 tons per year (tpy) at a given facility, Volatile Organic Compound (VOC) emissions in most ports do not exceed 100 tpy. Methods discussed in this chapter apply to area sources only. Emissions for point source facilities, such as petroleum refineries, should be calculated using more detailed methods. Petroleum vessel loading, ballasting and their associated emissions are typically concentrated in urban coastal areas and ports on inland waterways. Transit emissions are based on the amount of time that the vessel is in an area.

2.2.1 LOADING LOSSES (SHIPS/OCEAN VESSELS AND BARGES)

Loading losses occur as organic vapors in “empty” cargo tanks are displaced to the atmosphere by the liquid being loaded into the tanks. These vapors are a composite of vapors formed in three ways:

- Vapors which are formed in the “empty” tank by evaporation of residual product from previous loads;
- Vapors transferred to the tank from a vapor balance system that was used when the previous load was being unloaded; and
- Vapors generated in the tank as the new product is being loaded.

Loading losses are usually the largest source of evaporative emissions from petroleum vessels (EPA, 1996). This activity usually only occurs at refineries or at the terminal at the end of the pipeline where the product is loaded for distribution. However, petroleum liquids shipped in “super tankers” may be unloaded to barges or smaller ships in a harbor or bay to allow the larger tanker to enter shallower ports. In this situation called “lightering operations”, vessel loading emissions occur along with ship transit and ballasting emissions. Barges (compartment depth 10 to 12 feet) exhibit higher emissions levels than ocean vessels which have greater compartment depth (approximately 40 feet).

2.2.2 BALLASTING LOSSES (SHIP/OCEAN VESSELS)

Ballasting losses are associated with the unloading of petroleum liquids at marine terminals and refinery loading docks from vessels which do not have segregated ballast tanks. It is common practice to load several cargo tank compartments with sea water after the cargo has been unloaded. This water, called “ballast,” improves the stability of the empty tanker during the subsequent voyage. Ballasting emissions occur as vapor-laden air in the empty cargo tank is displaced to the atmosphere by ballast water being pumped into the tank. More often, the vessel being ballasted will be equipped with segregated ballasting tanks and ballasting will not result in emissions of VOC to the atmosphere. However, if the vessels being ballasted are not equipped with segregated ballasting tanks, then ballasting may range between 15 to 40 percent of the vessels’ capacities (EPA, 1996).

2.2.3 TRANSIT LOSSES (SHIP/OCEAN VESSELS AND BARGES)

Transit losses are similar to breathing losses associated with petroleum storage. Transit loss is the expulsion of vapor from a vessel compartment through vapor contraction and expansion, which are the result of changes in temperature and barometric pressure. This loss may be

accompanied by slight changes in the level of the liquid in the tank due to liquid expansion or contraction due to the temperature change. Some ships are equipped with controls for these losses.

2.3 FACTORS INFLUENCING EMISSIONS

VOC emissions from petroleum vessel loading, ballasting, and transit are influenced by several factors. Emissions are a function of the physical and chemical characteristics of both previous and new cargos. Emissions are also a function of the vessel size. Many U.S. harbors are too shallow to receive large tankers. Instead, these tankers must remain outside the harbor area and off-load their cargo to smaller vessels in a process known as lightering. Since most lightering occurs more than 30 miles offshore, emissions from these operations are well dispersed before they reach the land. Lightering operations that occur outside the inventory study area may not need to be included in the inventory. Preparers of inventories should check with policymakers, modelers, or other inventory clients to determine whether it is necessary to include offshore lightering emissions. If lightering emissions do need to be included in an inventory, estimating the potential emissions from loading or ballasting will reflect the same processes as those discussed in Sections 2.2.1 and 2.2.2 of this chapter.

VOC emissions are also a function of the method of vessel loading. In splash loading, the fill pipe dispensing the cargo is lowered only partway into the cargo tank, resulting in higher turbulence during loading and subsequent high levels of vapor generation and loss. On the other hand, in submerged loading, the fill pipe extends almost to the bottom of the cargo tank, thus controlling liquid turbulence, and resulting in much lower vapor generation than encountered during splash loading.

2.4 CONTROL TECHNIQUES

The U.S. Coast Guard administers regulations (33 CFR, Part 157) that apply to all vessels exceeding 150 gross tons and are either documented under U.S. laws or are foreign vessels that transfer cargoes at ports subject to the jurisdiction of the U.S., or otherwise enter or operate in the navigable waters of the United States. The only exceptions are for foreign ships that are simply passing through U.S. waters or are exempt by the Port and Tanker Safety Act, as amended. The Coast Guard rule requires that all affected ships must have segregated ballast tanks, which should eliminate emissions from ballasting for these ships. Vessels unaffected by the regulation should be considered potential sources of ballasting emissions.

Many states require controls on vessel loading. State and local rules should be investigated before collecting other data for this category. Cases exist where companies have agreed to install

controls where none are required by Federal, state or local regulations. Inventory preparers should identify these instances.

Emissions from vessel loading can be controlled through loading practice or through control equipment. Submerged loading, in which the fill pipe opening is below the liquid surface level, reduces liquid turbulence and resulting vapor generation (EPA, 1996). Emissions from splash loading can also be reduced by restricting the loading rate until the fill pipe is submerged. This practice reduces the liquid turbulence during the splash loading portion of the load cycle.¹ When vessel loading is part of a lightering operation, vapor balancing may be used to transfer the vapor from the vessel being loaded to the vessel being unloaded. Emissions from vessel loading may also be controlled at terminals through vapor balance systems or with vapor control systems, such as carbon adsorption, refrigeration, or thermal destruction units.¹

Controls for emissions from ballasting include using segregated non-contaminated ballast tanks, or placing the ballast between hulls on double-hulled ships (33 CFR, Part 157).

Emissions during transit can be reduced through the use of an inert gas system that maintains an inert gas atmosphere at a slight positive pressure in each tank to minimize emissions and reduce the risk of explosions.¹

The use of any of these controls within the inventory area should be investigated before emissions are calculated.

¹ Personal communication between Allen Ellet, Senior Environmental Consultant, BP Oil Company, and L. Adams, Eastern Research Group Inc., February 1998.

3

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATION METHODOLOGIES

This document does not present an alternative method of estimating emissions from marine vessels carrying petroleum liquids. The preferred method can be used for any type of marine vessel, traffic classification, crude oil or refined petroleum product type, and any area of the United States served by marine vessels.

3.1.1 VOLATILE ORGANIC COMPOUNDS

The preferred method for estimating VOC emissions from marine vessel loading, ballasting, and transit is based on estimates of amount and type of products transported to or from the inventory area by waterways as well as the traffic classification (import, domestic, internal upbound, etc.). Fuels and other petroleum liquids transported are classified into five major product types of significantly different densities, vapor pressures, and physical compositions and the types of losses (emission points) expected from a specific operation are determined based on the traffic classification identified above. Inventory preparers with detailed information about the products being handled in their inventory area can use *AP-42* equations for estimation calculations, after activity data has been collected. VOC emissions are estimated by multiplying the throughput by the appropriate emission factors corresponding to the type of loss occurring in a specific traffic classification.

3.1.2 HAZARDOUS AIR POLLUTANTS

Hazardous air pollutant (HAP) emissions from this source are assumed to be proportional to the HAP vapor phase weight concentrations of the petroleum liquid for which the emissions are being calculated.

3.2 DATA NEEDS

3.2.1 DATA ELEMENTS

Several data sources are available on the movement of crude oil and other petroleum products; tonnage shipped and received; and capacities of refineries and bulk terminals at the national, regional, Petroleum Administration for Defense (PAD) District, state and local levels.

The minimum data elements needed to calculate emission estimates for marine vessel loading, ballasting, and transit are as follows:

- Petroleum liquids by traffic classification shipped¹ by type and volume aggregated by vessel type;
- Petroleum liquid by traffic classification received² by type and volume aggregated by vessel type;
- Petroleum liquid in transit through inventory area;
- Controls in place for all operations, and control effectiveness;
- Product type within each traffic classification;
- Information on transport situation (i.e., barge loading, ballasting, transit) inferred from the traffic classification; and
- Fraction of transit time spent in inventory area.

Traffic classifications will depend on the data source used. Examples used in this document are based on the publication *Waterborne Commerce of the United States*.³

As mentioned in Section 2 of this chapter, regulations administered by the U.S. Coast Guard require that large marine vessels control organic vapors from ballasting through measures such as segregated ballast tanks. As a result, ships affected by this rule do not need to be included in

¹ Traffic classification shipped: Materials classified as shipments or outbound are moved from the subject port to another location.

² Traffic classification received: Materials classified as receipts or inbound are moved from another location to the subject port.

³ The publication can be obtained from the U.S. Army Corps of Engineers, New Orleans District, Waterborne Commerce Statistics Center, P.O. Box 61280, New Orleans, LA, 70161-1280. Tel. 504-862-1400; Waterborne commerce statistics may also be obtained on the internet from the Waterborne Commerce Statistics Center Wide World Web site at <http://www.bts.gov/ntda/acewcsc/>

estimates of emissions from ballasting. Ballasting emissions from smaller vessels will need to be investigated.

3.2.2 POINT SOURCE CORRECTIONS

Although there are certain ports where handling of crude oil and other petroleum products may result in large emissions, annual VOC emissions at most ports would not exceed 100 tons. As a result, emissions from marine vessel loading and other operations generally should be considered area sources. Some areas may have petroleum refineries where vessel loading operations have been accounted for as point sources. If so, the area source emissions estimating methodology should be designed to not double-count any sources that have been inventoried as point sources.

3.2.3 APPLICATION OF CONTROLS

Control techniques for loading, ballasting and transit are discussed in Section 2.4 of this chapter. Rules will vary by locale and the size of the terminal or vessel. Inventory preparers should investigate the rules in place in the inventory area, and determine if those rules apply to the smaller sources that make up an area source inventory. Air agencies, local port authorities, and marine vessel operators should be contacted about rules that apply in the inventory area. In addition to controls that are put in place because of rules, inventory preparers should identify instances of controls that are not required, but still used.

Air pollution control regulations in Louisiana and Pennsylvania require that marine loading facilities serving ships and/or barges loading crude oil, gasoline, or volatile organic compounds be equipped with a vapor collection system designed to collect the organic compounds vapors displaced from ships and/or barges during loading. The vapors are then processed by recovery and/or destruction systems such that uncontrolled emissions are reduced by at least 90 percent by weight. Pennsylvania air laws also require that by September 28, 1996, a minimum of 65 percent of the total volume of receipt of crude oil and gasoline during a specified period be delivered to a facility in vessels which do not ballast, such as barges, or in vessels which do not emit VOC when ballasted, such as tankers using segregated ballast tanks.

Chapter 1 of this volume, the *Introduction to Area Source Emission Inventory Development*, provides general guidance for determining and applying rule effectiveness (RE) for a source category. In addition, the EPA document *Procedures for Estimating and Applying Rule Effectiveness in Post-1987 Base Year Emission Inventories for Ozone and Carbon Monoxide State Implementation Plans* provides more detailed information on RE (EPA, 1989).

3.2.4 SPATIAL ALLOCATION

The preferred method estimates emissions from loading, ballasting, and transit at the study region level. Emissions from these operations are concentrated in coastal areas, areas surrounding the Great Lakes, and areas adjacent to ports on inland waterways.

3.2.5 TEMPORAL RESOLUTION

Seasonal Apportioning

Some emissions from loading, ballasting, and transit of petroleum liquids from marine vessels are expected to be spread evenly over time, while other emissions will exhibit seasonal variations. Crude oil activities are relatively stable throughout the seasons. However, seasonal variations are expected in gasoline shipments and in those areas where wintertime frozen waters make ports inaccessible, such as the Great Lakes region.

Alternatively, temporal allocation of vessel loading, ballasting, and transit emissions can be accomplished by (1) obtaining detailed monthly activity data for the port in question and applying these data to the estimation equation, or (2) by apportionment factors based on use of the various products. The second method would capitalize on data which should already exist from area/mobile source inventory efforts (e.g., monthly or seasonal allocation of motor fuel; consumption and/or vehicle miles traveled; home heating fuels; aircraft fuels, etc.).

VOC emissions from these marine vessel operations vary due to changes in temperature as well as vapor pressure. Equations are available that account for such variations. However, this source category generally accounts for a relatively small portion of the overall area inventory.

Daily Resolution

Vessel loading and unloading operations are assumed to occur on a daily basis, seven days a week.

3.3 PROJECTING EMISSIONS

The EIIP Projections Committee has developed a series of guidance documents containing information on options for forecasting future emissions. You can refer to these documents at <http://www.epa.gov/ttn/chief/eiip/project.htm>.

Projecting emissions from petroleum vessel loading, ballasting, and transit requires information on anticipated changes in demand for those products and prices, as well as changes in storage capacity at ports and harbors. If no information is available, the inventorying agency can assume no changes to the existing level of activities. Alternatively, historic activity at the ports in the inventory area would be the best source of data for projecting future vessel activity.

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4

PREFERRED METHODS FOR ESTIMATING EMISSIONS

4.1 PREFERRED METHOD

The preferred method for estimating emissions from petroleum vessel loading, ballasting, and transit is described below. This method has limitations because the data that are needed are often not available. The method is intended to produce representative area source emissions estimates without requiring the expenditure of an unreasonable amount of resources to fill information gaps. However, it is recommended that, as a first step, inventory preparers identify controls that are in use in the area, and determine if emissions are primarily inventoried as part of the point source inventory. See Sections 2.4 and 3.2.3 of this chapter for more information about controls. Because some controls may eliminate emissions from certain processes and vessels altogether, data collection can be reduced to only those vessels and processes that are actually creating emissions. The steps of the methodology are as follows:

4.1.1 DETERMINATION OF AMOUNT OF PETROLEUM LIQUIDS TRANSPORTED TO OR FROM THE INVENTORY REGION

Determine the amount and type of petroleum liquids transported to or from the inventory region by waterway. The publication *Waterborne Commerce of the United States*¹ can be used to obtain data on the movements of commodities and vessels at individual ports and harbors and on individual waterways and canals of the United States. Both foreign and domestic commerce are included. Other sources of potentially useful information are the *Petroleum Supply Annual*,² *Petroleum Storage and Transportation* (DOE, 1989), publications from the U.S. Maritime

¹ The publication can be obtained from the U.S. Army Corps of Engineers, New Orleans District, Waterborne Commerce Statistics Center, P.O. Box 61280, New Orleans, LA, 70161-1280. Tel. 504-862-1400; Waterborne commerce statistics may also be obtained on the internet from the Waterborne Commerce Statistics Center Wide World Web site at <http://www.bts.gov/ntda/acewcsc/>

² The *Petroleum Supply Annual* can be obtained from the Energy Information Administration (EIA), Department of Energy, Washington, DC; refer to the EIA web site at <http://www.eia.doe.gov>.

Administration (U.S. Maritime Administration, 1985), and the *Petroleum Terminal Encyclopedia*.³ Estimates of percentage of each fuel type carried by each type of vessel are available from National or Regional Petroleum Administrations for Defense district, or the state.

The New Orleans District Data Request Office of the U.S. Army Corps of Engineers also handles special requests (at a cost), for water commerce statistics such as port- and harbor-specific information regarding shipping and receiving operations. Available data include the following:

- Crude oil and other petroleum products shipped and received at each harbor aggregated by fuel and type of vessel (i.e., tankers versus barges);
- Refinery receipts of crude oil and petroleum products by type of vessel; and
- Refinery shipments of crude oil and petroleum products by type of vessel.

In some cases, only one shipping company ships specific products to and from certain locations. If the Data Request Center were to reveal the tonnage for each product shipped, the Confidential Business Information for that particular company may be compromised. In this situation the Data Request Center prefers to submit the data as lump sum totals without specifying the tonnage to each destination.

4.1.2 IDENTIFICATION OF EMISSION POINTS

Use Table 12.4-1 to identify the emission points for each traffic classification. Determine emission points for all petroleum commodity types. Additional traffic classifications may exist. Classifications listed here represent the most likely emission process assignments. Table 12.4-1 is based on the following assumptions:

- All traffic involves transit emissions;
- Loading (ship, vessel, barge) emissions only result from export, shipment, and outbound traffic;
- Ballasting emissions only result from import and receipts traffic where the return voyage requires balancing;
- Through traffic results only in transit emissions; and

³ A periodic report from Salsby/Wilson Press, Houston, Texas; also available at <http://www.opisnet.com/terminal.htm>

- Barge loading emissions result only from exports and shipments traffic in shallower waterways (e.g. internal, lakeside waterways). Inventory preparers should investigate the use of barges and ships in their area.

The emission points presented in Table 12.4-1 are defined based on the traffic type definitions presented in the U.S. Army Corps of Engineers' *Waterborne Commerce of the United States*. Definitions of the traffic classifications can be found in that document. Loading operations (ship/vessel loading and barge loading) occur when the commodity is moved from the subject port to another port or location. Other traffic is assumed to be either traffic that has originated from another port or location and represents an unloading operation, or through traffic that does not stop at the port/waterway. One exception to this rule is intra-port or intra-waterway traffic which is loaded and unloaded in the subject waterway.

Unloading operations do not result in emissions from the vessel itself. Unloading operations only result in emissions counted as part of this source category if ballasting into non-segregated cargo tanks occurs to the vessel being unloaded. Otherwise the emissions that result due to the loading of the receiving tank or truck are counted as the source category covering emissions from loading tanks or trucks. Unless the receiving vessel is another marine vessel, loading of the tank or truck would not be considered marine loading and would not be part of this area source category.

4.1.3 CLASSIFICATION OF PETROLEUM PRODUCTS BY FUEL TYPE

Classify the petroleum liquids transported in the inventory region into five fuel type classifications using Table 12.4-2. If inventory data quality objectives require more detailed emission estimates, the inventory preparer may want to use the equations for calculating emissions from *AP-42*, Section 5.2, Transportation and Marketing of Petroleum Liquids, and portions of *AP-42*, Section 7.1, Liquid Storage Tanks, including Table 7.1-2, Properties of Selected Petroleum Liquids. The equations in *AP-42* require considerably more data collection than the data collection discussed in this chapter. The inventory preparer may want to consider the costs and benefits of using the more detailed approach, and may want to use the *AP-42* equations on a small subset of products that will most make the most significant improvement to the overall estimate, and use the emission factors presented here for the remaining products.

TABLE 12.4-1
EMISSION POINTS FOR PETROLEUM VESSEL
TRAFFIC CLASSIFICATIONS

Traffic Classification ^a	Ship/Ocean Vessel Loading	Barge Loading ^{b,c}	Ballasting ^c	Transit
Foreign Imports			X	X
Foreign Exports	X			X
Foreign Intratransit Merchandise				X
Foreign Through Upbound				X
Foreign Through Downbound				X
Canadian Exports	X ^d	X ^d		X
Canadian Imports			X ^d	X
Canadian Through Upbound				X
Canadian Through Downbound				X
Coastwise Receipts			X	X
Coastwise Shipments	X			X
Coastwise Through Upbound				X
Coastwise Through Downbound				X
Lakewise Receipts			X	X
Lakewise Shipments		X		X
Internal Receipts			X	X
Internal Shipments		X		X
Internal Inbound Upbound			X	X
Internal Inbound Downbound			X	X
Internal Outbound Upbound		X		X
Internal Outbound Downbound		X		X
Internal through Upbound				X
Internal through Downbound				X
Internal Intra-waterway Upbound		X	X	X
Internal Intra-waterway Downbound		X	X	X
Internal Inraport		X	X	X
Intra-territory Shipments		X		X
Intra-territory Receipts			X	X

^a These classifications are used in the *Waterborne Commerce of the United States*, U.S. Army Corps of Engineers, Waterborne Commerce Statistics Center, New Orleans, LA.

^b Barges may not be used at all ports by the indicated traffic classification.

^c Inventory preparers should research ballasting practices in their area to identify the traffic classifications where ballasting actually occurs.

^d Inventory preparers should research the use of barges and ships in their area.

TABLE 12.4-2**PRODUCT TYPE CLASSIFICATIONS FOR COMMON PETROLEUM
VESSEL COMMODITIES^a**

Petroleum Vessel Commodity	Product Type Classification
Crude petroleum	Crude oil
Gasoline	Gasoline
Kerosene	Distillate oil
Distillate fuel oil	Distillate oil
Residual fuel oil	Residual oil
Lube oil and greases	Distillate oil
Petro. jelly and waxes	Distillate oil
Naphtha and solvents	Jet naphtha
Asphalt, tar, and pitch	Residual oil
Petroleum coke	Residual oil
Liquid natural gas	Gasoline
Petroleum products not elsewhere classified	Jet naphtha

^a These classifications were determined by approximately matching the density, vapor pressure, and physical composition of the commodities to the five product types. The product types match available AP-42 emission factors.

An example of how data from the *Waterborne Commerce* document can be compiled for one large waterway is shown in Example 12.4-1.

Example 12.4-1:

Data from Example Area A, an area where large amounts of petroleum liquids are handled, is listed in Appendix A as it is provided in the *Waterborne Commerce of the United States*. Shipments and receipts of commodities are listed by product type and traffic classification. Definitions of traffic classifications can be found in the *Waterborne Commerce* document. For an area source inventory, the information needs to be compiled first by traffic classifications representing similar processes, and then by product types that can be linked to existing emission factors. For this example, these steps are accomplished using a spreadsheet. The first step, shown in Table 12.4-3, is to enter the data into the spreadsheet so it can be sorted by traffic classification and product type.

Table 12.4-4 shows the data further combined into groups based on traffic classification and sorted by product types that will match AP-42 emission factors. Table 12.4-1 can be used to match traffic classifications and AP-42 processes, e.g. ship loading or barge loading. Note that based on local information, only foreign and Canadian and coastwise receipt categories were subject to ballasting.

4.1.4 ESTIMATION OF TRANSIT EMISSIONS

For transit emissions, estimate the average time traffic is in the inventory area. Specific data may be difficult to obtain. The best resource for this information may be the local port authorities.

4.1.5 CORRECTION FOR POINT SOURCE EMISSIONS

It is possible for some marine loading operations, such as those at large petroleum refineries operating their own port, to be included in point source inventories. To make the double-counting correction, the material throughputs from specific point source SCCs should be totaled and subtracted from the total area source material transferred. Area source emissions should then be estimated based on this corrected material transferred amount.

If the point source material throughputs are not available, the correction can be made at the emissions level (subtract total emissions from specific point source SCCs from total area source emissions). Emissions from vessel loading/unloading operations at facilities such as petroleum refineries located in the inventory area should be deducted from the area source totals. Point source SCCs may include 40600231 through 40600259. Additional point source SCCs may exist, so the point source inventory should be carefully reviewed.

TABLE 12.4-3
EXAMPLE SPREADSHEET FOR AREA A^a

Product Code	Commodity Name	AP-42 Product Type Class	Foreign & Canadian Total	Foreign & Canadian Imports	Foreign & Canadian Exports	Coastwise Total	Coastwise Receipts	Coastwise Shipments	Coastwise Through	Internal Total	Internal Inbound	Internal Outbound	Internal Through	Internal Intra
2100	Crude Petroleum	Crude	38,744	38,744	0	75	72	4	0	5,654	841	575	4,205	33
2211	Gasoline	Gasoline	518	0	518	1,654	21	1,633	0	5,294	626	940	3,536	192
2221	Kerosene	Distillate	0	0	0	0	0	0	0	290	0	131	159	0
2330	Distillate Fuel Oil	Distillate	20	12	8	322	83	239	0	4,494	570	1,398	2,484	72
2340	Residual Fuel Oil	Residual	232	72	160	144	59	85	0	5,613	541	1,947	2,920	205
2350	Lube Oil & Grease	Distillate	737	690	47	570	256	314	0	1,112	27	356	726	3
2410	Petro Jelly & Waxes	Distillate	0	0	0	0	0	0	0	56	0	0	56	0
2429	Naphtha & Solvents	Jet Naphtha	177	155	22	27	27	0	0	2,119	421	373	1,109	216
2430	Asphalt, Tar & Pitch	Residual	43	2	41	19	0	0	19	1,075	14	23	1,038	0
2540	Petroleum Coke	Residual	3,676	241	3,435	0	0	0	0	776	446	64	261	4
2640	Liquid Natural Gas	Gasoline	158	131	27	0	0	0	0	552	239	55	255	4
2990	Petroleum Prod, NEC	Jet Naphtha	0	0	0	7	0	7	0	624	101	226	284	15

^a All commodity amounts in one thousand tons

TABLE 12.4-4
PROCESS/ PRODUCT CATEGORIES^a

AP-42 Product Type Class	Product Code	Commodity Name	Ship loading		Barge Loading		Ballasting		Transit		
			Foreign & Canadian Exports	Coastwise Shipments	Internal Outbound	Internal Intra	Foreign & Canadian Imports	Coastwise Receipts	Foreign & Canadian Total	Coastwise Total	Internal Total
Crude	2100	Crude Petroleum	0	4	575	33	38,744	72	38,744	75	5,654
Distillate	2330	Distillate Fuel Oil	8	239	1,398	72	12	83	20	322	4,494
Distillate	2350	Lube Oil & Grease	47	314	356	3	690	256	737	570	1,112
Distillate	2221	Kerosene	0	0	131	0	0	0	0	0	290
Distillate	2410	Petroleum Jelly and Waxes	0	0	0	0	0	0	0	0	56
Gasoline	2640	Liquid Natural Gas	27	0	55	4	131	0	158	0	552
Gasoline	2211	Gasoline	518	1,633	940	192	0	21	518	1,654	5,294
Jet Naphtha	2990	Petroleum Prod., NEC	0	7	226	15	0	0	0	7	624
Jet Naphtha	2429	Naphtha & Solvents	22	0	373	216	155	27	177	27	2,119
Residual	2340	Residual Fuel Oil	160	85	1,947	205	72	59	232	144	5,613
Residual	2430	Asphalt, Tar and Pitch	41	0	23	0	2	0	43	19	1,075
Residual	2540	Petroleum Coke	3,435	0	64	4	241	0	3,676	0	776

^a All commodity amounts in one thousand tons

4.1.6 ESTIMATION OF EMISSIONS FROM PETROLEUM VESSELS

Use the estimates of petroleum liquids, grouped by traffic classification and sorted by product types, and the emission factors in Table 12.4-5 to estimate total VOC emissions from petroleum vessels for each of the five types of petroleum liquids (p) at each emission point. It should be noted that these factors are for dispensed product at 60°F and can be adjusted for significantly different conditions using original derivation methods in *AP-42*. It should also be noted that some emission factors may not apply to a particular port, e.g., barge loading or ballasting, may not take place.

In Section 2.2.2 of this chapter, ballasting practices are discussed. If ballasting only occurs using segregated ballast tanks, it is not necessary to estimate ballasting emissions. However, if ballasting uses the empty cargo tank, emissions will occur, and must be calculated. Note that the calculation for ballasting emissions in the equation includes a correction term of 0.30. This correction term reflects the practice of loading a ship or barge at some fraction of capacity when ballasting. Emission estimates will be improved if local information about typical percentages can be located and used. The correction term presented here represents a conservative assumption.

Apply any control efficiency to the appropriate terms in Equation 12.4-1, or Equation 12.4-2 can be used to apply control efficiency.

$$PV_p = [(SOEF_p \times PP_{S,p}) + (BREF_p \times PP_{B,p}) + (BLEF_{p,U} \times 0.30 \times PP_{BL,p}) + (TREF_p \times PP_{T,p})] \div 2000 \quad (12.4-1)$$

where:

PV_p	=	Total VOC emissions from petroleum vessel loading, ballasting, and transit for each of the petroleum liquids (p) transported: crude oil, gasoline, kerosene, distillate oil, and residual oil (tons)
$SOEF_p$	=	Ship/ocean vessel loading emission factor (pounds VOC per 1,000 gallons transferred)
$PP_{S,p}$	=	Amount of petroleum liquid (p) loaded into ships and ocean vessels in the inventory region (1,000 gallons)
$BREF_p$	=	Barge vessel loading emission factor (pounds VOC per 1,000 gallons transferred)
$PP_{B,p}$	=	Amount of petroleum liquid (p) loaded into barges in the inventory region (1,000 gallons)
$BLEF_p$	=	Ballasting emission factor (pounds VOC per 1,000 gallons water ballasted)
$PP_{BL,p}$	=	Amount of petroleum liquid (p) unloaded from vessels that are ballasted (1,000 gallons)

$TREF_p$ = Vessel transit emission factor (pounds VOC per week per 1,000 gallons transferred)
 $PP_{T,p}$ = Amount of petroleum liquid (p) transported by marine vessels in the inventory region (1,000 gallons)

TABLE 12.4-5

UNCONTROLLED VOC EMISSION FACTORS FOR PETROLEUM CARRYING MARINE VESSELS (EPA, 1996)

Petroleum Liquid	Ship/Ocean Vessel Loading (Pounds VOC per 1,000 gallons Transferred)	Barge Loading (Pounds VOC per 1,000 gallons Transferred)	Ballasting (Pounds VOC per 1,000 gallons Ballasted)^a	Transit (Pounds VOC per week per 1,000 gallons Transported)
Crude Oil	0.61	1	1.1 ^b	1.3
Gasoline ^b	1.8 ^b	3.4 ^b	0.8 ^b	2.7 ^b
Jet Naphtha/ Other	0.5	1.2	NA	0.7
Distillate Oil/Kerosene	0.005	0.012	NA	0.005
Residual Oil	4 x 10 ⁻⁵	9 x 10 ⁻⁵	NA	3 x 10 ⁻⁵

^a It may not be necessary to estimate ballasting emissions. See Section 3, of this chapter, Data Elements for discussion.

^b These are AP-42 "typical overall situation" factors; various additional factors related to specific types of service can be found in AP-42. In addition, AP-42 equations could be used, if necessary, to calculate emission factors for specific compounds, given values for true vapor pressures and average liquid molecular weights.

If controls exist, then control efficiency can be calculated:

$$PP_C = PP_U * (1 - CE/100) \quad (12.4-2)$$

where:

PP_C = Controlled emissions (tons)
 PP_U = Uncontrolled emissions (tons)
 CE = Control efficiency (%)

Data obtained from sources such as the *Waterborne Commerce of the United States* are typically provided in terms other than 1,000 gallons (Mgal) as is required in Equation 12.4-1 and must be converted. Equation 12.4-3 can be used to convert units from 1,000 ton (Mtons) to Mgal.

$$PP_v = (PP_m/d) * 2,000 \text{ lb/ton} * \text{Mgal/1,000 gallons} * 1,000 \text{ tons/Mtons} \quad (12.4-3)$$

where:

PP_v	=	Amount of petroleum liquid (Mgal)
PP_m	=	Amount of petroleum liquid (Mtons)
d	=	Density of petroleum liquid; see Table 7.1-2 in AP-42 (lb/gallon)

Example 12.4-2 illustrates the calculations used to estimate emissions from tons of fuel.

Example 12.4-2

The inventory area had an annual throughput of gasoline from vessel loading, barge loading, and transit operations as indicated below:

Operation	Throughput (1,000 tons)
Vessel loading	2,178
Barge loading	1,191
Ballasting	152
Transit	8,176

Using the gasoline density factor found in AP-42, Table 7.1-2 (5.6 lb/gal), and Equation 12.4-3, the mass throughputs are converted to volumetric throughputs. Vessels loading throughputs are converted by:

$$PP_v = [2,178 \text{ Mtons}/(5.6 \text{ lb/gal})] * \frac{2,000 \text{ lb}}{\text{ton}} * \frac{\text{Mgal}}{1,000 \text{ gal}} * \frac{1,000 \text{ tons}}{\text{Mtons}}$$

The results of the calculation are shown below:

Conversion of Mass Throughputs to Volumetric Throughputs			
Operation	Equation 12.4-1 Parameter	Throughput (Mtons)	Throughput (Mgal)
Vessel loading	$PP_{S,gas}$	2,178	777,857
Barge loading	$PP_{B,gas}$	1,191	425,357
Ballasting	$PP_{BL,gas}$	1,213	54,286
Transit	$PP_{T,gas}$	8,176	2,920,000

Example 12.4-2 (Continued)

For vessel loading operations, 90 percent of the total throughput was loaded at terminals with a control system of 95 percent efficiency. According to the local port authorities, transit time in the inventory area is two days (2/7 of a week). Emissions for each emission point are calculated using Equation 12.4-1 and the emission factors from Table 12.4-5. In this example, emissions for each emission point are calculated separately and then totaled. Note that CE is applied to vessel loading emissions, and transit emissions are apportioned to two days per week by multiplying emissions by 2/7.

Vessel Loading emissions are calculated:

$$\begin{aligned} PV_{\text{gas}} &= [1.8 \text{ lb VOC/Mgal} * 777,857 \text{ Mgal/yr}] * (0.10 + (0.9 * \left(1 - \frac{95}{100}\right))) \div 2,000 \text{ lb/ton} \\ &= 102 \text{ tons/yr} \end{aligned}$$

Barge Loading emissions are calculated:

$$\begin{aligned} PV_{\text{gas}} &= [3.4 \text{ lb VOC/Mgal} * 425,357 \text{ Mgal/yr}] \div 2,000 \text{ lb/ton} \\ &= 723 \text{ tons/yr} \end{aligned}$$

Ballasting emissions are calculated:

$$\begin{aligned} PV_{\text{gas}} &= [0.8 \text{ lb VOC/Mgal} * 54,286 \text{ Mgal/yr}] * 0.30 \div 2,000 \text{ lb/ton} \\ &= 7 \text{ tons/yr} \end{aligned}$$

Transit emissions are calculated:

$$\begin{aligned} PV_{\text{gas}} &= (2.7 \text{ lb VOC/Mgal} * 2,920,000 \text{ Mgal/yr} * 2/7 \text{ wk}) \div 2,000 \text{ lb/ton} \\ &= 1,128 \text{ tons/yr} \end{aligned}$$

Example 12.4-2 (Continued)

Total VOC emissions are calculated as follows:

$$\begin{aligned}\text{Total VOC} &= 102 \text{ tons/yr} + 723 \text{ tons/yr} + 7 \text{ tons/yr} + 1,128 \text{ tons/yr} \\ &= 1,957 \text{ tons/yr}\end{aligned}$$

Contributions from the point source inventory are 82 tons/yr VOC. The total VOC emissions in the area source inventory are:

$$1,957 \text{ tons/yr} - 82 \text{ tons/yr} = 1,875 \text{ tons/yr}$$

5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

No alternative methods are known to exist, nor are any necessary since the preferred method and data associated with it can be used for any type of vessel, any type of traffic, any type of fuel, and any area of the United States serviced by petroleum vessels.

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6

QUALITY ASSURANCE/ QUALITY CONTROL

Data collection and handling for the marine vessel loading, ballasting, and transit source category should be planned and documented in the Quality Assurance Plan. In particular, material type assignments and emission estimation calculations should be reviewed as part of the QA/QC procedures. Refer to the discussion of inventory planning and QA/QC in Chapter 1, *Introduction to Area Source Emission Inventory Development*, of this volume, and the QA volume (VI) of the EIIP series.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

One method is provided in this chapter for estimating emissions from marine vessel loading, ballasting, and transit. Data collection for this source category involves identifying the most suitable data source from those listed in Section 4 of this chapter, and compiling the information. Although data collection for this category can require a significant amount of effort, the quality of the activity data is high, and the effort required may be justified by the importance of the estimated emissions in areas where there is a significant amount of marine vessel loading, ballasting, and transit.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The Data Attribute Rating System (DARS) has been developed as a tool to rate emission inventories. A description of the system and the EIIP recommendations for its use can be found in Appendix F of EIIP Volume VI, *Quality Assurance Procedures*. The following discussion uses the DARS rating system as a way to compare the estimation approaches presented in this chapter and analyze their strengths and weaknesses.

The DARS scores for the preferred method are summarized in Table 12.6-1. A range of scores is provided to account for differences in the implementation of the method. Lower activity scores are shown for activity data that are not drawn from records collected specifically for the inventory area. This would be the case if specific product data are not available for the inventory area and the tonnage of each product loaded or unloaded in the inventory area must be apportioned from regional data. Higher DARS scores than those assigned in Table 12.6-1 could

be assigned if the equations from AP-42 are used, rather than emission factors that have been derived from the equations.

Lower emission factor scores reflect the necessary simplifications that must be made for an area source method. The first simplification is the use of emission factors developed from the equations provided in *AP-42*. Assumptions have been made concerning the fuel type vapor pressure and the molecular weight of vapors, which are addressed in the source specificity score, and average annual temperature, which is addressed in the spatial congruity score. The emission factor measurement scores will vary depending on whether the product is actually the product type for which the emission factor was developed, or a similar product that has been grouped into that product classification (see Table 12.4-1). Variability in local practices affect the spatial congruity score. Seasonal temperature differences and potential changes in equipment and filling practices since the latest update of the emission equations and parameters in *AP-42* affect the temporal congruity score.

TABLE 12.6-1

PREFERRED METHOD: DARS SCORES

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.3 - 0.5	0.9	0.27 - 0.45
Source Specificity	0.7 - 0.9	0.7 - 0.9	0.49 - 0.81
Spatial Congruity	0.5	0.7 - 1.0	0.35 - 0.5
Temporal Congruity	0.5	0.9 - 1.0	0.45 - 0.5
Composite Scores	0.5 - 0.6	0.80 - 0.95	0.39 - 0.57

6.1.2 SOURCES OF UNCERTAINTY

There are several sources of uncertainty in estimating emissions from this source category. When the method provided in this chapter is used, activity data are collected, the data may be apportioned to reflect activity in the inventory area, and amounts of some materials are grouped with similar material types into product classifications. Each of these steps will have some associated uncertainty, and the uncertainty cannot be quantified.

An additional source of uncertainty comes from using emission factors rather than equations that use a number of parameters. In this case, the sensitivity of the equations to different parameters could be quantified using typical sensitivity analysis techniques.

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7

DATA CODING PROCEDURES

The inventory preparer should check the EPA website (<http://www.epa.gov/ttn/chief/>) for the latest information (codes) available to characterize emission estimates from marine vessel loading, ballasting, and transit. A complete list of Source Classification Codes (SCC) can be retrieved at <http://www.epa.gov/ttn/chief/codes/>. Table 12.7-1 lists the applicable SCCs for marine vessel loading, ballasting, and transit.

Available codes and process definitions influence and help guide the preparation of emission estimates for this category. Data transfer formats should be taken into account when an inventory preparer plans for data collection, calculation, and inventory presentation. Consistent categorization and coding will result in greater continuity between emission inventories for use in regional and national scale analyses.

7.1 NECESSARY DATA ELEMENTS

If the category emissions data will be transferred to EPA for incorporation into the national criteria and toxics air pollutant inventory, specific data transfer formats are acceptable. The acceptable data transfer format(s) are described and available for download at <http://www.epa.gov/ttn/chief/net/>. The acceptable data transfer formats contain the data elements necessary to complete the data set for use in regional or national air quality and human exposure modeling. The inventory preparer should review the area source portion of the acceptable file format(s) to understand the necessary data elements. The EPA describes its use and processing of the data for purposes of completing the national inventory, in its Data Incorporation Plan, also located at <http://www.epa.gov/ttn/chief/net/>.

TABLE 12.7-1**AREA AND MOBILE SOURCE CATEGORY CODES FOR MARINE VESSEL LOADING,
BALLASTING AND TRANSIT**

Process Description	Source Category Code
Gasoline: Ship Loading -Cleaned and Vapor Free Tanks	40-60-002-31
Gasoline: Ocean Barges Loading	40-60-002-32
Gasoline: Barge Loading - Cleaned and Vapor Free Tanks	40-60-002-33
Gasoline: Ship Loading - Ballasted Tank	40-60-002-34
Gasoline: Ocean Barges Loading - Ballasted Tank	40-60-002-35
Gasoline: Ship Loading -Uncleaned Tanks	40-60-002-36
Gasoline: Ocean Barge Loading - Uncleaned Tanks	40-60-002-37
Gasoline: Barge Loading - Uncleaned Tanks	40-60-002-38
Gasoline: Tanker Ship - Ballasted Tank Condition	40-60-002-39
Gasoline: Barge Loading - Average Tank Condition	40-60-002-40
Gasoline: Tanker Ship - Ballasting	40-60-002-41
Crude Oil: Loading Tankers	40-60-002-43
Jet Fuel: Loading Tankers	40-60-002-44
Kerosene: Loading Tankers	40-60-002-45
Distillate Oil: Loading Tankers	40-60-002-46
Crude Oil: Loading Barges	40-60-002-48
Jet Fuel: Loading Barges	40-60-002-49
Kerosene: Loading Barges	40-60-002-50
Distillate Oil: Loading Barges	40-60-002-51
Crude Oil: Tanker Ballasting	40-60-002-53
Tanker/Barge Cleaning	40-60-002-59
Gasoline: Barge Loading - Ballasted	40-60-002-60
Not Classified	40-60-002-98
Not Classified	40-60-002-99

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Appendix A

Example Waterborne Commerce Data

EXAMPLE AREA A

Section Included: Gulf of Mexico to turning basins at West Port Arthur, Beaumont, and Orange, TX, about 85.8 miles; Adams Bayou Channel, about 1.6 miles; and Cow Bayou Channel, about 7 miles. Controlling Depth: Sabine Pass Channel, TX, 40 feet; Port Arthur, TX, 37 feet; Beaumont, TX, 39 feet; extension to Bethlehem Steel Shipyard, 32 feet; Orange, TX, 27 feet except channel around Harbor Island, 20 feet; Adams Bayou Channel, 9 feet; and Cow Bayou Channel, 8 feet. Project Depth: Sabine Pass Harbor, TX, 40 to 42 feet; Port Arthur, TX, 40 feet; Beaumont, TX, 40 feet except turning basin, 34 feet, and extension to Bethlehem Steel Shipyard, 30 feet; Orange, TX, 30 feet except channel around Harbor Island, 25 feet, Adams Bayou, 12 feet, and Cow Bayou, 13 feet, mean lowtide.

Comparative Statement of Traffic
(thousand tons)

Year	Total	Year	Total
1986	75,943	1991	84,213
1987	79,742	1992	88,348
1988	89,091	1993	95,191
1989	96,564	1994	99,675
1990	90,819	1995	103,254

Freight Traffic, 1995
(thousand tons)

Commodity	Total	Foreign		Canadian	
		Imports	Exports	Imports	Exports
Total, all commodities	49,124	40,724	8,178	167	55
Total petroleum and petroleum products	44,305	39,886	4,203	161	55
Subtotal crude petroleum	38,744	38,583	-----	161	-----
2100 crude petroleum	38,744	38,583	-----	161	-----
Subtotal petroleum products	5,562	1,303	4,203	-----	55
2211 gasoline	518	-----	518	-----	-----
2330 distillate fuel oil	21	12	8	-----	-----
2340 residual fuel oil	232	72	160	-----	-----
2350 lube oil & greases	737	690	47	-----	-----
2429 naphtha & solvents	177	155	22	-----	-----
2430 asphalt, tar & pitch	43	2	41	-----	-----
2540 petroleum coke	3,676	241	3,380	-----	55
2640 liquid natural gas	158	131	27	-----	-----
Total chemicals and related products	757	33	724	-----	-----
Subtotal fertilizers	12	-----	12	-----	-----
3190 fert. & mixes nec	12	-----	12	-----	-----
Subtotal other chemicals and related products	745	33	712	-----	-----
3211 acyclic hydrocarbons	26	22	4	-----	-----
3212 benzene & toluene	44	-----	44	-----	-----
3219 other hydrocarbons	104	4	100	-----	-----
3220 alcohols	103	3	100	-----	-----
3240 nitrogen func. comp	10	-----	10	-----	-----
3260 organic comp. nec	25	3	22	-----	-----
3275 inorg. elem., oxides, & halogen salts	0	0	-----	-----	-----
3276 metallic salts	430	-----	430	-----	-----
3281 radioactive material	0	0	-----	-----	-----
3282 pigments & paints	0	-----	0	-----	-----
3285 perfumes and cleansers	0	-----	0	-----	-----
3286 plastics	0	0	0	-----	-----
3291 pesticides	0	-----	0	-----	-----
3297 chemical additives	1	-----	1	-----	-----
3298 wood & resin chem.	0	0	0	-----	-----

Commodity	Total	Foreign		Canadian	
		Imports	Exports	Imports	Exports
Total crude materials, inedible except fuels	727	441	286	-----	-----
Subtotal forest products, wood and chips	231	6	224	-----	-----
4161 wood chips	224	-----	224	-----	-----
4170 wood in the rough	0	0	-----	-----	-----
4189 lumber	6	6	0	-----	-----
Subtotal pulp and waste paper	62	-----	62	-----	-----
4225 pulp & waste paper	62	-----	62	-----	-----
Subtotal soil, sand, gravel, rock and stone	432	432	-----	-----	-----
4322 limestone	30	30	-----	-----	-----
4331 sand & gravel	402	402	-----	-----	-----
Subtotal iron ore and scrap	2	2	-----	-----	-----
4420 iron & steel scrap	2	2	-----	-----	-----
Subtotal non-ferrous ores and scrap	0	0	-----	-----	-----
4680 non-ferrous scrap	0	0	-----	-----	-----
Subtotal other non-metal. min.	0	-----	0	-----	-----
4900 non-metal. min. nec	0	-----	0	-----	-----
Total primary manufactured goods	549	333	211	6	-----
Subtotal paper products	22	0	21	-----	-----
5120 paper & paperboard	21	0	21	-----	-----
5190 paper products nec	0	0	0	-----	-----
Subtotal lime, cement and glass	2	0	1	-----	-----
5290 misc. mineral prod.	2	0	1	-----	-----
Subtotal primary iron and steel products	313	304	4	6	-----
5312 pig iron	2	1	0	-----	-----
5320 i&s primary forms	262	256	-----	6	-----
5330 i&s plates & sheets	1	1	-----	-----	-----
5360 i&s bars & shapes	3	-----	3	-----	-----
5370 i&s pipe & tube	1	0	1	-----	-----
5390 primary i&s nec	45	45	-----	-----	-----
Subtotal primary non-ferrous metal products	2	1	1	-----	-----
5422 aluminum	1	1	0	-----	-----
5429 smelted prod. nec	0	-----	0	-----	-----
5480 fab. metal products	1	0	1	-----	-----
Subtotal primary wood products	211	27	183	-----	-----
5540 primary wood prod.	211	27	183	-----	-----
Total food and farm products	2,778	30	2,748	-----	-----
Subtotal grain	1,733	-----	1,733	-----	-----
6241 wheat	1,486	-----	1,486	-----	-----
6344 corn	0	-----	0	-----	-----
6442 rice	20	-----	20	-----	-----
6447 sorghum grains	227	-----	227	-----	-----
Subtotal oilseeds	513	-----	513	-----	-----
6522 soybeans	513	-----	513	-----	-----
6590 oilseeds nec	0	-----	0	-----	-----
Subtotal vegetable products	15	-----	15	-----	-----
6653 vegetable oils	1	-----	1	-----	-----
6654 vegetables & prod.	14	-----	14	-----	-----

Commodity	Total	Foreign		Canadian	
		Imports	Exports	Imports	Exports
Subtotal processed grain and animal feed	507	27	480	-----	-----
6746 wheat flour	385	-----	385	-----	-----
6747 grain mill products	95	-----	95	-----	-----
6782 animal feed, prep.	27	27	-----	-----	-----
Subtotal other agricultural products	11	3	7	-----	-----
6858 fruit juices	0	0	0	-----	-----
6871 coffee	3	3	-----	-----	-----
6885 alcoholic beverages	0	-----	0	-----	-----
6889 food products nec	8	1	7	-----	-----
6893 cotton	0	-----	0	-----	-----
Total all manufactured equipment, machinery and products	8	2	6	-----	-----
7110 Machinery (not elec)	3	1	2	-----	-----
7120 electrical machinery	3	0	2	-----	-----
7210 vehicles & parts	0	0	0	-----	-----
7220 air craft & parts	0	-----	0	-----	-----
7230 ships & boats	1	-----	1	-----	-----
7400 manufac. wood prod.	0	0	-----	-----	-----
7500 textile products	0	0	0	-----	-----
7600 rubber & plastic pr.	0	0	0	-----	-----
7900 manufac. prod. nec	0	0	0	-----	-----
Total unknown or not elsewhere classified	0	0	-----	-----	-----
9900 unknown or nec	0	0	-----	-----	-----
Ton-miles (x1000) Foreign & Canadian	123,373	80,527	42,846	0	0

Commodity	Total	Coastwise		
		Receipts	Shipment	Through Upbound
Total, all commodities	3,949	576	3,346	27
Total petroleum and petroleum products	2,818	518	2,828	19
Subtotal crude petroleum	75	72	4	-----
2100 crude petroleum	75	72	4	-----
Subtotal petroleum products	2,743	446	2,278	19
2211 gasoline	1,654	21	1,633	-----
2330 distillate fuel oil	322	83	239	-----
2340 residual fuel oil	144	59	85	-----
2450 lube oil & greases	570	256	314	-----
2429 naphtha & solvents	27	27	-----	-----
2430 asphalt, tar & pitch	19	-----	-----	19
2990 petro. products nec	7	-----	7	-----
Total chemicals and related products	1,059	4	1,050	5
Subtotal other chemicals and related products	1,059	4	1,050	5
3212 benzene & toluene	31	4	26	-----
3219 other hydrocarbons	105	-----	105	-----
3220 alcohols	113	-----	113	-----

Commodity			Total	Coastwise		
				Receipts	Shipment	Through Upbound
3271	sulphur(liquid)		352	-----	352	-----
3274	sodium hydroxide		4	-----	-----	4
3276	metallic salts		12	0	10	1
3297	chemical additives		436	-----	436	-----
3299	chem. products nec		7	-----	7	-----
Total crude materials, inedible except fuels			56	53	2	1
Subtotal soil, sand, gravel, rock and stone			3	-----	1	1
4338	soil & fill dirt		3	-----	1	1
Subtotal iron ore and scrap			53	53	-----	-----
4420	iron & steel scrap		53	53	-----	-----
Subtotal sulphur, clay and salt			0	-----	0	-----
4782	clay refrac. mat.		0	-----	0	-----
Subtotal other non-metal. min.			0	-----	0	-----
4900	non-metal. min. nec		0	-----	0	-----
Total primary manufactured goods			14	1	13	-----
Subtotal primary iron an steel products			11	-----	11	-----
5320	i&s primary forms		11	-----	11	-----
Subtotal primary non-ferrous metal products			3	1	1	-----
5421	copper		1	1	-----	-----
5480	fab. metal products		1	-----	1	-----
Total all manufactured equipment, machinery and products			2	0	0	1
7110	machinery (notelec)		0	0	0	-----
7400	manufac. wood prod.		1	-----	-----	1
Ton-miles (x1000)			199,731	28,002	169,459	2,270
Coastwise						

Commodity		Total	Internal							
			Inbound		Outbound		Through		Intra	
			Upbound	Downbnd	Upbound	Downbnd	Upbound	Downbnd	Upbound	Downbnd
Total, all Commodities		50,181	5,879	1,529	1,226	7,880	14,797	17,425	972	474
Total coal		107	1	1	48	-----	5	51	-----	-----
1100	Coal lignite	8	1	-----	-----	-----	-----	7	-----	-----
1200	coal coke	99	-----	1	48	-----	5	44	-----	-----
Total Petroleum and Petroleum products		27,660	2,935	860	994	5,096	7,360	9,673	510	231
Subtotal crude petroleum		5,654	841	-----	30	545	852	3,353	23	10
2100	crude petroleum	5,654	841	-----	30	545	852	3,353	23	10

Commodity	Total	Internal							
		Inbound		Outbound		Through		Intra	
		Upbound	Downbnd	Upbound	Downbnd	Upbound	Downbnd	Upbound	Downbnd
Subtotal petroleum products	22,006	2,094	860	964	4,551	6,508	6,320	487	222
2211 gasoline	5,294	581	45	162	778	1,526	2,010	86	106
2221 kerosene	290	-----	-----	130	1	92	67	-----	-----
2330 distillate fuel oil	4,494	492	48	107	1,291	691	1,793	62	10
2340 residual fuel oil	5,613	483	58	290	1,657	1,863	1,057	198	7
2350 lube oil & greases	1,112	23	4	137	219	519	207	2	1
2410 petro. jelly & waxes	56	-----	-----	-----	-----	51	5	-----	-----
2429 naphtha & solvents	2,119	384	37	4	369	571	538	126	90
2430 asphalt, tar & pitch	1,075	11	3	1	22	767	271	-----	-----
2540 petroleum coke	776	8	438	64	-----	241	20	-----	4
2640 liquid natural gas	552	58	181	-----	55	124	131	-----	4
2990 petro. products nec	624	54	47	67	159	63	221	15	-----
Total chemicals and related products	16,101	1,439	53	161	2,367	5,789	5,587	462	243
Subtotal fertilizers	741	1	0	-----	0	151	588	-----	-----
3110 nitrogenous fert.	506	-----	-----	-----	-----	71	436	-----	-----
3120 phosphatic fert.	135	-----	-----	-----	-----	6	129	-----	-----
3130 potassic fert.	4	-----	0	-----	-----	-----	3	-----	-----
3190 fert. & mixes nec	96	1	-----	-----	-----	75	20	-----	-----
Subtotal other chemicals and related products	15,360	1,437	53	161	2,366	5,638	5,000	462	243
3211 acyclic hydrocarbons	1,084	386	-----	-----	5	134	559	-----	-----
3212 benzene & toluene	1,369	196	32	7	485	99	362	33	156
3219 other hydrocarbons	4,669	96	6	122	417	3,015	814	197	-----
3220 alcohols	2,559	119	2	1	564	589	908	33	43
3230 carboxylic acids	381	27	-----	-----	57	252	45	-----	-----
3240 nitrogen func. comp.	813	102	-----	-----	280	374	57	-----	-----
3260 organic comp. nec	602	57	-----	-----	3	242	299	-----	-----
3271 sulphur (liquid)	82	48	-----	-----	-----	5	30	-----	-----
3272 sulphuric acid	231	19	-----	-----	45	35	132	-----	-----
3273 ammonia	1,016	-----	-----	-----	-----	-----	-----	-----	-----
3274 sodium hydroxide	970	30	-----	-----	186	-----	800	-----	-----
		40	-----	-----	29	352	549	-----	-----

Commodity	Total	Internal							
		Inbound		Outbound		Through		Intra	
		Upbound	Downbnd	Upbound	Downbnd	Upbound	Downbnd	Upbound	Downbnd
3275 inorg. elem., oxides, & halogen salts	230	2	-----	-----	1	99	129	-----	-----
3276 metallic salts	61	-----	5	0	4	10	42	-----	-----
3297 chemical additives	1,184	286	4	9	205	332	106	199	43
3298 wood & resin chem.	2	-----	-----	-----	-----	2	-----	-----	-----
3299 chem. products nec	407	29	4	21	86	98	169	-----	-----
Total crude materials, inedible except fuels	3,003	1,136	98	1	15	1,239	515	-----	-----
Subtotal forest products, wood and chips	13	0	-----	-----	-----	3	9	-----	-----
4110 rubber & gums	3	-----	-----	-----	-----	3	-----	-----	-----
4189 lumber	2	0	-----	-----	-----	-----	2	-----	-----
4190 forest products nec	8	-----	-----	-----	-----	-----	8	-----	-----
Subtotal soil, sand, gravel, rock and stone	1,029	768	53	-----	1	2	205	-----	-----
4432 limestone	390	300	52	-----	-----	-----	38	-----	-----
4432 limestone	390	-----	-----	-----	-----	-----	57	-----	-----
4323 gypsum	57	-----	-----	-----	-----	-----	7	-----	-----
4327 phosphate rock	7	-----	-----	-----	-----	-----	-----	-----	-----
4331 sand & gravel	496	458	0	-----	1	2	35	-----	-----
4335 waterway improve. mat	73	10	0	-----	-----	-----	63	-----	-----
4338 soil & fill dirt	6	-----	-----	-----	-----	-----	6	-----	-----
Subtotal iron ore and scrap	558	363	-----	-----	5	140	50	-----	-----
4410 iron ore	115	67	-----	-----	-----	9	39	-----	-----
4420 iron & steel scrap	443	295	-----	-----	5	131	12	-----	-----
Subtotal marine shells	68	-----	43	-----	-----	-----	25	-----	-----
4515 marine shells	68	-----	43	-----	-----	-----	25	-----	-----
Subtotal non-ferrous ores and scrap	1,119	3	-----	-----	-----	1,067	49	-----	-----
4650 aluminum ore	1,058	-----	-----	-----	-----	1,043	14	-----	-----
4670 manganese ore	51	3	-----	-----	-----	19	29	-----	-----
4690 non-ferrous ores nec	11	-----	-----	-----	-----	5	6	-----	-----
Subtotal sulphur, clay and salt	16	2	0	0	4	3	7	-----	-----
4782 clay & refrac. mat.	16	2	0	0	4	3	7	-----	-----
Subtotal slag	108	-----	-----	-----	3	-----	105	-----	-----
4860 slag	108	-----	-----	-----	3	-----	105	-----	-----

Commodity	Total	Internal							
		Inbound		Outbound		Through		Intra	
		Upbound	Downbnd	Upbound	Downbnd	Upbound	Downbnd	Upbound	Downbnd
Subtotal other non-metal. min.	91	0	2	1	2	23	63	-----	-----
4900 non-metal min. nec	91	0	2	1	2	23	63	-----	-----
Total primary manufactured goods	1,856	297	2	1	277	106	1,173	-----	-----
Subtotal paper products	14	-----	0	-----	-----	-----	14	-----	-----
5110 newsprint	14	-----	-----	-----	-----	-----	14	-----	-----
5120 paper & paperboard	0	-----	0	-----	-----	-----	-----	-----	-----
Subtotal lime, cement and glass	101	88	0	0	0	10	3	-----	-----
5210 lime	3	-----	-----	-----	-----	-----	3	-----	-----
5220 cement & concrete	98	88	0	0	0	10	-----	-----	-----
Subtotal primary iron and steel products	1,638	209	0	0	272	69	1,088	-----	-----
5312 pig iron	281	206	-----	-----	-----	3	72	-----	-----
5315 ferro alloys	81	1	-----	-----	-----	9	70	-----	-----
5320 i&s primary forms	68	-----	-----	-----	15	5	48	-----	-----
5330 i&s bars & sheets	568	-----	-----	-----	-----	26	542	-----	-----
5360 i&s bars & shapes	274	-----	-----	-----	257	9	8	-----	-----
5370 i&s pipe & tube	246	1	0	0	-----	5	239	-----	-----
5390 primary i&s nec	121	-----	-----	-----	-----	12	109	-----	-----
Subtotal primary non-ferrous metal products	97	-----	1	-----	4	27	64	-----	-----
5421 copper	2	-----	-----	-----	-----	2	-----	-----	-----
5422 aluminum	1	-----	-----	-----	-----	-----	1	-----	-----
5429 smelted prod. nec	8	-----	-----	-----	-----	2	6	-----	-----
5480 fab. metal products	86	-----	1	-----	4	24	56	-----	-----
Subtotal primary wood products	5	-----	-----	1	1	-----	4	-----	-----
5540 primary wood prod.	5	-----	-----	1	1	-----	4	-----	-----
Total food and farm products	736	16	5	15	61	247	392	-----	-----
Subtotal grain	347	-----	-----	-----	-----	92	255	-----	-----
6241 wheat	116	-----	-----	-----	-----	48	68	-----	-----
6344 corn	7	-----	-----	-----	-----	7	-----	-----	-----
6442 rice	200	-----	-----	-----	-----	24	176	-----	-----
6445 oats	11	-----	-----	-----	-----	-----	11	-----	-----
6447 sorghum grains	13	-----	-----	-----	-----	13	-----	-----	-----

Commodity	Total	Internal							
		Inbound		Outbound		Through		Intra	
		Upbound	Downbnd	Upbound	Downbnd	Upbound	Downbnd	Upbound	Downbnd
Subtotal oilseeds	16	-----	-----	-----	11	5	-----	-----	-----
6522 soybeans	16	-----	-----	-----	11	5	-----	-----	-----
Subtotal vegetable products	9	-----	-----	-----	-----	6	3	-----	-----
6653 vegetable oils	3	-----	-----	-----	-----	-----	3	-----	-----
6654 vegetables & prod.	6	-----	-----	-----	-----	6	-----	-----	-----
Subtotal processed grain and animal feed	28	-----	4	13	3	5	4	-----	-----
6746 wheat flour	5	-----	-----	-----	1	3	-----	-----	-----
6838 animal feed, prep.	24	-----	4	13	1	2	4	-----	-----
Subtotal other agricultural products	337	16	1	2	48	139	130	-----	-----
6835 fish, prepared	3	-----	-----	-----	-----	3	-----	-----	-----
6838 tallow, animal oils	8	-----	-----	-----	-----	-----	8	-----	-----
6861 sugar	204	-----	-----	-----	-----	124	79	-----	-----
6865 molasses	28	-----	-----	-----	-----	2	27	-----	-----
6871 coffee	1	-----	-----	-----	-----	0	0	-----	-----
6885 alcoholic beverages	11	-----	-----	-----	-----	-----	11	-----	-----
6887 groceries	0	-----	-----	-----	0	-----	-----	-----	-----
6888 water & ice	76	16	1	2	48	-----	5	-----	-----
6889 food products nec	7	-----	-----	-----	0	4	-----	-----	-----
						7			
Total all manufactured equipment, machinery and products	172	26	2	3	59	51	32	-----	-----
7110 machinery (notelec)	120	25	2	3	57	13	21	-----	-----
7210 vehicles & parts	0	-----	-----	-----	0	-----	-----	-----	-----
7230 ships & boats	0	-----	-----	-----	-----	-----	0	-----	-----
7300 ordnance & access.	5	-----	-----	-----	-----	0	5	-----	-----
7500 textile products	6	-----	-----	-----	-----	3	3	-----	-----
7600 rubber & plastic pr.	16	1	-----	-----	-----	15	1	-----	-----
7900 manufac. prod. nec	25	-----	-----	-----	2	20	2	-----	-----

Commodity	Total	Internal							
		Inbound		Outbound		Through		Intra	
		Upbound	Downbnd	Upbound	Downbnd	Upbound	Downbnd	Upbound	Downbnd
Total waste and scrap nec	547	29	509	3	5	-----	1	-----	-----
8900 Waste and scrap nec	547	29	509	3	5	-----	1	-----	-----
Ton-miles Internal (x100)	3,033,660	159,544	32,842	25,880	139,905	1,194,804	1,456,126	17,674	6,713
Tons All Traffic (x 1000)			103,254						
Ton-miles All Traffic (x 1000)			3,356,592						

AUTO BODY REFINISHING

Draft
EIIP Area Sources Committee

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Emission Inventory Improvement Program

DISCLAIMER

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1

INTRODUCTION

This chapter describes the procedures and recommended approaches for estimating emissions from automobile (auto body) refinishing operations. Section 2 of this chapter contains a general description of the auto body refinishing category and an overview of available control technologies. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation methods for auto body refinishing, and Section 5 presents alternative emission estimation techniques. Quality assurance and quality control procedures are described in Section 6. Data coding procedures are discussed in Section 7, and Section 8 lists all references cited in this chapter.

This EIIP chapter is one of a series of chapters developed to provide cost-effective, reliable and consistent approaches to estimating emissions for area source inventories. Multiple methods are provided in the chapters to accommodate needs of state agencies with different levels of available resources and skills, and different levels of needs for accuracy and reliability of their estimates. More information about the EIIP program can be found in Volume 1 of the EIIP series, *Introduction and Use of EIIP Guidance for Emissions Inventory Development*.¹

Throughout this chapter and other EIIP area source methods chapters, we stress that area source categories should be prioritized by the inventory planners so that resources can be spent on the source categories that are the largest emitters; most likely to be subject to regulations or are already subject to regulations; or require special effort because of some policy reason. Prioritization is particularly important for area source inventories, because in some cases, a source category that is difficult to characterize may contribute very little to overall emissions and attempting to prepare a high quality estimate for that source category may not be cost effective.

EIIP chapters are written for the state and local air pollution agencies, with their input and review. EIIP is a response to the U.S. Environmental Protection Agency's (EPA's) understanding that state and local agency personnel have more knowledge about their inventory area's activities, processes, emissions, and availability of information; and require flexible inventory methods to best use their sometimes limited resources. These EIIP area source chapters are written as a set of options presented to inventory professionals capable of using their own experience and judgement to apply the method that best fits their overall needs and constraints.

¹ EIIP volumes area available at: <http://www.epa.gov/ttn/chief/eiip/>.

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2

SOURCE CATEGORY DESCRIPTION

2.1 CATEGORY DESCRIPTION

Auto body refinishing is the repairing of worn or damaged automobiles, light trucks, and other vehicles, and refers to any coating applications that occur subsequent to those at original equipment manufacturer (OEM) assembly plants. (Coating of new cars is not included in this category.) The majority of these operations occur at small body shops that repair and refinish automobiles. This category covers solvent emissions from the refinishing of automobiles, including paint solvents, thinning solvents, and solvents used for surface preparation and cleanup. According to data published in 1994, nationwide solvent usage in automobile refinishing was estimated to be 37.5 million gallons per year (Kline and Company, 1995). Data published in 1998 estimate that about 64,000 auto body shops were operating in the United States (Dun and Bradstreet, 1998). Facilities performing these operations are classified with the Standard Industrial Classification (SIC) code 7532 (establishments primarily engaged in the repair of automotive tops, bodies, and interiors, or automotive painting and refinishing). Two parts of SIC code 7532 are *top and body repair shops*, which are establishments primarily engaged in the repair of automobile tops and bodies with or without painting, and *refinishing and paint shops*, which include establishments primarily engaged in automobile painting and refinishing. Coatings applied at OEM assembly plants are classified with SIC code 3711, and are not included here.

Most auto refinishing jobs are performed as part of collision repair and involve only a small portion of a vehicle, such as a panel or a spot on a panel (“spot” repair). About 17 percent of refinishing jobs involve the entire vehicle. For a typical shop, approximately 90 percent of the work consists of spot and panel repairing, and the entire vehicle is completely refinished only about ten percent of the time. Shops specializing in repainting entire automobiles are referred to as “production” shops.

Auto body refinishing shops may be area or point sources, but the majority of shops are considered area sources of emissions. Point source emissions must be subtracted from total emissions to produce an estimate of auto body refinishing area source emissions.

2.2 PROCESS DESCRIPTION AND EMISSION SOURCES

Auto body refinishing operations consist of four steps: (1) vehicle preparation, (2) primer application, (3) topcoat application, and (4) spray equipment cleaning. The products and equipment used in these steps are usually bought from distributors, also known as jobbers. Prior to any painting, the surface is prepared, *i.e.*, washed thoroughly with water and detergent and allowed to dry. It is then cleaned with a solvent (generally a blend of toluene, xylene, and other petroleum distillates) to remove any wax, grease, and dirt to ensure proper adhesion of the primer and topcoats. Solvents typically used are 100 percent volatile, with the volatile organic compound (VOC) content ranging from 5.8 pounds VOC per gallon to 6.5 pounds VOC per gallon (EPA, 1994a). A tack cloth is often used as a final step to remove any remaining dirt or debris prior to the coating application.

Next, the surface is primed to provide corrosion resistance, fill surface imperfections, and provide a bond for the topcoat. Primers fall into four general categories: prepcoat, primer-surfacer, primer-sealer, and sealer. A prepcoat is a metal conditioner that etches the surface and prevents flash rusting, which can occur from base metal exposure to the atmosphere. Prepcoats have good corrosion resistance and adhesion properties, but have little or no filling capacity. Primer-surfacer provide the best filling or “build” properties for deep scratches or dents, but some of these provide limited corrosion protection. They are frequently used over prepcoats. The three types of primer-surfacer are nitrocellulose lacquer, acrylic lacquer, and alkyd enamel. Primer-sealer combine the corrosion resistance and adhesion properties of prepcoats with some of the scratch-filling capacity of primer-surfacer. Primer-sealer also add a sealing property needed when an old finish is being repainted. This type of primer is typically enamel-based. Sealers differ from primer-sealer in that they cannot be used as a primer and must be sprayed over a prepcoat, a primer-surfacer, or an old finish. Sealers are acrylic lacquer-based products.

The third step is topcoat application, which consists of a series of coats applied over the primer. Topcoat determines the final color and appearance of the refinished area. For optional results, topcoats (as well as other coating applications) are typically applied in a spray booth, which minimizes the possibility of dirt adhering to the wet coating. Metallic finishes and some other finishes require a two-stage topcoat system, consisting of a basecoat and a clearcoat. Since most repairs are spot and panel repairs, the refinisher is concerned with matching the OEM color as closely as possible. Paint mixing machines are typically provided by the shop’s paint supplier. These machines are capable of mixing coatings to manufacturer’s specifications to allow for precise matching. As paints fade, it becomes increasingly difficult for refinishers to match OEM paints to the faded paint. OEM paints manufactured after 1991 typically have more durability and less fading, which makes matching paints easier, but older paints are more likely to fade. In some cases, the paint may be so faded that it is impossible to match colors. Topcoats can be divided into four categories: acrylic lacquer, alkyd enamel, acrylic enamel,

and polyurethane. Based on 1994 data derived from the *Chemical Economics Handbook* (SRI International, 1997), acrylic lacquers accounted for 20 percent of topcoats, acrylic and alkyd enamels 20 percent, and urethanes 60 percent.

The last step in auto body refinishing is spray equipment cleaning. Spray equipment can be cleaned manually or with gun cleaning systems specially designed for this purpose. Shops that do not have spray gun cleaning systems usually rinse the outside of the gun and cup, add solvent to the cup, and then spray the solvent into the air or into a drum set aside for spent solvent (EPA, 1994a). The cleaning solvent is recirculated until it is too contaminated to use. Waste solvents are then disposed of by evaporation or incineration, or are reclaimed via distillation. The EIIP chapter on solvent cleaning contains a thorough description of equipment cleaning operations.

The breakdown of solvent usage and emissions among the four steps is approximately 2 percent for vehicle preparation, 20 percent for primer application, 70 percent for topcoats, and 8 percent for equipment cleaning (EPA, 1994a).

2.3 FACTORS INFLUENCING EMISSIONS

VOC emissions from automobile refinishing are influenced by several factors. Emissions from surface preparation and coating applications are a function of the VOC content of the product used. Emissions are also a function of the transfer efficiency of the spray equipment. Transfer efficiency is the percent of paint solids sprayed that actually adheres to the surface being painted.

Equipment with lower transfer efficiency would require more material to be sprayed, thus, increasing VOC emissions. Emissions from cleaning operations are dependent on the type of cleanup and housekeeping practices used.

2.4 CONTROL TECHNIQUES

There are three main approaches for reducing VOC emissions from auto body refinishing shops: (1) use of lower-VOC coatings, (2) increased transfer efficiency, and (3) use of enclosed equipment cleaning devices. Specific control strategies for auto body refinishing operations include the following: for vehicle preparation - using reduced-VOC cleaners and using a second detergent for cleaning; for primer application - improving transfer efficiency of spray guns (e.g., high-volume, low-pressure, or HVLP, spray guns), and using lower-VOC primers, such as waterborne primers and urethane primers; for topcoat application - improving transfer efficiency of spray guns (HVLP spray guns) and using reduced-VOC coatings; and for equipment cleaning - using a solvent recovery system. By using a cleanup solvent recovery system, facilities of any size can reduce VOC emissions by about 15 percent.

Reductions of 30 to 45 percent can be achieved when HVLP spray guns are used in place of conventional air-atomizing spray guns (EPA, 1988). In addition, shops can use add-on controls for their spray booths such as thermal incineration, catalytic incineration, and carbon adsorption. A control efficiency of 90 percent or more can be achieved with the use of add-on controls (EPA, 1991a). Although the use of these add-on controls is technically feasible, cost has been the primary limiting factor. One 1990 reference estimated the annual operating cost of an incinerator at \$120,000 and of a carbon adsorber at \$40,000 (EPA, 1990). These costs are prohibitive to body shops, one-quarter of which have annual sales less than \$100,000 (Babcox Publications, 1993). In addition, since small facilities may not have spray booths, the add-on control techniques are not applicable to their situation.

Other housekeeping activities can also be used to reduce emissions from auto body refinishing operations. These activities include using tight fitting containers, reducing spills, mixing paint to need to avoid waste paint disposal, providing operator training, and maintaining rigid control of inventory.

On September 11, 1998, national EPA regulations were promulgated to control VOC emissions from the use of automobile refinishing coatings. The regulations set specific VOC content limits on seven categories of automobile refinish coatings. The VOC limits are to be met by the manufacturers of refinish coatings that are manufactured on or after January 11, 1999. Table 13.2-1 provides the approximate emission reductions that can be achieved based on the VOC limits set forth in the September 11, 1998, rulemaking.

A few states also have regulations in place that require VOC content limits on coatings as they are applied in body shops. In these states, body shops are usually required to keep extensive records on coating usage and VOC content. Maximum Achievable Control Technology (MACT) standards applicable to hazardous air pollutant (HAP) emissions for existing and new facilities engaged in automobile and light-duty truck refinishing operations are scheduled to be promulgated before November 15, 2000.

TABLE 13.2-1. ESTIMATED VOC EMISSION REDUCTIONS FOR AUTOMOTIVE REFINISHING COATINGS

Coating Category	Regulation VOC Content Limit (lb/gal)^a	Approximate Percent Reduction in Emissions^b
Pretreatment Wash Primer	6.5	0
Primer/Primer Surfacer	4.8	55
Primer Sealer	4.6	75
Single/2-Stage Topcoats	5.0	40-70 ^c
Topcoats of 3 or more stages	5.2	30
Multicolored Topcoats	5.7	Not Available
Specialty Coatings	7.0	0
Overall		37

^a Federal Register, 1998.^b EPA, 1995.^c The percent reduction ranges from about 70 percent for lacquers to approximately 40 percent for all other topcoats.

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3

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATION METHODOLOGIES

There are several methodologies available for calculating emissions from auto body refinishing. The selection of a method to use depends on the degree of accuracy required in the estimate, the available data, and the available resources. Estimating emissions accurately depends on accurately estimating the amount and type of coating materials used. This section discusses the methods available for estimating emissions from auto body refinishing and identifies the preferred method for this category.

3.2 AVAILABLE METHODOLOGIES

3.2.1 VOLATILE ORGANIC COMPOUNDS

Methods available for estimating emissions from auto body refinishing operations include conducting surveys to collect activity (e.g., annual solvent and coatings usage), and apportioning a national estimate to the local level by using a per employee or per capita emission factor. These methods are summarized in Table 13.3-1.

Although theoretically it would be possible to conduct a survey to collect activity, product use, and product-specific VOC content data to develop product-specific, site-specific detailed emissions estimates, this approach is not practical due to resource and information availability at both the facility and the inventorying agency levels, and to the variety of surface preparation, primers, coatings, and cleaning products. For example, five companies (i.e., E.I. duPont de Nemours and Company, Inc., including Nason Automotive Finishes; PPG Industries; the Sherwin-Williams Company; BASF Chemicals; and Akzo Coatings) account for about 95 percent of automobile refinish coating sales. These five manufacturers also produce components such as catalysts, solvents (thinners or reducers), and additives for use with their coatings. The remaining five percent of coatings are supplied by approximately 12 smaller manufacturers. About two dozen other U.S. manufacturers produce lower-cost coating components that are marketed for use with the coatings produced by the major manufacturers (EPA, 1994a).

TABLE 13.3-1**PREFERRED AND ALTERNATE METHODS FOR ESTIMATING
EMISSIONS FROM AUTO BODY REFINISHING**

Methods	Description
Preferred Method - Apportion National Data and Survey Very Large Shops	<p>Part I - Using information from Dun and Bradstreet^{a,b}, apportion the national estimate for each shop size category to the state or county level by multiplying the national estimate by the ratio local-to-national SIC code employment.</p> <p>Part II - Survey shops with expected annual revenues greater than \$624,000 for annual coatings and solvent usage data. Using the MSDS, calculate emissions for each facility and then sum the emissions for the local level. This local estimate may replace the estimate from Part I for very large shops.</p>
Alternate Method 1 - Apportion National Data With Employment	Similar to the preferred method, except without the survey. If Dun and Bradstreet data are not available, then County Business Patterns ^c can be used to apportion the national estimate based on the ratio of local-to-national SIC code employment.
Alternate Method 2 - Apportion National Data With Population	Similar to alternate method 1, except that population data from the Bureau of Census is used instead of SIC code employment for the ratio.

^a Dun and Bradstreet data are available electronically on their Internet World Wide Web page at <http://www.dnb.com/>. Note, there is a fee for accessing Dun and Bradstreet information.

^b There are also alternate sources that provide auto body shop information. For example, American Business Information (ABI) provides shop-specific information similar to Dun and Bradstreet; the difference is that ABI only gives employment by size ranges for each shop instead of specific values (ABI/INFORM is a registered trademark of Bell & Howell Information and Learning, Ann Arbor, MI).

^c Annual County Business Patterns data are available electronically on the U.S. Census Internet World Wide Web page at: <http://www.census.gov/epcd/cbp/view/cbpview.html>, and can be reached by phone at (301) 457-2580.

Individual manufacturers often market several lines of products, with each line containing a specific series of surface preparation, primer, coating, cleaning, thinning, reducing, etc., products. Material Safety Data Sheets (MSDS) are available from the manufacturers for each product in each line and

show the chemical species and percent (or range of percent) contribution of each species. These MSDS can be used with information on amount of each specific product used from local surveys to develop emission estimates. However, the level of effort required to complete a detailed survey to collect the product-specific VOC content and use data may be a significant burden on the auto body refinishing shop. Some coating suppliers may, however, have software programs that can assist shop personnel in tracking this information. In addition, your agency may not have sufficient resources to interpret, analyze, and compile these data.

Instead, surveys of the largest shops can be conducted to collect only general activity data (e.g., annual usage of coatings and solvents). These survey data can then be used with MSDS to develop emission estimates.

Another method for estimating emissions from auto body refinishing operations involves apportioning a national estimate to the county level. The national estimate may be apportioned by using a ratio of local-to-national SIC code employment, or population.

3.2.2 HAZARDOUS AIR POLLUTANTS

HAP emissions from this source are determined by the survey methods discussed above for VOC emissions. Since the type(s) of HAPs present differ from product to product, developing a detailed inventory may be very resource intensive. You may choose to forego some level of accuracy by determining the most commonly used products in the inventory from the survey and assuming that the HAP makeup of those products is representative of the product category in general. The emissions of each HAP are assumed to be proportional to the amount of HAP in each product.

3.3 DATA NEEDS

3.3.1 DATA ELEMENTS

The data elements needed to calculate emission estimates for auto body refinishing operations depend on the methodology used for data collection. The data elements needed for each emission estimation technique are presented in Table 13.3-2.

3.3.2 ADJUSTMENTS TO EMISSIONS ESTIMATES

Adjustments applied to annual emissions estimates include point source corrections, applications of controls, spatial allocation, and temporal resolution. The type of adjustment is dependent on the type of inventory required. The data needs for point source emission estimate adjustments

TABLE 13.3-2

DATA ELEMENTS NEEDED FOR EACH METHOD

Data Element	Method		
	Preferred	Alt 1	Alt 2
Annual solvent and coatings usage for very large shops	x		
Material Safety Data Sheets (MSDS)	x		
National and inventory area Dun and Bradstreet employment data sorted by revenue for SIC code 7532 ^a	x		
Annual Sales ^b	x ^b		
National and inventory area County Business Pattern employment data for SIC code 7532 ^a		x	
National and inventory area population from the U.S. Bureau of the Census			x

^a SIC code 7532 (Top, body and upholstery repair shops and paint shops) includes establishments primarily engaged in the repair of automobile tops, bodies, and interiors, or automotive painting and refinishing.

^b This data element is used only for Part II of the Preferred Method. Revenue is then used to determine which facilities will receive surveys.

are dependent in part on the methodology used. Data needs for the adjustments listed below are as follows:

- Point source corrections point source emissions or point source employment for inventory area for SIC code 7532
- Application of controls control efficiency; rule effectiveness; rule penetration

- Spatial allocation employment; population; facility locale; rural/urban population
- Temporal resolution seasonal throughput; operating days per week; operating hours per day

3.3.3 POINT SOURCE CORRECTIONS

The point source correction is performed by subtracting point source emissions for SIC code 7532 from the area source estimate.

Note however that employment in SIC code 7532 includes not only establishments primarily engaged in automotive painting and refinishing, but also establishments involved in the repair of automotive interiors (upholstery) and auto top (plastic and canvas) installation and repair.

3.3.4 APPLICATION OF CONTROLS

Section 3.8 of *Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone, Volume I* (EPA, 1991b) provides guidance for determining and applying rule effectiveness (RE) for a source category. In addition, the EPA document *Procedures for Estimating and Applying Rule Effectiveness in Post-1987 Base Year Emission Inventories for Ozone and Carbon Monoxide State Implementation Plans* (June, 1989) provides more detailed information on RE (EPA, 1989).

Sections 4.1.1 and 5.4 of the EPA procedures document (1991b) describe how to account for emissions reductions expected to result from applying a regulation. If a regulation exists for auto body refinishing in the inventory area and you use a “top down” approach to estimate emissions from this category, you should incorporate an estimate of rule penetration.

If an area source is controlled (e.g., VOC content of surface coating products controlled by regulation), the following general equations can be used to calculate emissions:

$$CAE_A = (RA)(Q)[1 - (CE)(RP)(RE)] \quad (13.3-1)$$

or

$$CAE_A = (UAE_A)[1 - (CE)(RP)(RE)] \quad (13.3-2)$$

where:

CAE_A	=	controlled area source emissions of pollutant A
RA	=	Ratio of local-to-national SIC code employment or population
Q	=	national estimate
CE	=	control efficiency/100
RP	=	rule penetration/100
RE	=	rule effectiveness/100
UAE_A	=	uncontrolled area source emissions of pollutant A

3.3.5 SPATIAL ALLOCATION

If a survey, Dun and Bradstreet, or some other source is used to develop emission estimates for the very large shops, then the spatial allocation of part of the emissions can be based on facility location, as with the point source inventory, or with local employment data. If allocation is based on facility location, you can use the address matching capability of a Geographical Information System to assign map coordinates to shop locations. From these coordinates, shops can then be assigned to grid cells for spatial allocations of emissions.

If you need to estimate emissions at the sub-county level, you should consider that the location of auto body shops does not necessarily mirror the location of population within a county. You will need to evaluate options for allocating county emissions, such as urban versus rural population (available from U.S. Bureau of the Census publications), actual location data identified from surveys, etc.

3.3.6 TEMPORAL RESOLUTION

Seasonal Apportioning. In *Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone, Volume I: General Guidance for Stationary Sources*, EPA (1991b) reports that auto body refinishing emissions do not seem to demonstrate differences in activity from season to season. However, other references have indicated that since there is a direct relationship between auto body refinishing activity and number of automobile accidents, if there is a seasonal difference in accident occurrence, the same seasonal variation may be seen in auto body refinishing activity. If time permits, you could review annual accident statistics to determine if any seasonal variability exists for your inventory area. The National Safety Council annual publication, *Accident Facts* provides this information.

Daily Resolution. From the EPA procedures document (1991b), auto body refinishing shops typically operate five days per week. This figure may be used if local data on daily resolution are not available.

3.4 PROJECTING EMISSIONS

The type of surrogate used to project emissions is dependent on the methodology used to develop the initial emissions estimate. In “growing” the emissions estimate, you should use the same activity parameter as was used to develop the initial estimate. For example, if a per capita factor was used to develop the initial estimate, population growth should be used to develop the projected emissions estimate. Any source survey conducted to gather information on auto body refinishing activity should include questions on source growth and expected changes in factors that affect emissions (EPA, 1991b).

The equation for developing the projected emissions is:

$$EMIS_{PY} = ORATE_{BY,O} * RAT_{PY,pc} * EMF_{PY,pc} * [1 - (\frac{CE_{PY}}{100})(\frac{RP_{PY}}{100})(\frac{RE_{PY}}{100})] * G \quad (13.3-3)$$

where:

$EMIS_{PY}$	=	projection year emissions: ozone season typical weekday (mass of pollutant/day)
$ORATE_{BY,O}$	=	base year operating rate: ozone season daily activity level
$EMF_{PY,pc}$	=	emission factor (mass of pollutant per activity level)
$RAT_{PY,pc}$	=	ratio of local-to-national SIC code employment or population
CE_{PY}	=	projection year control efficiency (percent)
RE_{PY}	=	projection year rule effectiveness (percent)
RP_{PY}	=	projection year rule penetration (percent)
G	=	growth factor (dimensionless)

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4

PREFERRED METHODS FOR ESTIMATING EMISSIONS

The preferred method for estimating emissions from auto body refinishing operations involves apportioning a national estimate to the local level for each shop size category, and surveying shops with annual revenues in excess of \$624,000 (i.e., very large size shops) for annual coatings and solvents usage data. Emission estimates for the surveyed shops will replace those apportioned to very large shops from the national estimate. Figure 13.4-1, at the end of this section, is an example survey questionnaire for auto body refinishing facilities. The questionnaire should be modified to meet your specific needs, but should contain sections for the following types of information: (1) identification, including firm name, address, and contact, and type of facility, (2) number of employees, and (3) annual coating and solvent usage based on user information.

4.1 NATIONAL VOC EMISSION ESTIMATE

A national VOC emission estimate of 79,429.39 tons per year has been developed using 1997 activity and 1998 and 1999 emission rate information. Dun and Bradstreet sales and employment statistics for auto body refinishing businesses were used to scale emission rates for equipment cleaning solvent use from the Connecticut Department of Environmental Protection Bureau of Air Management (CT DEP, 1998); and to scale emission rates for coating applications from the Texas Natural Resources Conservation Commission (TNRCC) (Smith and Dunn, 1999).

4.2 PREFERRED METHOD

Using the preferred method, the first step is to apportion the national estimate to the local level for each shop size. This operation is shown by the following equation:

$$E_{As} = NE_{As} \times (E_I + E_N) \quad (13.4-1)$$

where:

E_{AS}	=	Local VOC emissions for shop size S (tons/year)
NE_{AS}	=	National VOC emissions for shop size S (tons/year)
E_I	=	Number of employees for SIC code 7532 in area of interest
E_N	=	Number of employees for SIC code 7532 in U.S.

National emissions by shop size are shown in Table 13.4-1.

The second step in estimating emissions is to determine if the survey responses for very large shops adequately represent the local activity. You can compare the survey responses to Dun and Bradstreet employee counts for SIC code 7532 to estimate the coverage of the survey. If you believe the survey results are a more accurate reflection of the activity for very large shops, then the survey-derived estimates should replace the estimates apportioned to very large shops from the national estimate.

Using the preferred method, the equation for estimating emissions for each specific auto body refinishing product at each very large shop:

$$E_A = P_x \times 4 \times 12 \times C_x + 2,000 \text{ lbs/ton} \quad (13.4-2)$$

where:

E_A	=	VOC emissions (tons/year)
P_x	=	Amount of product x used in quarts (from survey) per month
C_x	=	VOC content of product x in pounds per gallon (from MSDS)

The emission totals from all products and shops would then be summed to develop total emissions for all very large shops.

Depending on the quality of the survey responses, you may need to modify the source of C_x , the VOC content of product x. If you do not have the resources or the survey responses do not provide sufficient data to evaluate each MSDS for each product to develop VOC content values, you may calculate emissions using average or default values for product categories (e.g., pretreatment, precoat, base coats, etc.). Table 13.4-2 provides data on VOC range (in pounds per gallon), and average VOC content (in pounds per gallon) by product category.

Be sure to account for point source emissions by subtracting point source emissions from the total emissions estimate developed through this preferred method.

TABLE 13.4-1**NATIONAL VOC EMISSIONS BY BODY SHOP SIZE**

Body Shop Size	Average Annual Revenue/Shop	National Annual VOC Emissions from Coating Applications (tpy)^a	National Annual VOC Emissions From Equipment Cleaning (tpy)^b	Total National Annual VOC Emissions (tpy)
Small	<\$104,000	6,401.49	4,753.65	11,155.14
Medium	\$104,000 - 364,000	22,426.94	18,671.85	41,098.79
Large	\$364,000 - 624,000	4,166.96	5,791.65	9,958.61
Very Large	>\$624,000	6,733.55	10,483.50	17,217.05
Total		39,728.94	39,700.65	79,429.59

^a Estimate is for all shops this size in the U.S. based on data collected in 1999.

^b Estimate is for all shops this size in the U.S. based on data collected in 1998.

TABLE 13.4-2

**VOC PARAMETERS OF CONVENTIONAL (PRE-REGULATION) AUTO BODY
REFINISHING PRODUCTS (EPA, 1988; EPA 1994a)**

Category	VOC Range (lb/gal)	Average VOC Content (lb/gal)
Pretreatment	5.8 - 6.5	6.3
Primers		
Precoat	4.6 - 7.1	5.8
Primer/Primer-Surfacer	4.6 - 7.1	5.7
Primer-Sealer	5.0 - 6.7	6.3
Coatings		
Single Stage - Lacquer	5.8 - 6.7	6.3
Single Stage - Enamel	4.8 - 6.0	5.6
Basecoat	5.8 - 6.7	6.2
Acrylic Lacquer	N/A	6.3
Acrylic Enamel	N/A	5.3
Clearcoat	4.6 - 6.7	5.2
Acrylic Lacquer	N/A	6.4
Acrylic Enamel	N/A	5.6
Specialty Coatings	N/A	7.0
Surface Cleaners	6.2 - 7.3	6.75
Cleanup	6.2 - 7.3	6.75

N/A = Not available.

^a Assumes 0.25 pints of surface preparation products are used per job (EPA, 1994a).

Auto Refinishing Questionnaire**A. Identification**

1. Firm Name: _____
Mailing Address: _____
City: _____ State _____ Zip _____
Street Location: _____
Business Telephone Number: (____) _____ - _____
Respondent's Name: _____
Respondent's Title: _____
2. Please indicate which type of operation is your primary function.
A. New and Used Car Dealership C. Auto Refinishing Shop
B. Used Car Dealership D. General Automotive Repair Shop
E. Other (specify) _____
3. Do you provide autobody refinishing services at this location?
01 . . . YES ➡ CONTINUE to B.1. 02 . . . NO STOP. Thank you for your
time. Return the questionnaire in
the envelope provided.
4. How many total employees do you currently have working at this shop location?
Number of employees: _____

Figure 13.4-1. Example Survey Questions**B. Solvent and Coatings Usage**

1. We need to know about the amount of volatile organic compound (VOC)-containing material your shop is using. *This is the most important question in this survey.* **Ask your distributor or jobber to help you with any of this information.**

We would like to obtain information about your paint and solvent usage during *one month*. Specifically, we are interested in the quantity of surface preps, primers, surfacers/fillers, sealers, topcoats (single and base/clear), thinners/reducers, hardeners, catalysts, newly purchased cleaning solvent, and other solvent-based products used and their VOC content.

This information can be provided using Table 1. Please enter the time period for your information on the line at the top of the table. The table is organized into columns that are described below. An example is shown in the first few lines of the table; start your shop's information in the next available space.

Column 1: Category. A definition of the general class of solvent-containing materials used in your shop such as topcoats, surface preps, primers, surfacers, fillers, sealers, thinners, reducers, hardeners, catalysts, and cleaners.

Column 2: Name and/or Specific Identifier. Identification of the specific products used in your shop. At a minimum, we would like the manufacturer's name (e.g., DuPont, BASF, ICI Autocolor, PPG Industries), the material ID or product number, and a brief description of the product (color and/or paint type).

Column 3: Quarts Used. The number of quarts of the material used during the month reported.

Column 4: How the Quarts Used Were Estimated. How you calculated the number of quarts of material. Examples include: "summarizing customer invoices," "monthly material inventory," and "best guess."

Column 5: VOC Content. This information can be found on the label for each material. Alternatively, we can determine this information if you provide the product manufacturer's name and ID/product number.

C. Control Equipment

Various equipment is available to control VOC emissions in work areas (i.e., carbon filters, incinerators). Does this body shop use any of this equipment? If so, please describe the equipment.

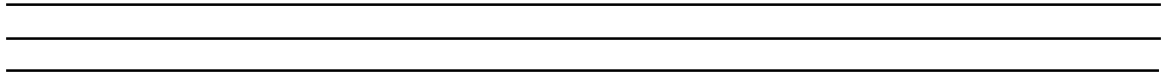


Figure 13.4-1. Example Survey Questions (Continued)

Example for Table 1. Information for the Time Period: August 1999

Column 1	Column 2	Column 3	Column 4	Column 5
Category	Name and/or Specific Identifier	Quarts Used	How the Quarts Used Were Estimated	VOC Content (pounds/gallon)
Base coat	PPG-DBC Acrylic Basecoat	4.5	Inventory records	6.7
Primer/surfacer	PPG-NCP270 Surfacer	1.5	Invoices	6.0
Cleaner	PPG-DX440 Wax and Grease Remover	0.5	Guess	6.9
Cleaner	PPG-Solvent Mixture	1.0	Invoices	6.7
Primer	PPG-DPU35 Durethane Primer	4.0	Inventory records	6.7
Hardener	PPG-DAU3 Acrylic Urethane Hardener	2.0	Guess	6.2
Additive	PPG-DBX689 Basecoat Additive	0.5	Guess	6.8
Blender	PPG-DBC500 Blender	1.0	Invoices	6.2
Reducer	PPG-DRR1150 Reactive Reducer	0.5	Invoices	6.5
Clear Topcoat	PPG-DCU2050 Graffiti Resistant Clear Coat	4.5	Invoices	2.9

Figure 13.4-1. Example Survey Questions (Continued)

TABLE 1. Information for the Time Period _____.

LIST YOUR SHOP'S INFORMATION IN THE SPACES BELOW				
Column 1	Column 2	Column 3	Column 4	Column 5
Category	Name and/or Specific Identifier	Quarts Used	How the Quarts Used Were Estimated	VOC Content (pounds/gallon)
Surface Preps				
Primers/sealers				
Surface/fillers				
Topcoats				
Hardeners/catalysts				
Newly-purchased cleaning solvents				

NOTE: DON'T FORGET TO PUT THE MONTH AND YEAR FOR THIS INFORMATION

5

ALTERNATE METHODS FOR ESTIMATING EMISSIONS

5.1 ALTERNATE METHOD 1 - APPORTION NATIONAL EMPLOYMENT DATA

This method is identical to the preferred method except that survey data are not included in the development of the estimate. Equation 13.4-1 is applicable for this method, with the following modification: if only County Business Patterns data are available (i.e., Dun and Bradstreet data are not available), then instead of calculating emission estimates for each shop size, a single estimate for all shop sizes will result from Equation 13.4-1. County Business Patterns data do not contain revenue data, so emissions cannot be determined for each “revenue-based” shop size category. Dun and Bradstreet data is the preferred source for developing emissions using this method; however, limited resources on the part of the inventorying agency may prevent it from being used.

5.2 ALTERNATE METHOD 2 - APPORTION NATIONAL POPULATION DATA

This method is similar to the alternate method 1 except that instead of using employment data to allocate a national emissions estimate, population data from the Bureau of Census are used:

$$E_A = NE_A \times (P_I \div P_N) \quad (13.5-1)$$

where:

E_A	=	Local VOC emissions
NE_A	=	National VOC emissions
P_I	=	Population of the area of interest
P_N	=	U.S. population

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6

QUALITY ASSURANCE/ QUALITY CONTROL (QA/AC)

Data collection and handling for the auto body refinishing source category should be planned and documented in the Quality Assurance Plan. When using survey methods, the survey planning and data handling should also be documented. Refer to the discussion of survey planning and survey QA/QC in Chapter 1, Introduction to Area Source Emission Inventory Development, of this volume, and Volume VI, Quality Assurance Procedures, of the Emission Inventory Improvement Program (EIIP) series. Potential pitfalls to avoid when developing emission estimates by using a survey for this category are data gaps due to surveys not returned, unanswered or misunderstood survey questions, inappropriate assumptions used to compensate for missing information or scaling up the survey sample, errors in compiling the returned survey information, and calculation errors which can include unit conversion errors, and data handling errors.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

In this chapter, one preferred and two alternate methods are presented. In the preferred method, activity level is the amount of product used by large shops, and is being collected by a survey. Alternate Methods 1 and 2 recommend scaling the national VOC emissions estimate to the local level using either employment or population.

6.2 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The DARS scores for each method are summarized in Tables 13.6-1 through 13.6-3. A range of scores is provided for the method that uses surveys because the implementation of this method can vary. The higher scores assume that reliable data were collected specifically for the inventory area, the inventory time period, and the full range of very large auto body refinishing operations and few, if any, assumptions or generalizations have been made in using the data gathered. All scores assume that satisfactory QA/QC measures are performed and no significant deviations from good inventory practice have been made. If these assumptions are not met, new DARS scores should be developed according to the guidance provided in the QA volume.

The survey of products used for the inventory area and time period by large shops, the preferred method, has the highest potential DARS scores (Table 13.6-1). This method also requires the most effort, because this category includes many facilities, which can be difficult to include in a survey even when limited to only very large shops. Ranges in the scores for this method are based on the completeness of the survey used for this category. Spatial and temporal scores are highest when local product usage data are collected because the national emissions do not take into account the effects of local rules or work practices. Temporal scores can be improved if new emissions data are developed from the most recent data available when the inventory is undertaken. The auto body refinishing industry is changing rapidly, and new paint formulations mean that emission estimates for the industry should go down. The industry has also enjoyed technological advances in high efficiency equipment like HVLP guns, whose improved efficiency has reduced paint use emissions.

Tables 13.6-2 and 13.6-3 provide DARS scores for the two alternate methods. The level of effort required for each method goes down as the DARS score for the method becomes smaller. For this category, activity surrogates such as employment and population are not necessarily very specific to activity in the category, which may be influenced more by population density, climate, and economic factors. Given the uncertainty associated with this industry overall, however, they can be used unless more refined estimates are needed.

6.3 SOURCES OF UNCERTAINTY

Another way to evaluate the emission estimates is to examine the associated uncertainty. For estimates derived from survey data, the uncertainty can be quantified (see Chapter 4 of Volume VI of the EIIP series). Statistics needed to quantify the uncertainty of emissions derived by emission factor methods are incomplete.

Sources of uncertainty in estimating emissions from this source category include the difficulty of collecting information that truly represents auto body refinishing operations, variability in the types and amounts of products used, and the rapidly changing level of emissions from the industry. Emissions will decrease as higher VOC products can no longer be manufactured because of the federal rule that applies to the VOC content of coating manufactured on or after January 11, 1999. When using a national average, state- or local-level rules, product formulations, or frequency of repairs may increase the uncertainty of the emission estimate.

TABLE 13.6-1**PREFERRED METHOD: AUTO BODY REFINISHING SURVEY OF VERY LARGE SHOPS**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5	0.6 - 0.8	0.30 - 0.40
Source Specificity	0.7 - 0.8	0.7	0.49 - 0.56
Spatial Congruity	0.6	0.6 - 0.7	0.36 - 0.42
Temporal Congruity	0.7	0.7 - 0.8	0.49 - 0.56
Composite Scores	0.63 - 0.65	0.65 - 0.75	0.41 - 0.49

TABLE 13.6-2**ALTERNATE METHOD 1: APPORTION NATIONAL EMPLOYMENT DATA**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5	0.7	0.35
Source Specificity	0.7	0.6	0.42
Spatial Congruity	0.6	0.6	0.36
Temporal Congruity	0.7	0.7	0.49
Composite Scores	0.63	0.65	0.41

TABLE 13.6-3**ALTERNATE METHOD 2: APPORTION NATIONAL POPULATION DATA**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5	0.6	0.30
Source Specificity	0.7	0.3	0.21
Spatial Congruity	0.6	0.5	0.30
Temporal Congruity	0.7	0.7	0.49
Composite Scores	0.63	0.53	0.33

DATA CODING PROCEDURES

This section describes the codes available to characterize auto body refinishing emission estimates. Consistent categorization and coding will result in greater uniformity among inventories.

7.1 PROCESS AND CONTROL CODES

The process codes for auto body refinishing operations are shown in Table 13.7-1. These codes are compatible with the AIRS AMS source category codes (EPA, 1994b). The control codes for use with AMS are shown in Table 13.7-2. Federal, State, and local regulations can be used as guides to estimate the type of control used and the level of efficiency that can be achieved. Be careful to apply only the regulations that specifically includes area sources. If the regulation is applicable only to point sources, it should not be assumed that similar controls exist at area sources without a survey. The "099" control code can be used for miscellaneous control devices that do not have a unique identification code. The "999" code can be used for a combination of control devices where only the overall control efficiency is known.

TABLE 13.7-1

AMS CODES FOR AUTO BODY REFINISHING OPERATIONS

Category Description	Process Description	AMS Code	Units
Auto Body Refinishing: SIC Code 7532		24-01-005	
	All Solvent Types	24-01-005-000	Tons Consumed
	Acetone	24-01-005-030	Tons Consumed
	Butyl Acetate	24-01-005-055	Tons Consumed
	Butyl Alcohols: All Types	24-01-005-060	Tons Consumed
	n-Butyl Alcohol	24-01-005-065	Tons Consumed
	Isobutyl Alcohol	24-01-005-070	Tons Consumed
	Diethylene Glycol Monobutyl Ether	24-01-005-125	Tons Consumed
	Diethylene Glycol Monoethyl Ether	24-01-005-130	Tons Consumed
	Diethylene Glycol Monomethyl Ether	24-01-005-135	Tons Consumed
	Ethyl Acetate	24-01-005-170	Tons Consumed
	Ethylene Glycol Monoethyl Ether (2-Ethoxyethanol)	24-01-005-200	Tons Consumed
	Ethylene Glycol Monomethyl Ether (2-Methoxyethanol)	24-01-005-210	Tons Consumed
	Ethylene Glycol Monobutyl Ether (2-Butoxyethanol)	24-01-005-215	Tons Consumed
	Glycol Ethers: All Types	24-01-005-235	Tons Consumed
	Isopropanol	24-01-005-250	Tons Consumed
	Methyl Ethyl Ketone	24-01-005-275	Tons Consumed
	Methyl Isobutyl Ketone	24-01-005-285	Tons Consumed
	Special Naphthas	24-01-005-370	Tons Consumed
	Solvents: NEC	24-01-005-999	Tons Consumed

TABLE 13.7-2
AIRS CONTROL DEVICE CODES

Control Device	Code
Catalytic Afterburner	019
Catalytic Afterburner with Heat Exchanger	020
Direct Flame Afterburner	021
Direct Flame Afterburner with Heat Exchanger	022
Carbon Adsorption	048
Miscellaneous Control Device	099
Combined Control Efficiency	999

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8

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VOLUME III: CHAPTER 14

TRAFFIC MARKINGS

Final

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DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

This chapter describes the procedures and recommended approaches for estimating emissions from traffic markings. Section 2 of this chapter contains a general description of the traffic marking category and an overview of available control technologies. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation method for traffic markings, and Section 5 presents alternative emission estimation techniques. Quality assurance and control (QA/QC) procedures are described in Section 6. Coding procedures used for data input and storage are discussed in Section 7, and Section 8 is the reference section.

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2

SOURCE CATEGORY DESCRIPTION

Traffic marking operations consist of marking of highway center lines, edge stripes, and directional markings and painting on other paved and nonpaved surfaces, such as markings in parking lots. Materials used for traffic markings include solvent-based paints, water-based paints, thermoplastics, preformed tapes, field-reacted materials, and permanent markers. Solvent-based formulations of alkyd resins or chlorinated rubber resins are the most commonly used traffic paints. This chapter focuses on applications of traffic paints that emit a significant quantity of volatile organic compounds (VOCs). The use of traffic paints is entirely an area source.

Traffic paints are applied by maintenance crews or by contractors during new road construction, resurfacing, and other maintenance operations. The method of application is usually a spray. The paints are subjected to harsher conditions than most other paints and must withstand wear from tires, rain, sun, and other environmental factors for a considerable period of time.

Solvent- and water-based paints have roughly the same durability, with both beginning to deteriorate about a year after their application. Both solvent- and water-based paints must be applied in dry conditions and at temperatures above 40°F. If applied properly, water-based paint is considered to be of better quality than solvent-based paint; however, application of water-based paint is more susceptible to weather constraints such as humidity. Plastic-based paints (i.e., thermoplastics, preformed tapes, and field-reacted systems) are more durable than either solvent- or water-based paints.

2.1 EMISSION SOURCES

VOC emissions result from the evaporation of organic solvents during and shortly after the application of the marking paint. Of the painting materials commonly used for traffic marking, three types emit VOCs in appreciable amounts:

- Nonaerosol traffic paint, water- and solvent-based: Solvent-based paints include aliphatic hydrocarbons, toluene, xylene, ketones, and chlorinated hydrocarbons. Water-based paints contain some organic solvent components, usually emulsions of glycols and alcohols; however, the VOC emissions are considerably lower than those from solvent-based paints.

- Aerosol marking paint, water- and solvent-based: These paints are used to apply stripes or markings to outdoor surfaces, such as streets, golf courses, athletic fields, or construction sites. Markings can be either temporary or permanent. Chapter 5, of this volume, *Consumer and Commercial Solvent Use*, page A-9, includes an emission factor of 0.0254 lb/person for the use of these products. Total annual emissions in the U.S. for this subcategory are estimated as 3,154 tons of reactive VOC per year. Emissions from these paints are **not included** in this chapter.
- Preformed tapes applied with adhesive primer: Emissions from traffic marking adhesives are included as part of Chapter 5, *Consumer and Commercial Solvent Use*, on page A-7, under the subcategory of "other adhesives." Emissions from these adhesives are **not included** in this chapter.

VOC emissions are negligible from application of some alternative paints including thermoplastics, preformed tapes with no adhesive primer, and two-component, field-reacted systems. In addition to the painting material used, VOCs from solvents utilized in cleaning the striping equipment should be quantified in the category.

2.2 FACTORS INFLUENCING EMISSIONS

2.2.1 PROCESS OPERATING FACTORS

Emissions from traffic marking vary depending on the marking material used and the frequency of application. Table 14.2-1 compares estimated annual VOC emissions for the different marking types. These emission factors account for traffic marking applications that take place either more frequently or less frequently than once a year, since a more durable marking material will effectively emit less because it needs to be applied less frequently. Climate conditions and paint durability, coupled with factors such as pavement type, traffic density, and position of the marking, will influence the frequency of application.

2.2.2 CONTROL TECHNIQUES

Because the use of organic solvents in traffic markings is the primary source of emissions, control techniques for this source category involve either product substitution or product reformulation. Alternative formulations include low-solvent-content coatings, water-based coatings, and plastic-based coatings. Because the performance requirements for different marking situations differ, and because these materials have different physical and chemical properties and a wide range of costs, different materials are advantageous for specific application situations. Table 14.2-2 lists the advantages and disadvantages of various traffic marking materials.

TABLE 14.2-1

COMPARISON OF ESTIMATED VOC EMISSIONS (EPA, 1988)

Marking Materials	Estimated VOC Emissions (lb/lane mile-yr) ^a
Solvent-based (non-aerosol)	69 ^b
Water-based (non-aerosol)	13 ^c
Thermoplastic	--- ^d
Field-reacted	
Polyester	--- ^d
Epoxy	0.25
Preformed Tapes	
Without adhesive primer	0
With adhesive primer	58 ^e
Permanent Markers	0

^a Mile refers to one 4-inch-wide solid stripe that is 1 mile long.

^b Solvent-based paints typically consist of a resin, pigment, and various additives, all suspended in an organic solvent. The average VOC content for solvent-based paints listed in this reference is 3.15 lb/gal.

^c Water-based paints typically consist of latex emulsions which also include some organic solvent. The average VOC content for water-based paints listed in this reference is 0.76 lb/gal.

^d Negligible.

^e Adhesive primers for tapes are included in Chapter 5, *Consumer and Commercial Solvent Use*.

TABLE 14.2-2
ADVANTAGES AND DISADVANTAGES OF
ALTERNATIVE TRAFFIC MARKING MATERIALS (EPA, 1988)

Marking Material	Advantages	Disadvantages
Solvent-based Paints	Low initial cost Good dry-night visibility Short drying times available Good equipment availability Well-established technology No pavement-type limitations	High VOC emissions Short life Poor wet-night visibility
Water-based Paints	Low VOC emissions Low initial cost Good dry-night visibility Easy to adapt from solvent-based formulations Easy cleanup No pavement-type limitations	Poor wet-night visibility Short life Weather restrictions for application
Thermoplastics	Negligible VOC emissions Long life Good night visibility (wet & dry) 100 percent solids	High initial cost High application temperature Reduced durability on Portland cement More difficult application than for paint
Preformed Tapes	No VOC emissions if adhesive primer is not used Long life Little or no application equipment needed Excellent material safety 100 percent solids	High VOC emissions if primer is used Very high initial cost Variable night visibility
Field-reacted Systems	Negligible VOC emissions Long life Moderate initial cost Essentially 100 percent solids Good night visibility	Polyester type adheres poorly to Portland cement Special application equipment needed
Permanent Markers	Negligible VOC emissions Long life Excellent night visibility (wet & dry)	High initial cost Poor durability in snowplow areas

3

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATION METHODOLOGIES

Several methodologies are available for calculating emissions from traffic markings. The method used is dependent upon the degree of accuracy required in the estimate, available data, and available resources.

This section presents the methods available for calculating emission estimates from traffic markings and identifies the preferred calculation method. The data elements needed for each method are also discussed.

3.2 AVAILABLE METHODOLOGIES

3.2.1 VOLATILE ORGANIC COMPOUNDS

The VOCs released into the air by traffic marking application are from the evaporation of the VOCs contained in the coating. Determining the amount of the VOCs in coatings should provide a good estimate of the VOC emitted by this source category. There are four approaches to estimating the amount of VOC emitted from this source category:

Preferred Method: Survey of traffic marking use in the inventory area;

Alternative Method 1: Emissions based on Manufacturing Census data on paint production, Federal Highway Administration data, and the national average per gallon emission factor;

Alternative Method 2: Lane miles emission factor; and

Alternative Method 3: Per capita usage and the national average per gallon emission factor.

The preferred method is the best approach for emissions estimation because it will most accurately reflect the actual use, seasonal application, and content of traffic coatings in the inventory area and, if requested in the survey, will include cleanup solvent estimates. If required by the inventory, the level of detail provided by this method allows for greater accuracy in VOC as well as hazardous air pollutant (HAP) emissions estimation and control strategy modeling.

The alternative approaches do not provide the same level of detail as does the survey method in terms of the specific amounts and types of paints used in the inventory area. This means that information on the use of water- versus solvent-based coatings, or the amount and type of cleanup solvents used is not available when the alternative methods are used. Alternative Method 3 in particular does not take into account variability among regions, but will take into account the variability of usage at the national level from year to year. The alternative methods are best used if controls are limited or nonexistent and no further controls are anticipated for the source category.

3.2.2 HAZARDOUS AIR POLLUTANTS

HAP emissions for this category can be estimated using two methods:

- Surveying traffic marking use in the inventory area; or
- Applying speciation profiles to the VOC emissions estimate, obtained by using either the preferred or alternative methods for VOCs.

The survey method is the preferred method, because it will provide the most accurate information on coating usage and HAP content of the coatings used. The effect of VOC controls on HAP emissions will also be apparent when using this method.

Speciation profiles can be used as an alternate approach when conducting a detailed survey is not practical. Although specific profiles will be provided in Section 5, updated or local speciation profiles should be used when available.

3.3 DATA NEEDS

3.3.1 DATA ELEMENTS

The data elements used to calculate emission estimates for this category will depend on the methodology used for data collection. The data elements necessary for an emission calculation that should be requested in a survey of state and county highway departments include:

- Product type;
- Product amount distributed by type (gallon) for the inventory period;
- Product density (pounds per gallon);

- VOC and HAP content of each product, or solvent content by type, and VOC percentage of solvents (weight percent) for each product;
- Information on the amount and type of cleanup solvent; and
- Information on disposal of unused products.

If an emission factor method is used, the following data elements are needed depending on the chosen method: national or local coating usage, statistics for highway maintenance spending, national and local population, number of lane miles in the inventory area, and a VOC emission factor and HAP speciation profiles (both provided in Section 5). Emission factors may be developed at the national or state level or representative sample subsection, then apportioned to the inventory level.

3.3.2 APPLICATION OF CONTROLS

Because the use of controls will affect the VOC or HAP content of the coating itself, a survey of coating usage and VOC or HAP content, or development of an emission factor from recent usage data, will reflect controls that are in place. Because a reformulation or substitution represents an irreversible process change and, thus, a reduction in emissions, rule effectiveness can be assumed to be 100 percent for that coating type.

Rule penetration will be based on the weighted percentage of coatings within the inventory area that are affected by the rule.

3.3.3 SPATIAL ALLOCATION

Spatial allocation is used in two cases in the preparation of an area source inventory: (1) to allocate emissions or activity to the county level and (2) to allocate county-level emission estimates or activity to a modeling grid cell. Allocation of emissions or activity to the county level is addressed in the discussion of each preferred or alternative method.

Allocation of emission estimates or activity to a modeling grid cell level can be done using one of three potential spatial surrogates, shown below in order of preference:

1. Use detailed information about the number of lane miles within each grid cell, or a group of grid cells. This information may be available from inventory personnel involved in estimating mobile source emissions or from county or state departments of transportation.

2. Use other land use data, if land use can be generalized to estimate the number of lane miles. This information is usually available through county planning departments.
3. Use population data, available from the U.S. Census Bureau.

3.3.4 TEMPORAL RESOLUTION

Seasonal Apportioning

Traffic marking use is influenced by the seasons, since spreading and drying characteristics for many paints are dependent on temperature. Solvent-based traffic paints are usually applied only when the temperature of the road surface is 50°F or higher. Best results from water-based paints are achieved when they are applied when air temperature is 50°F or higher and there is low humidity. The preferred method for seasonal apportioning is to survey state or local highway departments. Because it can be assumed that seasonal usage is similar among all users in the area, the survey sample can be small. If a survey is not practical, the seasonal activity factor for the ozone season is 1.3 or 33 percent of annual activity (EPA, 1991). See Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development* for more information about using seasonal activity factors and seasonal apportioning.

Daily Resolution

Traffic marking application typically takes place 5 days a week during the active season.

3.3.5 PROJECTING EMISSIONS

A discussion about developing growth factors and projecting emission estimates can be found in Section 4 of Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development*. Projecting emissions for this source category will take two variables into account, the change in activity (e.g., road miles painted, or gallons of paint used) and the change in the formulations of paints and other marking materials used, which will determine the emission factor that is used. Projected emission estimates may need to be calculated differently in the two following cases:

- | | |
|---------|--|
| Case 1: | There are no controls and thus there is no change in the emission factor;
and |
| Case 2: | There are controls in place for traffic markings, and emission reductions
are reflected in the emission factor. |

Each case uses a different projection equation. If there are no controls and no changes in the emission factor, projected emissions are calculated using the following equation:

$$\text{EMIS}_{\text{PY}} = \text{ORATE}_{\text{BY}} * \text{EMF} * \text{GF} \quad (14.3-1)$$

where:

EMIS_{PY}	=	Projection year emissions
ORATE_{BY}	=	Base year activity rate
EMF	=	Emission factor
GF	=	Growth factor

For Case 2, where controls are reflected in the emission factor, the equation would be:

$$\text{EMIS}_{\text{PY}} = \text{ORATE}_{\text{BY}} * \text{EMF}_{\text{PY}} * \left[\frac{(200 - \text{RP}_{\text{PY}})}{100} \right] * \text{GF} \quad (14.3-2)$$

where:

EMF_{PY}	=	Projection year emission factor
RP_{PY}	=	Projection year rule penetration (%)

Tools for the development and use of growth factors are discussed in Chapter 1 of this volume.

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4

PREFERRED METHOD FOR ESTIMATING EMISSIONS

The preferred method for calculating emission estimates from traffic markings is to conduct a survey of marking use by state and county highway departments, and city road maintenance departments. The highway and road maintenance departments are responsible for the predominant part of traffic coatings applied. Records should be accessible and information should be sufficiently detailed to calculate VOC and HAP emissions. This section provides an outline for preparing and using a traffic markings survey, and calculating emission estimates from the information collected.

Survey planners are asked to refer to Section 2.1 of this chapter, Emission Sources, before developing any survey. There are three types of traffic markings that have appreciable emissions, traffic paints, aerosol traffic markings, and traffic tapes that use an adhesive primer. Of those three, the traffic aerosols and traffic tape adhesives are discussed in Chapter 5 of this document, *Consumer and Commercial Solvent Use*. A survey of traffic markings may include the use of traffic tapes and possibly the use of aerosols, but if the survey results for those products are used, then estimated emissions for the aerosol and adhesive subcategories of the consumer products source category will need to be reduced to avoid double counting of emissions. However, information about the proportion of adhesives or aerosol products that can be attributed to traffic marking uses is not available.

Drawbacks to the survey method are that not all highway and maintenance departments may keep records of coating usage. If highway and maintenance departments do not keep these records, then using this method is not practical. Also, a survey of highway and maintenance departments will not include markings used for parking lots by private contractors unless the contractors are also surveyed. However, it is unlikely that a survey of contractors would be as reliable as that of government highway departments for a number of reasons. First, the response rate will likely be lower; second, they may not keep as complete or as detailed records; and third, a contractor will do work over county or state boundaries and may not be able to estimate coating use for just the inventory area. However, a national-level survey of traffic coating end users shows that government highway departments are using 95 percent of the traffic coatings in the United States (EPA, 1993).

The final drawback to this method is that a well-planned, well-run survey requires more time, effort and expense than a top-down approach. Inventory preparers must judge whether the costs of this approach are outweighed by the benefit of having an estimate that is more specific to the inventory area and time period.

Costs and labor efforts are highest for the first time that a regional or local survey of traffic marking use is performed. Subsequent updates to the survey may be done using fewer samples at much less cost. In the years following the baseline survey, updates on coating usage may be all that is needed. Periodically, information on changes in formulations, methods of application, and the percentages of different types of coatings used will be needed to accurately estimate emissions.

Surveys for area sources are specifically discussed in Volume I of the Emission Inventory Improvement Program (EIIP) series and in Chapter 1 of this volume. A survey of state and county highway departments will consist of: (1) survey planning, (2) survey preparation, (3) survey distribution, (4) survey compilation and scaling, and (5) emission estimation. Discussion of these steps follows.

4.1 SURVEY PLANNING

During the planning phase, the following issues should be addressed:

- Survey data quality objectives (DQOs) should be identified, and how the DQOs will be realistically reached specified.
- The survey recipients and data needs must be identified.
 - Information from the state and county levels may cover an area larger or smaller than the inventory area. Should scaling be needed for survey results, identify an available scaling surrogate (e.g., number of lane miles, population).
 - In some cases, highway departments in several counties will arrange to purchase paint and will contract with a private contractor to have the painting done. During survey planning, this sort of situation should be identified, an allocation approach will need to be defined, and data should be collected for it.
 - When counties in the inventory area include extensive state or national parks, military bases, or very large commercial properties which arrange for their own traffic marking, the maintenance offices for these areas may

need to be surveyed. However, these areas may not need to be surveyed if the facility already reports traffic marking activities as part of a point source inventory, or the amount of traffic marking at the facility is proportionally small in comparison to the activity in the rest of the county.

- If the usage of different types of coatings and solvents is known to be consistent from county to county, a standard profile of product types can be developed and the survey need only collect the total amount of coatings and solvents used per county.
- Data handling needs specific to this survey must be identified.
- Survey QA/QC methods must be delineated and implemented.

The survey package should include a cover letter explaining the program, the survey form, a list of definitions and a postage-paid return envelope. Both state and county highway departments may need to be surveyed in order to collect information needed for the traffic markings category. Additional disposal information may be collected as part of a waste disposal or recycling category. The portion of emissions that correspond to recycled or discarded traffic coating materials from the disposal or recycling category should be subtracted from the emission estimate for traffic marking. This is necessary to avoid double counting.

4.2 SURVEY PREPARATION

A survey may be planned to collect either a detailed amount of data or only the minimum amount needed for to estimate emissions. The minimum amount of information needed to calculate an emission estimate is the number of gallons of solvent-based and water-based traffic paints used in the inventory area or inventory county. The national averages of VOCs for solvent-based and water-based traffic coatings can be multiplied by the number of gallons of each coating type to estimate emissions. National averages of VOC content for types of coatings have been prepared by the National Paint and Coatings Association (NPCA) (EPA, 1993) shown in Table 14.4-1.

A more detailed survey will request:

- Product type, including thinning and cleanup solvents;
- Product amount used by type (gallon);
- Product density (pound per gallon);
- Estimates of the proportion of products used during the inventory season; and

- VOC or solvent content of each product type (pounds per gallon or weight percent) for a VOC inventory, or, for a HAP inventory, HAP or solvent content of each product type (pounds per gallon or weight percent).

Survey preparers should clearly define the time period that the survey information is being collected for. A request for annual data, for instance, should specify the range of months to avoid confusion between fiscal and calendar years. It is preferable to collect data specific to the inventory period, but for periods less than 12 months, usage will probably have to be apportioned by the inventory preparer.

If the survey results need to be scaled to a different spatial scale, or are expected to be adjusted for future inventories, factors that may be useful to adjust the survey information may also be collected. For example, the road miles or lane miles within the county that the department is responsible for could be requested from that department. Road miles or lane miles may also be available from mobile emissions inventory preparers. Then, a county-specific emission factor based on the number of road miles or lane miles can be developed and used in future inventories.

TABLE 14.4-1

EMISSION FACTORS FOR TRAFFIC MARKINGS (EPA, 1993)^a

Coating Type	VOC Content (lb/gal)
Water-based coatings	0.72
Solvent-based coatings	3.64
National average, water- and solvent-based	3.36

^a Data are based on a 1991 survey.

The advantages of the more detailed approach are that the inventory developed is more specific to the locality, and the information collected can be more readily projected to inventories for subsequent years.

Instructions for using the survey form are provided on the survey cover page, shown in Figure 14.4-1. As shown in Table 14.4-2, respondents must first estimate the annual amount of coatings as the amount stocked and VOC weight percent or pounds per gallon used in coatings, less waste disposed of off-site or unused. For HAP inventories, material safety data sheets (MSDS) for each product should be requested. This information can be combined with the

coating and solvent density to yield the pounds of product used in a given year. HAP weight-percent information can be derived from the MSDS provided with each coating.

An alternative survey-based method for a HAP inventory would use a representative sample of the HAP contents for each product type, applied to a more complete inventory of traffic marking types and usage.

4.3 SURVEY DISTRIBUTION

This method requires contact with every transportation department that uses traffic coatings in the inventory area. Surveys can be distributed by mail, or the information can be collected through a telephone survey. Initial contacts and follow-up contacts may also be undertaken as part of the survey to answer any questions. Survey distribution issues are discussed in Chapter 1 of this volume.

4.4 SURVEY COMPILATION AND SCALING

Survey compilation and scaling issues are discussed in Volume I of this series. Completed surveys will result in information that includes many types of coatings and multiple pollutants, so compilation of this information will require planning for data transfer and data management. Efficient transfer to the data handling system will benefit from inventory planner's consideration of the data transfer step during the design of the survey.

QC checks should be performed during this phase of the work (see Volume VI for QA/QC methods). Incoming surveys should be checked for errors such as potential unit conversion errors or misidentification of products or chemicals. Survey information should be checked for reasonableness. Compiled survey information should also be subject to similar checks. Survey recipients may need to be recontacted in order to correct any errors.

Name of Highway Department: _____

Street Address: _____

City: _____

Contact Person/Phone Number: _____

The purpose of this survey is to collect information about the amounts of traffic paints used so that estimates of air pollution from the traffic paints can be made. Please enter the following information on the attached form.

1. List the product types stocked in year _____. Product types should include all traffic coatings and any solvents used for thinning or cleanup in association with them.
2. Provide the weight percent of VOCs for each product or, if it is available, provide the amount of VOCs, as pounds per gallon of product. Please clearly mark the entry as a percent (%) or pounds per gallon (lb/gal).
3. If the entry in Column B is weight percent, provide the specific gravity of the product.
4. Provide the amount, in gallons, of each product stocked.
5. Subtract from the products listed under Column A any coating or solvent that was disposed of off-site (Column E), lost as waste (spills, etc.) in Column F, or portions that were unused (Column G). If only the total amounts of these losses are known, split the total between the different products.
6. Attach copies of the Material Safety Data Sheets (MSDSs) for all of the products listed (*for HAP inventories*).

**FIGURE 14.4-1. SURVEY REQUEST FORM FOR TRAFFIC MARKINGS
STATE AND COUNTY HIGHWAY DEPARTMENTS**

TABLE 14.4-2

TRAFFIC MARKINGS DATA REQUEST FORM^a

A Product Type	B Product VOC Weight Percent or Pounds/Gallon	C Specific Gravity of Product ^b	D Amount Stocked in year	E Amount Disposed of Off-site	F Amount Lost as Waste	G Amount Unused	Amount Used = D - (E + F + G)

^a Volume of product expressed gallons unless otherwise noted.

^b The specific gravity of the product is needed only if VOC content of the product is in weight percent.

Depending on the recipients to the survey, results may need to be either scaled up for all counties in the inventory area or scaled down to the inventory area. In either case, a scaling factor should have been identified in the planning phase, and any necessary requests for information from the survey respondents included on the survey form. Refer to Sections 3.3.3 Spatial Allocation, and 3.3.4 Temporal Resolution for more information about allocation and scaling factors for this source category.

4.5 EMISSION ESTIMATION

Emission estimation calculations involve determining emissions of the pollutant(s) of interest, and then the application of any necessary spatial or temporal adjustments. Because the application of traffic markings is defined as an area source, there should not be a need to subtract point source emission estimates from the total. Emission estimate calculations from the information collected by survey require the following steps:

If pounds of VOC per gallon are not available, then emissions are calculated as follows:

- Multiply the specific gravity of the product by 8.34 lb/gal, the density of water, to get the product density.

$$\text{Product Density} = \left(\begin{array}{c} \text{Specific Gravity} \\ \text{of the Product} \end{array} \right) * 8.34 \quad (14.4-1)$$

- Multiply the gallons of product used by the density to yield the pounds of each product used.

$$\begin{array}{c} \text{Pounds of} \\ \text{Product} \end{array} = \begin{array}{c} \text{Gallons} \\ \text{of Product} \end{array} * \begin{array}{c} \text{Product} \\ \text{Density} \end{array} \quad (14.4-2)$$

- For a VOC inventory, multiply the VOC weight percent by the pounds of product for each coating or cleaning solvent. For a HAP inventory, identify the HAP components from the coating MSDS and multiply the weight percent of each HAP by the pounds of product for the coating or cleaning solvent.

$$\begin{array}{l} \text{Pollutant} \\ \text{Emissions} \\ \text{(lb)} \end{array} = \begin{array}{l} \text{Pounds} \\ \text{of Product} \end{array} * \begin{array}{l} \text{Pollutant} \\ \text{Weight \%} \end{array} \quad (14.4-3)$$

Emissions for each product type should be calculated separately.

If pounds of VOCs per gallon for each product type is available, then VOCs are calculated as:

$$\begin{array}{l} \text{VOC} \\ \text{Emissions} \\ \text{(lb)} \end{array} = \begin{array}{l} \text{Amount of} \\ \text{Product} \\ \text{(gal)} \end{array} * \begin{array}{l} \text{VOCs per} \\ \text{Gallon} \\ \text{(gal)} \end{array} \quad (14.4-4)$$

Emissions for each product type should be calculated separately.

Example 4-1

In this example, information on the pounds of VOCs per gallon of each type of coating used in one county has been collected. The data collected and calculation for the total amount of VOCs emitted for the county is shown below:

Example traffic coating usage for one county:

- 10,000 gallons yellow traffic paint; solvent-based, 3.21 lb VOCs/gal
- 1,560 gallons white traffic paint; solvent-based, 3.26 lb VOCs/gal
- 6,324 gallons yellow traffic paint; water-based, 0.54 lb VOCs/gal
- 7,610 gallons white traffic paint; water-based, 0.69 lb VOCs/gal

The calculation will be:

$$\begin{aligned} \text{VOC Emissions} & \\ \text{from} & \\ \text{Traffic Coatings} & = [(10,000 \text{ gal} * 3.21 \text{ lb/gal}) + (1,560 \text{ gal} * 3.26 \text{ lb/gal}) + \\ & (6,324 \text{ gal} * 0.54 \text{ lb/gal}) + (7,610 \text{ gal} * 0.69 \text{ lb/gal})] \\ & = 45,852 \text{ lb VOC} \end{aligned}$$

Example 4-2

In this example, the HAP emissions from one paint type are calculated from the HAP volume percent for that paint type and the HAP density. Representative HAP volume percents and densities are shown in Table 14.4-3.

Emissions for carbon tetrachloride from traffic paint used in an area would be calculated:

$$\begin{aligned}\text{Carbon tetrachloride emissions} &= 10,000 \text{ gal} * 0.009 \% * 12.19 \text{ (lb/gal)} \\ &= 10.97 \text{ lb}\end{aligned}$$

Emissions from each HAP from each type of paint are calculated as they are above, then summed to get the total for all paint types.

Spatial allocation of emissions to individual counties or other inventory area units can be done by proportioning emissions with a surrogate factor. Potential surrogate factors, in order of preference, are lane mile data, land use data, or population.

Temporal allocation may be necessary if the inventory requires seasonal or daily emission estimates, and is discussed in Section 3 of this chapter.

TABLE 14.4-3

**HAP SPECIES PROFILES FOR TRAFFIC MARKINGS
(EPA, 1993)^a**

HAP	Volume Percent (%)	Density (lb/gal)
Carbon tetrachloride	0.009	12.19
Cumene	0.002	7.19
Ethylbenzene	0.009	7.24
Ethylene glycol	0.086	9.31
Glycol ethers	0.040	7.01
Methyl ethyl ketone	1.514	6.89
Methyl isobutyl ketone	0.002	6.71
Methyl methacrylate	0.044	7.84
Naphthalene	0.002	9.55
Propylene oxide	0.115	6.93
Styrene	0.277	7.55
Toluene	6.914	7.23
Xylenes (mixed isomers)	0.499	7.18

^a Data based on a 1991 survey.

^b These volume percent factors are based on the amounts of each HAP component in a sales-weighted average traffic paint.

5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

This section provides an outline for developing and using emission factors as alternative methods for calculating emissions from traffic markings. Procedures for using the three alternative methods described in Section 3 are provided in the following discussion.

5.1 VOLATILE ORGANIC COMPOUNDS

5.1.1 ALTERNATIVE ONE: NATIONAL TRAFFIC PAINT SALES AND NPCA EMISSION FACTOR

This method uses NPCA per gallon emission factors multiplied by traffic paint usage values that are specific to the inventory year, but are apportioned from the national level to the county level in two steps. The national to state apportioning step proportions the amount of traffic paint by the dollars spent on roads and highways in the inventory state. This information is available in Federal Highway Administration reports, and is well suited as a surrogate for apportioning. The apportioning approach of using dollars spent will reflect differences between states in the number of lane miles in each state that the states have to maintain, differences in the types of roads in each state, and variations between states in the levels of maintenance for roads. The federal report does not provide this information for individual counties, so apportioning from the state to the county level requires another surrogate. Paved lane miles or population are used in this method because they are easily available, but other surrogates, such as state-generated, per-county highway maintenance spending, or vehicle registration numbers can be used to calculate a per-county estimate of traffic paint used.

The advantage to this method is that most of the information needed for the calculations should be relatively simple to collect and manage. The disadvantage is that the estimate will not include cleanup emissions (although thinning is included in the NPCA emission factor), and the usage numbers will not be as specific as those from the survey method.

The steps needed to use the first alternative method are as follows:

- Determine the amount of U.S. traffic paint usage for the inventory year. Use data from the U.S. Census Bureau, Report MA28F-Paint and Allied Products.

^a Table 14.5-1 is an example report.

- Apportion the national traffic paint usage to the state level based on spending for highway maintenance. The Federal Highway Administration publishes *Highway Statistics* annually.^b Table HF-2, Total Disbursements for Highways, All Units of Governments, in the *Highway Statistics* publication will have the necessary information.
- Apportion the state estimate of traffic paint usage to the county level using either the proportion of the number of county paved lane miles to the number of state paved lane miles, or by the proportion of county to state population. Using paved lane miles as a surrogate is the preferred approach.
- If information is available on the proportion of solvent- versus water-based coatings for the state or county, those proportions can be used to develop a local emission factor from the NPCA solvent- and water-based coating factors in Table 14.4-1. Otherwise, the national average emission factor for both types of coatings from the NPCA survey should be used. The equation for calculating emissions is:

$$\text{VOC Emissions} = \frac{\text{NPCA Emission Factor (lb/gal)}}{\text{Factor (lb/gal)}} * \frac{\text{County Traffic Paint Usage (gal)}}{\text{Paint Usage (gal)}} \quad (14.5-1)$$

Example 5-1 shows the calculation for a typical county.

5.1.2 ALTERNATIVE METHOD TWO: LANE MILES EMISSION FACTOR

This method uses an emission factor for lane miles of road painted paired with local data. The emission factors are from a 1988 Control Technology Center (CTC) report (EPA, 1988). Emission factors for solvent- and water-based traffic paints, and for lane

^a Total national coating usage is compiled by the Bureau of the Census, Report MA28F-Paint and Allied Products, available from the U.S. Census Bureau, Department of Commerce, Washington, D.C.

^b Federal Highway Administration, U.S. Department of Transportation, Washington, D.C.

TABLE 14.5-1

QUALITY AND VALUE OF SHIPMENTS OF PAINT AND ALLIED PRODUCTS: 1994 AND 1993
(QUANTITY IN THOUSANDS OF GALLONS; VALUE IN THOUSANDS OF DOLLARS)^a

Product Code	Product Description	1994 Quantity	1994 Value	1993 Quantity	1994 Value
2851	Paint and allied products ^b	1,103,693	14,140,288	1,228,531	13,538,654
28513 11	Traffic marking paints (all types, shelf goods and highway department)	33,898	202,810	29,515	174,154

^a Source: U.S. Bureau of the Census Report MA28F-Paint and Allied Products.

^b Represents total shipments for those establishments producing paint and allied products that have 20 or more employees. These establishments represent approximately 95 percent of the total value of shipments for Standard Industrial Classification (SIC) industry 2851, paint, varnishes, lacquers, enamels, and allied products based on relationships observed in the 1992 Census of Manufactures preliminary report.

Example 5-1:

U.S. traffic paint sales totaled 29,515,000 gallons in 1993 (see Table 14.5-1). According to the Federal Highway Administration's annual *Highway Statistics* report, Table HF-2, total disbursements on roads and highways was \$62,351,345,000, and State A spent \$1,115,435,000. Gallons of traffic paint are apportioned from the national level to state level by:

$$\begin{aligned}\text{State A Traffic} &= [\$1,115,435,000 / \$62,351,345,000] * 29,515,000 \text{ gallons} \\ \text{Paint Usage} &= 528,009 \text{ gallons}\end{aligned}$$

The amount of traffic paint is apportioned from the state to the county level using population for County B and State A (77,055 and 6,386,600 people, respectively):

$$\begin{aligned}\text{County B Traffic} &= [77,055 / 6,386,600] * 528,009 \text{ gallons} \\ \text{Paint Usage} &= 6,370 \text{ gallons}\end{aligned}$$

In this case, no information is available about the proportions of solvent- versus water-based paints used in the inventory area, so the national average emission factor provided in Table 14.4-1 should be used. VOC emissions are calculated for County B by:

$$\begin{aligned}\text{County B VOC} \\ \text{Emissions from} &= 6,370 \text{ gallons paint} * 3.36 \text{ lb/gal} \\ \text{Traffic Paints} &= 21,403 \text{ lb VOCs} \\ &= 10.7 \text{ tons VOCs}\end{aligned}$$

miles painted or total lane miles are shown in Table 14.5-2. If the number of lane miles that were actually painted in the inventory year are available, a more specific estimate can be made using the factor for emissions per lane miles painted, in units of pounds per mile. If only the total lane miles in the inventory area are available, then emission estimates can be estimated using the factor for typical annual emissions, in units of pounds per mile and year. Lane miles painted data may be available from state and county highway departments. Total lane miles data should be available from state and county highway departments, or from air agency mobile inventory preparers.

The emission factors for solvent-based paints should be used if there is no information about whether solvent- or water-based paints are used. This will result in the most conservative estimate. However, the preferred approach is to gather information about the proportions of solvent-based versus water-based paint if at all possible. State or local rules may determine the type of paint or other marking type that can be used within an area, or a small telephone survey of a subset of highway departments may be used to define the proportions of paint type.

The equation used to calculate emissions using these emission factors is:

$$\begin{array}{l} \text{Inventory Area} \\ \text{Emissions from} \\ \text{Traffic Paints} \end{array} = \begin{array}{l} \text{Emission Factor} \\ (\text{lb/lane mile}) \end{array} * \begin{array}{l} \text{Traffic Lane} \\ \text{Miles Painted} \end{array} \quad (14.5-2)$$

If the lane mile data are available, this method has the advantage of being easy to use. However, the method does not take into account any region-specific use of lower-emitting coatings, such as water-based coatings or thermoplastic tapes. Using the typical annual emissions factor with total lane miles also will not reflect area-specific repainting schedules.

TABLE 14.5-2
LANE MILE VOC EMISSION FACTORS (EPA, 1988)

Traffic Paint Type	Typical Expected Life (years)	VOC Emissions Per Lane Mile Painted (lb/mile)	Typical Annual VOC Emissions (lb/mile-year)^a
Solvent-based	0.75	52	69
Water-based	1.0	13	13

^a Mile refers to one 4-inch-wide stripe that is 1 mile long.

5.1.3 ALTERNATIVE METHOD THREE: PER CAPITA EMISSION FACTOR

This method is a simplified version of Alternative Method One. A national average usage factor of gallons per person is developed from U.S. Census data for the inventory year. The per capita usage factor is multiplied by the NPCA per-gallon emission factor to calculate emissions. The steps needed for this method are:

- Collect the necessary data: National traffic paint sales data, in gallons, from U.S. Census Report MA28F-Paint and Allied Products, national population and inventory area population figures for the inventory year, and the NPCA per-gallon emission factor.
- Develop a national average per capita usage factor:

$$\begin{array}{lcl} \text{National} & & \\ \text{Per Capita} & = & \text{National Traffic} \\ \text{Usage} & & \text{Paint Usage} \\ \text{(gal/person)} & & \text{(gallons)} \end{array} \quad / \quad \begin{array}{l} \text{National Inventory} \\ \text{Year Population} \end{array} \quad (14.5-3)$$

- Multiply the usage factor, the NPCA per gallon emission factor, and the inventory area population to get the inventory area emission estimate:

$$\begin{array}{lcl} \text{Inventory Area} & = & \text{National Per Capita} \\ \text{Emissions from} & & \text{Usage Factor} \\ \text{Traffic Paints} & & \text{(gal/person)} \end{array} \quad * \quad \begin{array}{l} \text{NPCA Emission} \\ \text{Factor} \\ \text{(lb/gal)} \end{array} \quad * \quad \begin{array}{l} \text{Inventory} \\ \text{Population} \end{array} \quad (14.5-4)$$

The advantage of this method is that all of the information needed is easily obtained and the calculations are simple. If this source category is a low priority in the inventory and no controls are planned, this could be an appropriate method. However, limitations to this method are: population is not the most accurate surrogate for traffic coatings because it does not take into account the region-specific use of lower-emitting coatings, and the activity will not reflect whether an area has a higher or lower level of maintenance.

5.2 HAZARDOUS AIR POLLUTANTS

HAP emissions are calculated by multiplying the county traffic paint usage amount by the HAP volume percent (Table 14.4-3). The equation for this calculation is:

$$\text{VOC Emissions} = \frac{\text{County Traffic}}{\text{Paint Usage}} * \frac{\text{HAP Volume}}{\%} * \frac{\text{HAP}}{\text{Density}} \quad (14.5-5)$$

See Example 14.5-1 for an example calculation.

If Alternative Method Two is used, assume that 16 gallons of traffic paint of either type are used for every lane mile counted (EPA, 1988).

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6

QUALITY ASSURANCE/QUALITY CONTROL

When using the preferred method, the survey planning, sample design, and data handling should be planned and documented in the inventory QA/QC plan. Refer to the discussion of survey planning and survey QA/QC in Chapter 1 of this volume.

Data handling for the survey data and for data collected for the alternate methods should also be planned and documented in the inventory QA/QC plan and do not involve any category-specific issues. Please consult EIIP Volume VI on inventory QA/QC for more information.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

Surveys are theoretically the most accurate approach for estimating emissions, but also are the most expensive. Advantages to using surveys are that region- or area-specific information about the amount and type of traffic markings used will be collected. Markings surveyed will more precisely reflect the regulations for VOCs that are in place in the inventory area. Emissions of HAPs can be calculated based on the specific types of coatings in use in the area. The level of detail that is possible to collect with a survey is not available when using the alternative methods.

The preferred method gives higher quality estimates than any of the alternative methods, but requires significantly more effort. The level of effort required to calculate emissions using either of the alternative methods ranges from 8 to 40 hours. Conducting a survey of state, county, and city highway departments requires between 60 to 150 hours depending on the size of inventory region and the desired level of detail of the survey. However, the resultant increase in the quality may justify this expenditure of resources, especially if this category is believed to be a significant contributor to emissions or is subject to regulations. Emissions from traffic markings are typically among the top 15 area sources of VOCs and HAPs in urban areas.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The DARS scores for each method are summarized in Tables 14.6-1, 14.6-2, 14.6-3, and 14.6-4. A range of scores is given for the preferred method and first alternative method to reflect variability in survey techniques. A range of scores for spatial congruity is also given for the

second alternative method to account for the use of either the more specific lane miles painted activity or less specific total miles painted. In the case of the first alternative method, use of more specific apportioning surrogates and more specific information about the types of paint used in the area will improve the scores. All scores assume that good QA/QC measures are performed and that no significant deviations from the prescribed methods have been made. If these assumptions are not met, new DARS scores should be developed according to the guidance provided in Appendix F of EIIP Volume VI.

The preferred method gives higher DARS scores than any of the alternative methods. The alternative method DARS scores range between 0.51 and 0.33, and the preferred method's DARS scores are between 0.85 and 0.73. The preferred method scores higher on all attributes than the alternative methods.

Among the alternative methods, lane miles and an emission factor use the most locally specific surrogate activity factor and consequently has the higher activity composite score for the alternative methods.

6.1.2 SOURCES OF UNCERTAINTY

The uncertainty of the emission estimates developed through the preferred method can be quantified (see QA Procedures, Volume VI, Chapter 4). However, the statistics needed to quantify the uncertainty of the alternative methods are incomplete. Activity for the alternative methods is based on the use of surrogates: highway maintenance spending and population for the first alternative method, lane miles for the second alternative method, and population for the third alternative method. Actual paint use is expected to vary in relation to these surrogates, but is not defined.

The emission factors that are used in the alternative methods are also expected to vary by region. Factors that cause regional variation are climate, traffic density, and driving patterns all of which result in variations in wear, maintenance schedules, rules affecting the materials used for traffic markings, and lack of information about unused paints or the use of cleanup solvent use. Identifying the types of paints or other marking materials used in the inventory region so that a more specific factor can be developed will reduce variability, as will the development of locally specific activity factors.

TABLE 14.6-1

**PREFERRED METHOD DARS SCORES: SURVEY OF STATE AND COUNTY HIGHWAY
DEPARTMENTS COATING USE IN THE INVENTORY REGION**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5 - 0.6 ^a	0.8 - 1.0	0.40 - 0.60
Source Specificity	0.9 - 1.0	0.9 - 1.0	0.81 - 1.0
Spatial	1.0	0.9 - 1.0	0.90 - 1.0
Temporal	0.9	0.9	0.81
Composite Scores	0.83 - 0.88	0.88 - 0.98	0.73 - 0.85

^a Score assumes emissions are calculated using mass balance calculation of VOC content. If a VOC emission factor used or speciated to get HAPs, the score should be lowered.

TABLE 14.6-2

**ALTERNATIVE METHOD 1 DARS SCORES: ACTIVITY APPORTIONED FROM THE
INVENTORY YEAR NATIONAL LEVEL APPLIED TO NPCA 1991 EMISSION FACTORS**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5 ^a	0.6	0.30
Source Specificity	0.8	0.5 - 0.7	0.40 - 0.56
Spatial	0.5 - 0.7	0.8	0.40 - 0.56
Temporal	0.7	0.9	0.63
Composite Scores	0.60 - 0.65	0.70 - 0.75	0.43 - 0.51

^a Score assumes total VOC factor is used; if this is speciated to get HAPs, score should be lowered.

TABLE 14.6-3**ALTERNATIVE METHOD 2 DARS SCORES: LANE MILES APPLIED TO
1988 CTC EMISSION FACTORS**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5 ^a	0.6	0.30
Source Specificity	0.6	0.6	0.36
Spatial	0.5-0.7	0.9	0.45-0.63
Temporal	0.5	0.9	0.45
Composite Scores	0.52	0.75	0.39-0.44

^a Score assumes total VOC factor is used; if this is speciated to get HAPs, score should be lowered.

TABLE 14.6-4**ALTERNATIVE METHOD 3 DARS SCORES: ACTIVITY APPORTIONED BY POPULATION
AND APPLIED TO NPCA 1991 EMISSION FACTORS**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5 ^a	0.6	0.30
Source Specificity	0.8	0.3	0.24
Spatial	0.5	0.3	0.15
Temporal	0.7	0.9	0.63
Composite Scores	0.6	0.53	0.33

^a Score assumes total VOC factor is used; if this is speciated to get HAPs, score should be lowered.

7

DATA CODING PROCEDURES

This section describes the codes available to characterize traffic marking emission estimates. Consistent categorization and coding will result in greater uniformity between inventories. Inventory planning for data collection calculations and inventory presentation should take the data formats presented in this section into account. Available codes and process definitions may impose constraints or requirements on the preparation of emission estimates for this category.

7.1 PROCESS AND CONTROL CODES

The source category process codes for traffic marking operations are shown in Table 14.7-1. These codes are derived from the EPA's Aerometric Information Retrieval System (AIRS) Area and Mobile Source (AMS) source category codes (EPA, 1994). The control codes for use with AMS are shown in Table 14.7-2. The "099" control code can be used for miscellaneous control devices that do not have a unique identification code. The "999" code can be used for a combination of control devices where only the overall control efficiency is known.

Typically, the source category code for "total: all solvent types, traffic markings" will be used. Low-solvent or water-based coatings will be the control method, so either control device code 101 or 103 will be used.

TABLE 14.7-1

AIRS AMS CODES FOR TRAFFIC MARKINGS

Process Description	AMS Code
Total: All Solvent Types	24-01-008-000
Acetone	24-01-008-030
Butyl Acetate	24-01-008-055
Butyl Alcohols: All Types	24-01-008-060
n-Butyl Alcohol	24-01-008-065
Isobutyl Alcohol	24-01-008-070
Diethylene Glycol Monobutyl Ether	24-01-008-125
Diethylene Glycol Monoethyl Ether	24-01-008-130
Diethylene Glycol Monomethyl Ether	24-01-008-135
Ethyl Acetate	24-01-008-170
Ethylene Glycol Monoethyl Ether (2-Ethoxyethanol)	24-01-008-200
Ethylene Glycol Monomethyl Ether (2-Methoxyethanol)	24-01-008-210
Ethylene Glycol Monobutyl Ether (2-Butoxyethanol)	24-01-008-215
Glycol Ether: All Types	24-01-008-235
Isopropanol	24-01-008-250
Methyl Ethyl Ketone	24-01-008-275
Methyl Isobutyl Ketone	24-01-008-285
Special Naphthas	24-01-008-370
Solvent — General	24-01-008-999
Xylenes	N/A ^a

^a N/A = No AMS source code assigned.

TABLE 14.7-2

AIRS CONTROL DEVICE CODES

Control Device	Code
Process Modification — Low-Solvent Coatings	101
Process Modification — Powder Coatings	102
Process Modification — Water-Borne Coatings	103
Miscellaneous Control Device	099
Combination Control Efficiency	999

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VOLUME III: CHAPTER 15

LANDFILLS

Revised Final

January 2001



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Eastern Research Group, Inc.

Prepared for:
Area Sources Committee
Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

ACKNOWLEDGEMENT

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1

INTRODUCTION

This chapter is one of a series of documents developed to provide cost-effective, reliable and consistent approaches to estimating emissions for area source inventories. Multiple methods are provided in the chapters to accommodate needs of state agencies with different levels of available resources and skills; and different levels of needs for accuracy and reliability of their estimates. More information about the EIIP program can be found in Volume 1 of the EIIP series, *Introduction and Use of EIIP Guidance for Emissions Inventory Development*.

Throughout this chapter and other EIIP area source methods chapters, we stress that area source categories should be prioritized by the inventory planners so that resources can be spent on the source categories that are the largest emitters, most likely to be subject to regulations or are already subject to regulations, or require special effort because of some policy reason. Prioritization is particularly important for area source inventories, because in some cases, a difficult to characterize source category may contribute very little to overall emissions and attempting a high quality estimate for that source category may not be cost effective.

EIIP chapters are written for the state and local air pollution agencies, with their input and review. EIIP is a response to EPA's understanding that state and local agency personnel have more knowledge about their inventory area's activities, processes, emissions, and availability of information; and require flexible inventory methods to best use their sometimes limited resources. These EIIP area source chapters are written as a set of options presented to inventory professionals capable of using their own experience and judgement to apply the method that best fits their overall needs and constraints.

Landfills are significant sources of methane (CH₄) and carbon dioxide (CO₂). In addition to CH₄ and CO₂, small amounts of nonmethane organic compounds (NMOCs) are produced. NMOCs include reactive volatile organic compounds (VOCs) and hazardous air pollutants (HAPs). Unlike other area sources that may be small sources individually but numerous within the inventory area, only a few landfills may be found within a multi-county area. However, each landfill may emit significant amounts of pollutants. Landfills differ from sources typically categorized as point or major sources in that pollutants are emitted over the area of the landfill, not at a specific point or points. For these reasons, landfills have been treated as area sources in the past. Recently, air operating permits have been required for landfills, so that inventory preparers have begun to address them as point sources. The preferred method described in this chapter is very close to a point source inventory method, and, if site-specific test data are available, those data may be used to develop emissions estimates.

This chapter is one of a series of documents developed to provide cost-effective, reliable and consistent approaches to estimating emissions for area source inventories. Multiple methods are provided in the chapters to accommodate needs of state agencies with different levels of available resources and skills; and different levels of needs for accuracy and reliability of their estimates. More information about the EIIP program can be found in Volume 1 of the EIIP series, *Introduction and Use of EIIP Guidance for Emissions Inventory Development*.

This chapter describes the procedures and recommended approaches for estimating emissions from landfills. Section 2 of this chapter contains a general description of the landfills category, and an overview of available control techniques. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation method for landfills, and Section 5 presents alternative emission estimation techniques. Quality assurance/quality control (QA/QC) are discussed in Section 6. Data coding procedures are discussed in Section 7, and Section 8 is the reference section.

Throughout this chapter and other EIIP area source methods chapters, we stress that area source categories should be prioritized by the inventory planners so that resources can be spent on the source categories that are the largest emitters, most likely to be subject to regulations or are already subject to regulations, or require special effort because of some policy reason. Prioritization is particularly important for area source inventories, because in some cases, a difficult to characterize source category may contribute very little to overall emissions and attempting a high quality estimate for that source category may not be cost effective.

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2

SOURCE CATEGORY DESCRIPTION

The following description of landfills and discussion of landfill emission sources have been drawn from the *AP-42* section on landfills and the U.S. Environmental Protection Agency's (EPA's) Office of Policy Planning and Evaluation's (OPPE) report on anthropogenic methane emissions for 1990 (EPA, 1998a; EPA, 1994a).

A municipal solid waste (MSW) landfill unit is a discrete area of land or an excavation that receives household waste and that is not a land application unit, surface impoundment, injection well, or waste pile. An MSW landfill unit may also receive other types of wastes, such as commercial solid waste, nonhazardous sludge, and industrial solid waste (EPA, 1998a). Landfills that accept hazardous waste should be classified as treatment, storage, and disposal facilities (TSDFs). Open dumps should not be categorized as landfills, because the waste types are variable and are not necessarily MSW. Also, the waste is not compacted and covered as waste is in a sanitary landfill, so the anaerobic decomposition process that is the source of the landfill gas may not take place. The emission estimation methods presented in this chapter are not suitable for TSDFs or open dumps.

2.1 EMISSION SOURCES

Methane and CO₂ are the primary constituents of landfill gas, and are produced during anaerobic decomposition of cellulose and proteins in the landfilled waste. Anaerobic decomposition takes place in the absence of oxygen. Although particulate emissions are generated by landfill operations, only landfill gas emissions are addressed in this chapter. In addition to CH₄ and CO₂, NMOCs are produced as a small fraction of the landfill gas emissions. NMOCs include hazardous air pollutants and reactive VOCs. The decomposition is a complex process and requires certain environmental conditions. Environmental factors that affect the decomposition include moisture content of the waste, nutrient concentration, the presence and distribution of microorganisms, the particle size of the waste, water flux, pH, and temperature. Because of the complex set of conditions that must occur before landfill gas is generated, waste may be in place for a year or more before anaerobic decomposition begins and landfill gas is generated. Refuse in a landfill may produce landfill gas for 20 to 30 years. Uncontrolled dumps, where waste is exposed to air, result in aerobic decomposition (EPA, 1994a). Aerobic decomposition results mainly in CO₂ and water.

2.2 FACTORS INFLUENCING EMISSIONS

2.2.1 PROCESS OPERATING FACTORS

The number of landfills in the United States is declining, yet the amount of waste generated is increasing. Surveys of U.S. landfills have shown a steady decline in the estimated number of landfills taking MSW with 6,034 landfills in 1986, 3,558 landfills in 1994 and 2,216 in 1999 (EPA, 1988; Steuteville, 2000). In 1986, the average landfill capacity, based on survey data, was 2.65 million cubic yards, but the median landfill capacity of the same survey data set was 0.39 million cubic yards, showing that it is the less numerous larger landfills that handle most of the waste. A decreasing proportion of the total waste is being sent to U.S. landfills as well. In 1989, an estimated 80 percent of MSW was landfilled, and in 1994, 67 percent was sent to landfills, with recycling and incineration being the alternative form of treatment as reported in the April 1995 issue of *BioCycle* (Steuteville, 1995).

Because of stricter regulations affecting landfills, many of the smaller landfills have closed, and the larger, more technologically advanced landfills remain. Nearly one-third of MSW landfills were estimated to be privately owned in 1996, and the remainder were owned by federal, state, county, or other government entities. In the same year, an estimated 91 percent of the MSW landfills have permits, usually from the state (EPA, 1988).

Description (EPA, 1998a)

Landfill design and operation normally uses one or a combination of three fill methods. These are the area, trench, and ramp methods, all of which use a three-step process consisting of spreading the waste, compacting the waste, and covering the waste with soil. The trench and ramp methods are not commonly used, and are not the preferred methods when liners and leachate collection systems are used.

The area fill method entails placing waste on the ground surface or landfill liner, spreading it in a layer, and compacting it with heavy equipment. Successive layers are added until a depth of 3 to 4 meters (m) [10 to 12 feet (ft)] is reached. A daily soil cover is spread on the top and sides of the compacted waste. The soil cover can come from other parts of the landfill or be imported from outside the landfill. The trench method entails excavating daily trenches designed to receive a day's worth of waste. Successive parallel trenches are excavated and filled, with the soil from the excavation being used for cover material and wind breaks. The ramp method is typically employed on sloping land, where waste is spread and compacted in a manner similar to the area method; however, the cover material is generally obtained from the front of the working face of the filling operation.

The basic landfill unit is common to all landfilling methods, and is usually designed to accept a day's waste, after which it is closed, compacted, and covered with soil at the day's end. Generally, the height of a landfill unit is less than 2.4 m (8 ft), and the working face of the unit can extend to the facility boundaries. Waste densities generally range from 1,100 to 1,400 pounds per cubic yard after the waste has been compacted, and range from 1,700 to 1,900 pounds per cubic yard after waste degradation and settling. If site-specific data are not available, a density of 1,160 pounds per cubic yard is recommended.

Modern landfill design often incorporates liners constructed of soil such as recompacted clay, synthetics such as high-density polyethylene, or both to provide an impermeable barrier to leachate (water that has passed through the landfill) and gas migration from the landfill. Soil liners can reduce permeability to between 7 to 10 centimeters (cm) per second, and synthetic liners to between 10 to 13 cm per second.

Bioreactors within landfills are an emerging technology. Anaerobic bioreactors increase the rate of methane generation, which can then be collected and used for energy recovery, whereas aerobic bioreactors foster aerobic instead of anaerobic decomposition, reducing methane generation. These are not widely used to present. The emission estimation procedures recommended in this chapter do not reflect landfills that are being operated as a bioreactor under enhanced conditions where leachate is added.

Control Techniques

Landfill emissions are collected through either active or passive collection systems. Disposal or treatment of the collected gases can be accomplished by the combustion or purification of the landfill gas. Landfill gas collection and treatment methods and efficiencies are discussed in more detail in Section 3 of this chapter.

2.2.2 REGULATORY ISSUES

Air quality standards and regulations that affect municipal solid waste landfill facility operations are New Source Performance Standards (NSPS), and Emissions Guidelines. The Standards of Performance for New Municipal Solid Waste Landfills, 40 Code of Federal Regulations (CFR) part 60, Subpart WWW are federal regulations affecting air emissions for new landfills or landfills that began construction, modification, or reconstruction on or after May 30, 1991. The Emission Guidelines required States to develop State plans to regulate existing landfills that began construction before May 30, 1991 and that have accepted waste since November 8, 1987, or have capacity to accept additional waste.

The Emission Guidelines are contained in 40 CFR part 60 Subpart Cc. As of December 1999, existing landfills throughout the U.S. were covered by either approved State plans that

implement and enforce the Emission Guidelines, or by the Federal plan in 40 CFR part 62, Subpart GGG (see 40 CFR part 62 for a list of approved State plans).

In late 2000, EPA expects to propose national emission standards for hazardous air pollutants from landfills. The proposed rule contains the same requirements as the Emission Guidelines and NSPS. The collection and control requirements of the Emission Guidelines and NSPS are the best control technology available for hazardous air pollutant emissions from landfills. Under the proposed rule, in addition to the requirements in the Emission Guidelines and NSPS, landfills that have installed controls would be subject to additional recordkeeping and reporting requirements, such as documentation of startup, shutdown, and malfunction reports.

The NSPS and the State and Federal plans that implement the Emission Guidelines require owners or operators of new and existing landfills to file a design capacity report. Landfills equal to or larger than 2.5 million megagrams (Mg) and 2.5 million cubic meters (m³) must provide periodic estimates of annual NMOCs, either through calculation using standard assumed values or based on on-site measurements (Table 15.2-1). One exception to the annual reporting requirement is that if the landfill has an estimated NMOC emission rate of less than 50 Mg/yr for the next five years, the owner or operator may elect to submit an estimate of the NMOC emission rate for the next five years rather than an annual report.

New and existing landfills that have estimated annual emissions of NMOCs greater than the 50 Mg threshold must reduce emissions under either the NSPS (for new landfills) or the applicable State and Federal Plan for existing landfills. The EPA's final rule provides a tier system under which the landfill owner or operator can determine if controls are required. The tier system allows owners and operators to conduct testing for more site-specific values to prove that emissions are below the 50 Mg/yr emission threshold. If landfill emissions exceed 50 Mg/yr, emissions must be reduced by installing gas collection systems and routing the gas to a suitable energy recovery system or combustion device that is capable of reducing NMOC emissions by 98 weight-percent or to 20 parts per million by volume dry (ppmvd) as hexane. The collection system must be operated so that the methane concentration is less than 500 parts per million (ppm) above background at the surface of the landfill (EPA, 1999). Monitoring of surface concentration and other collection system and control device operating parameters is also required.

TABLE 15.2-1

APPLICABILITY OF THE NSPS AND EG TO MSW LANDFILLS (EPA, 1999)

Landfill Maximum Design Capacity	Constructed, Reconstructed, Modified, or Began Accepting MSW on or after 5/30/91	Constructed, Reconstructed, or Modified before 5/30/91. Accepted Waste after 11/8/87 or Has Additional Capacity
<2.5 million Mg or 2.5 million m ³	Must report design capacity. No further requirements.	Must report design capacity. No further requirements.
≥ 2.5 million Mg and 2.5 million m ³	Must comply with the requirements of the NSPS.	Must comply with the requirements of the EG.

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3

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATION METHODOLOGIES

The recommended method for calculating emission estimates from landfills is to use the equation in the section addressing landfills in *AP-42* (EPA, 1998a). The Landfill Gas Emissions Model (LandGEM) uses the *AP-42* equation and eases the calculation burden for estimating emissions for individual landfills (EPA, 1998b). However, several methods are available for collecting the data needed to use the emission estimation calculation for landfills. Determining the best method to use depends upon the degree of accuracy required in the estimate, the available data, and the available inventory resources. Refer to EIIP Volume VI, *Quality Assurance Procedures*, Sections 2.1 and 2.4.

Selection of the appropriate estimation method depends on the relative significance of emissions from this source in the inventory area and the data quality objectives (DQOs) of the inventory plan. Refer to EIIP Volume VI, *Quality Assurance Procedures*, Sections 2.1 and 2.4 for discussions of inventory categories and DQOs.

This section discusses the methods available for collecting landfill data and identifies the preferred data collection method. A discussion of the data elements needed for each method is provided. The preferred and first two alternative methods also take into account control technologies.

3.2 AVAILABLE METHODOLOGIES

The methods are as follows:

- Preferred Method: Required reporting;
- Alternative Method One: Guidelines for using assumptions with landfill data;
- Alternative Method Two: Regression model; and
- Alternative Method Three: Population-based waste generation factor.

Before choosing any of these methods, inventory preparers should investigate how many landfills are in the inventory area. Some counties send all of their waste to landfills in other counties or even other states. If there are no landfills that have accepted waste in the past 25 years in a county, then it may not be necessary to estimate emissions from this source category for that county. Before investing resources in collecting detailed information about landfills that closed before 1987, setting a cutoff level for landfill size and age could be worthwhile. Because of RCRA rules and the Emission Guidelines, States should have lists of landfills that accepted waste since 1987.

Preferred Method

Emission estimates for all landfill emission methods are calculated using either the LandGEM or the equations from the *AP-42* section on landfills. The *AP-42* landfills section was updated in November 1998. Check the EPA Technology Transfer Network (TTN) Web for the most current version of the *AP-42* section when preparing landfill emission estimates for an inventory. The EPA updates *AP-42* as new information becomes available. The LandGEM is a personal computer-based model that uses the same equation as that in *AP-42*, but provides the advantages of an automated calculation and utilities. Appendix A of this chapter contains an overview of the LandGEM, with example model runs for the program. The LandGEM and the landfill section of *AP-42* can be accessed from the EPA's Web site.¹ Please refer to Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development*, for more information about accessing the TTN Web site.

Total landfill gas, methane, carbon dioxide, and NMOC concentration can be calculated using the equations in *AP-42* and LandGEM. The *AP-42* section and the LandGEM use three equations to calculate (1) methane generation rate; (2) NMOCs or other pollutants expressed as cubic meters per year, and (3) convert the volume estimate of each pollutant to a mass estimate (kilograms per year). Reactive VOCs and air toxics can be calculated using default concentration values that are also provided. Reductions in emissions resulting from the use of controls can be calculated from control efficiency factors listed in the *AP-42* section. The emissions calculations for landfill gas require several steps and a combination of site-specific information and default values. The following site-specific information is required:

- The design capacity of the landfill;
- The years the landfill has been in operation;
- Controls in place in the landfill (if available); and

¹ For Internet access to the EPA TTN Web, use <http://www.epa.gov/ttn>.

- Whether the landfill has been used for disposal of hazardous waste (codisposal)

In addition, the following default values are available in LandGEM and AP-42:

- The methane generation rate (k);
- The potential methane generation capacity (L_0);
- The concentration of NMOCs found in the landfill gas;
- The concentration of toxic air pollutants found in the landfill gas (if air toxic pollutants are to be calculated); and
- The concentration of reactive VOCs found in the landfill gas.

The AP-42 section and the LandGEM provide default factors for the parameters k , L_0 , and NMOC concentration that are needed to calculate total landfill gas, methane, carbon dioxide, and NMOC concentration. In all cases, landfill-specific values are preferred over the use of default values.

The LandGEM provides two sets of default values for k , L_0 , and NMOCs. One set is based on the requirements of the NSPS and Emission Guidelines. This set of default values produces conservative emission estimates and should be used to determine whether the landfill is subject to the control requirements of the NSPS and Emission Guidelines. The other set of default values is the same as those in AP-42 and produces more representative emission values that can be used to produce typical emission estimates in the absence of site-specific test data. The default values presently in the model may be revised in future updates of the model based on new information collected by the EPA. Unlike the AP-42 equation, the LandGEM allows the user to enter annual waste acceptance amounts into the emission model. Reductions from controls are not included in the LandGEM. The model also provides utilities for estimating values for k and landfill waste in place. Calculations are performed automatically after the necessary information has been collected and entered (EPA, 1998b).

Alternative Method One: Guidelines for Using Assumptions with Landfill Data

The first alternative method is a set of guidelines for making the best possible estimates of the values needed to calculate emissions from landfills when actual values are not directly available. Possible sources of information are given in the discussion of the method. This method supplements the approach of the preferred method, in case detailed information for every landfill in an inventory area cannot be located or budget constraints limit the level of effort for the source category.

Alternative Method Two: Regression Model

The second alternative method uses a regression model to develop waste-in-place factors for landfills in a large inventory area or modeling domain from a subset of area landfills. This method requires a survey of a subset of landfills in the inventory area. The survey covers all of the landfills in counties that can be deemed typical for the larger area. The information collected should include waste-in-place and age of the landfill, or reliable local estimates of those factors. A factor is developed that can be used to estimate the waste in place and landfill age for the remaining counties using a surrogate for activity such as population or population density.

This method should provide more specific emission estimates than Alternative Method One in most cases but, unlike Alternative Method One, still requires a considerable amount of data collection. This method can be used when the inventory area is large (greater than 10 counties), time and budget constraints are such that collection of specific data for the preferred method is not practical, yet there is still a need for region-specific information. This method is not suitable for smaller areas, where the sample size may not be adequate for good results.

The agency should have the resources to collect complete information from several counties in the inventory area or region. Personnel should be available that can interpret the statistics to judge the validity of the regression model results and set a statistically valid sample size for the survey. Although survey planning and interpretation of results require statistical training, data collection and preparation for the model require only inventory and spreadsheet skills. Most spreadsheet packages provide regression analysis tools. Regression analysis provides a mathematical model that relates two or more sets of variables to one another. In this case, the surrogate factor(s), such as population density, property values, or education level, for the survey counties are related to the amount of waste in place in landfills in those counties.

Alternative Method Three: Population-based Waste Generation Factor

This method uses a population-based waste generation factor and population by county to estimate the waste-in-place value that is used in the *AP-42* equation. The advantage of this method is that it requires no specialized information and can be completed with very little effort. Disadvantages are that solid waste disposal methods other than landfills, waste reduction programs, or transport of the waste to other areas will not be taken into account. Controls in place in individual landfills also will not be taken into account.

3.3 DATA NEEDS

3.3.1 DATA ELEMENTS

The data elements used to calculate emission estimates for landfills will depend on the methodology used for the estimation and the level of detail required in the inventory. For all methods, the minimum information for using the *AP-42* equation or LandGEM is waste in place and the open and close dates for the landfills in the area. The alternative methods can use assumptions about the opening and closure dates. Knowledge of state and local regulations and average annual rainfall also are needed.

The data elements required for the preferred method are listed in Section 3.2 under the discussion of the *AP-42* landfill section and the LandGEM.

The first alternative method can use the same data elements as those listed for the preferred method, but does not require the same detailed information. When the detailed information is not available, other information is collected to substitute. Acreage of the landfills and local practices for landfill depth can be substituted for waste-in-place. Assumptions are used for open and close dates, when actual dates are not available.

The data elements needed to calculate emissions for this category when using Alternative Method Two, the regression model, are:

- The estimated number of landfills in the entire inventory area;
- Information about each landfill in the selected survey counties (see the data elements needed for the preferred and the first alternative method); and
- Surrogate activity information for all of the inventory counties.

3.3.2 APPLICATION OF CONTROLS

Larger and newer landfills are very likely to have landfill gas collection systems in place to control air emissions. The discussion of landfill gas collection systems in the *AP-42* landfill section should be consulted for information about landfill gas controls. In that section, average control efficiencies for landfill gas constituents and emission rates for secondary compounds are given for typical landfill gas control devices.

Emissions from landfills are typically controlled by installing a gas collection system and destroying the collected gas through the use of internal combustion engines, flares, or turbines.

Gas collection systems are not 100 percent efficient in collecting landfill gas, so emissions of CH₄ and NMOCs at a landfill with a gas recovery system still occur. To estimate controlled emissions of CH₄, NMOCs, and other constituents in landfill gas, the collection efficiency of the system must first be estimated. Reported collection efficiencies typically range from 60 to 85 percent, with an assumed average of 75 percent. If site-specific collection efficiencies are available, they should be used instead of the 75 percent average.

Controlled emission estimates also need to take into account the efficiency of the control device. Control efficiencies for CH₄ and NMOCs with different control devices are presented in the *AP-42* section. Emissions from control devices, also available in *AP-42*, need to be added to the uncollected emissions to estimate total controlled emissions. Equation 15.3-2 shows how to estimate total controlled emissions of pollutant P from a specific landfill:

$$\text{Controlled Landfill Emissions} = P \left(1 - \frac{\text{Percent Collection Efficiency}}{100} \right) + P \left(\frac{\text{Percent Collection Efficiency}}{100} \right) * \left(1 - \frac{\text{Percent Control Efficiency}}{100} \right) \quad (15.3-2)$$

Example 3-1 shows how emissions for a landfill with controls are calculated.

Example 3-1:

VOC emissions from Landfill A are estimated to be 3,197 cubic meters per year. Average collection efficiency of the landfill gas recovery system is not known at Landfill A, so a 75-percent collection efficiency rate is assumed. The collected landfill gas is controlled by a flare, which has a control efficiency for NMOCs of 83.16 percent.

$$\begin{aligned} \text{Controlled NMOC Emissions} &= 3,197 \text{ m}^3 * [1 - 0.75] + 3,197 \text{ m}^3 * [0.75] * [1 - 0.8316] \\ &= 799.25 \text{ m}^3 + 3,197 \text{ m}^3 * 0.1263 \\ &= 799.25 \text{ m}^3 + 403.78 \text{ m}^3 \\ &= 1,203 \text{ m}^3 \end{aligned}$$

When emissions have been calculated using the alternative methods, less specific information will be available about controls. However, if information is available, it should be used.

Emission factors and procedures for estimating secondary compounds (CO₂, CO, NO_x, SO₂, and HCl) from landfill gas combustion control devices are also included in *AP-42*.

Point Source Corrections

Some landfills in the inventory area may be counted as point sources in the point source inventory. Area source estimates for landfills should be corrected for these emissions. There are two ways to correct for the point source contribution depending on the area source estimation method used.

The first approach is to remove the point source landfills from the area source emission calculations. This approach can be used if emissions are being calculated from specific information, as in the preferred and first alternative methods. If the second or third alternative methods are used, estimated emissions from the point source landfills can be subtracted from the inventory area total estimate.

3.3.3 SPATIAL ALLOCATION

Spatial allocation may be needed during inventory preparation to allocate the emission estimates calculated using Alternative Methods Two or Three to smaller areas, such as modeling grid cells, or to allocate the surrogate activity factor(s) used in Alternative Method Three to a smaller area. The preferred method and the first alternative method do not require any spatial allocation because these methods collect data for individual landfills, and emissions are assigned according to the landfills' locations.

3.3.4 TEMPORAL RESOLUTION

Seasonal Apportioning/Daily Resolution

Emissions from this source category are expected to remain constant from season to season, and they are not expected to vary on a day-to-day basis. The seasonal activity factor that should be used for this source category is 1.0.

3.3.5 PROJECTING EMISSIONS

Unlike typical sources, landfill emissions increase each year as more waste is added to the landfill. Landfill emissions peak shortly after the landfill closes, then gradually decrease over time. For projecting future emissions, projected variables such as time since initial waste

placement, amount of waste in place, and average waste acceptance rate for the particular year of interest should be used, rather than using the current values.

Emissions projections for landfill emissions need to take into account changes in emissions due to any increase or decrease in waste generation, the age of the waste in place, and any potential changes in landfill controls. Factors that may affect the amount of waste in place in landfills in the inventory area are changes in waste generation or how the waste is handled: incineration, recycling, or transport in or out of the inventory area. Emissions may change because of added controls. The preferred approach to defining these changes is to collect information from planning departments and solid waste departments about projected changes in the amount of waste in place for the projection year, the status of landfill openings or closures, and future controls.

An alternative method is to use population to scale current emission estimates to the projection year, but the effects of factors like recycling programs or additional controls at landfills will not be included.

The EIIP Projections Committee has developed a series of guidance documents containing information on options for forecasting future emissions. You can refer to these documents at <http://www.epa.gov/ttn/chief/eiip/project.htm>. Tools for the development and use of growth factors are discussed in Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development*.

4

PREFERRED METHOD FOR ESTIMATING EMISSIONS

The preferred method for this source category uses information that has been compiled as part of a permit or reporting requirement such as for NSPS or RCRA. State and local solid waste management agencies and the federal EPA Office of Solid Waste can be contacted for RCRA information. State and local air agencies or EPA Regional Offices will also have information from air permits, the NSPS, or the State or Federal plan implementing the Emission Guidelines. In fact, as part of their State plans, states were required to develop inventories and emission estimates for existing landfills that commenced construction before May 30, 1991 and accepted waste since November 8, 1987. In many cases, the information will already be compiled into a spreadsheet or database. The equations in Section 2.4, Landfills, of *AP-42* or the LandGEM are used to calculate emissions.

The Standards of Performance for New Municipal Solid Waste Landfills (NSPS), 40 CFR 60, Subpart WWW, and the Emission Guidelines for Control of Existing Municipal Solid Waste Landfills (EG), 40 CFR 60, Subpart Cc, are briefly summarized in Section 2.2.2 of this chapter. The significance of these rules for inventory preparers is that owners or operators of any new or existing MSW landfill (as defined by the NSPS and the EG) need to report design capacity, and if the landfill has a design capacity at or above 2.5 million Mg and 2.5 million m³, then periodic estimates of NMOC emissions must be reported. New and existing landfills that have estimated annual emissions of NMOCs greater than the 50 Mg limit must either reduce emissions through collection and control, or must conduct testing to prove that emissions are below the emission threshold. Landfill operators may use sampling and gas flow testing to determine more specific values for NMOC concentration and k when estimating emissions (EPA, 1995).

4.1 DATA COLLECTION

Permits can be used to collect the information needed to calculate landfill emissions. The information needed is discussed in Section 3.2, but at a minimum, landfill opening and closure year and the current amount of waste-in-place is necessary for the calculation.

Additional information that can be used, if it is available, is the amount of waste brought in annually, landfill-specific information for calculating k and L₀, and measured concentration

values for CH₄, CO₂, NMOCs, and other pollutants in the landfill gas. If the amount of waste is reported as a volume measurement, the following conversion factors can be used (EPA, 1995):

- 1,100 to 1,400 pounds per cubic yard of compacted waste;
- 1,700 to 1,900 pounds per cubic yard of waste after degradation and settling; and
- 1,160 pounds per cubic yard of waste (if unknown if waste was compacted).

In some cases, emission estimates from permits can be used, but only if those estimates have been calculated using landfill-specific data for *k* or the AP-42 defaults. If emissions have been calculated using the more conservative *k* and *L*₀ values required under the NSPS and Emission Guidelines, then emission estimates should be recalculated using AP-42 default values for *k* and *L*₀. The AP-42 default for *L*₀ should be used.

4.2 LANDFILL GAS EMISSION CALCULATION (EPA, 1995)

The emission estimation equation used to calculate landfill gas emissions is a theoretical first-order kinetic model of methane production developed by the EPA (EPA, 1991). This is the equation used in AP-42 and in the LandGEM. The equation is as follows:

$$Q_{CH_4} = L_0 R (e^{-kc} - e^{-kt}) \quad (15.4-1)$$

where:

- Q_{CH_4} = Methane generation rate at time *t*, m³/yr;
- L_0 = Methane generation potential, m³ CH₄/Mg refuse;
- R = Average annual refuse acceptance rate during active life, Mg/yr;
- e = Base log, unitless;
- k = Methane generation rate constant, yr⁻¹;
- c = Time since landfill closure, years (*c* = 0 for active landfills); and
- t = Time since the initial refuse placement, years.

The average annual refuse acceptance rate (*R*) is calculated by dividing the current amount of fill by the number of years that the landfill has been accepting waste. If the landfill has a measured

value for k , then that value should be used; otherwise, the value recommended in *AP-42* should be used. Estimation of the methane generation constant, k , is a function of a variety of factors, including moisture, pH, and temperature, other environmental factors, and landfill operating conditions. Specific CH_4 generation constants (k) can be computed by use of the EPA Method 2E. L_0 is generally treated as a function of the moisture and organic content of the refuse, and the *AP-42* default value should be used.

If the computer model LandGEM is used, the measured values of k , L_0 , and NMOC concentration are preferred. Site-specific NMOC concentration can be measured using EPA Method 25C and the sampling procedures described in the NSPS. Otherwise, use the recommended values from *AP-42* for k , L_0 , and NMOC concentration. Note that *AP-42* provides separate default k values for arid areas (less than 25 inches of rain per year) and non-acid areas.

4.3 VOC AND HAZARDOUS AIR POLLUTANT EMISSION CALCULATION

When gas generation reaches steady state conditions, landfill gas consists of approximately 40 percent by volume CO_2 , 55 percent CH_4 , 5 percent N_2 and trace amounts of NMOCs when gas generation reaches steady state conditions. Therefore, the estimate derived for CH_4 generation using the method above can also be used to represent CO_2 generation. Addition of the CH_4 and CO_2 emissions will yield an estimate of total landfill gas emissions. If site-specific information is available to suggest that the CH_4 content of landfill gas is not 55 percent, then the site-specific information should be used, and the CO_2 emission estimate should be adjusted accordingly. LandGEM uses 50% of CH_4 and 50% CO_2 as the default landfill gas composition, however, these defaults can be overridden.

Emissions of pollutants other than CO_2 and CH_4 from landfills result from either their being contained in the landfilled waste or from their creation from biological processes and chemical reactions within the landfill cell. There is a wide range of values for various VOC species and air toxics in landfill emissions. For inventory purposes, it is preferable that site-specific information about landfill gas constituents be used to calculate VOC and air toxic emissions.

The emissions of reactive VOCs and toxic air pollutants must be calculated individually from the estimated emissions of total landfill gas. When using the LandGEM, enter any site-specific concentrations available for that landfill and run the model. Emissions for individual VOCs from the model results can be summed to get total VOC emissions. If the *AP-42* equations are used, use the most recent list of landfill gas constituents from *AP-42* and calculate emission estimates for each of those constituents that are defined as reactive VOCs using the equations in the *AP-42* landfill section. The *AP-42* section for landfills has default concentrations for 43 landfill gas constituents, of which 30 are currently defined as reactive VOCs and 24 are listed as hazardous air pollutants (HAPs). These landfill gas constituents are listed in Table 15.4-1.

AP-42 also contains equations and procedures for calculating controlled emissions of CH₄, NMOC, and speciated organics. It also contains procedures for calculating secondary emissions from landfills gas combustor devices (NO_x, CO, CO₂, SO₂, HCl).

TABLE 15.4-1

UNCONTROLLED LANDFILL GAS CONSTITUENTS

Compound	VOC ^a	Hazardous Air Pollutant ^b (HAP)
1,1,1-Trichloroethane (methyl chloroform)	N	Y
1,1,2,2-Tetrachloroethane	Y	Y
1,1-Dichloroethane (ethylidene dichloride)	Y	Y
1,1-Dichloroethane (vinylidene chloride)	Y	Y
1,2-Dichloroethane (ethylene dichloride)	N	Y
1,2-Dichloropropane (propylene dichloride)	Y	Y
2-Propanol (isopropyl alcohol)	Y	N
Acetone	N	N
Acrylonitrile	Y	Y
Bromodichloromethane	Y	N
Butane	Y	Y
Carbon disulfide	Y	Y
Carbon monoxide ^c	N	N
Carbon tetrachloride	Y	Y
Carbonyl sulfide	Y	Y
Chlorobenzene	Y	Y
Chlorodifluoromethane	N	N
Chloroethane (ethyl chloride)	Y	Y
Chloroform	Y	Y
Chloromethane	Y	N

TABLE 15.4-1

(CONTINUED)

Compound	VOC ^a	Hazardous Air Pollutant ^b (HAP)
Dichlorobenzene ^d	Y	Y
Dichlorodifluoromethane	N	N
Dichlorofluoromethane	N	N
Dichloromethane (methylene chloride)	N	Y
Dimethyl sulfide (methyl sulfide)	Y	N
Ethane	N	N
Ethanol	Y	N
Ethyl mercaptan (ethanethiol)	Y	N
Ethylbenzene	Y	Y
Ethylene dibromide	Y	Y
Fluorotrichloromethane	N	N
Hexane	Y	Y
Hydrogen sulfide	N	N
Mercury ^e	N	Y
Methyl ethyl ketone	Y	Y
Methyl isobutyl ketone	Y	Y
Methyl mercaptan	Y	N
Pentane	Y	N
Perchloroethylene (tetrachloroethylene)	N	Y
Propane	Y	N

TABLE 15.4-1

(CONTINUED)

Compound	VOC ^a	Hazardous Air Pollutant ^b (HAP)
Trichloroethylene (trichloroethene)	Y	N
t-1,2-Dichloroethene	Y	N
Vinyl chloride	Y	Y
Xylenes	Y	Y

NOTE: This is not an all-inclusive list of potential LFG constituents, only those for which test data were available at multiple sites (EPA 1995).

^a Reactive VOC.

^b Hazardous Air Pollutants listed in Title III of the 1990 Clean Air Amendments.

^c Carbon monoxide is not a typical constituent of LFG, but does exist in instances involving landfill (underground) combustion. Of 18 sites where CO was measured, only 2 showed detectable levels of CO.

^d Source tests did not indicate whether this compound was the para-or ortho- isomer. The para- isomer is a Title III-listed HAP.

^e No data were available to speciate total Hg into the elemental and organic forms.

5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

The alternative methods to estimate the data used in the landfill equation are as follows:

- Alternative Method One: Guidelines for using assumptions with landfill data;
- Alternative Method Two: Regression model; and
- Alternative Method Three: Population-based waste generation factor.

All of the methods use the *AP-42* landfill emissions equation or LandGEM to calculate emissions. Refer to *AP-42* and Sections 3 and 4 of this chapter for information about using the equation or the model.

5.1 ALTERNATIVE ONE: GUIDELINES FOR USING ASSUMPTIONS WITH LANDFILL DATA

This method is a set of decision-making rules to follow for data collection of landfill waste-in-place and landfill opening and closure dates used in the *AP-42* equation or the LandGEM, and assumptions to use when local data are not available. This method should be used when the agency's budget does not allow the extensive data collection that is needed for the preferred method, or the data for all of the landfills in the inventory area are not available. If the inventory area is made up of many counties (>10), then the second alternative method may be a better approach. Although the first method is very similar to the approach used in the preferred method, a distinction is being made between the two because the use of assumptions and generalizations in the alternative method increases the uncertainty of the emission estimates.

The first step to take for this method is to identify the landfills in the inventory area. Use solid waste agency data (county, state, or EPA Regional Office) or data from air permitting groups, local planning departments, or local or state tax records. Information about closed landfills may be available from long-term employees at state, county, or local health or sanitation departments.

Second, identify landfills in the inventory area that are listed in the point source inventory. These point sources will not need to be addressed in the area source inventory. Use the

preferred method for as many landfills as possible that remain. The landfills that have been addressed at this point will probably be active, the largest, and also most likely to have controls. The final remaining landfills may make only a minor contribution to the source category emissions. Therefore, the agency preparing the inventory should decide if these smaller landfills are significant enough to warrant the effort needed to produce emission estimates from them. The effort expended for these remaining landfills may be minimized if the proportion of emissions is small.

The third step is to collect information about the acreage of the remaining landfills. Land use information from planning boards and information from tax records is best. If the acreage that is filled at the time of the inventory year is available, it will be preferable to total acreage, which may be only partly used.

If information is available about the depth of the individual landfills and landfill opening and closure dates are available, then it should be collected as well. Some states and counties have rules about landfill construction that define appropriate depths. State and county solid waste experts should be able to define a reasonable depth for area landfills. Health and sanitation departments may also have information about older landfills. Employees of long standing in these departments may provide particularly useful information.

Fourth, develop waste-in-place estimates using the following:

- Estimate the capacity for each landfill:

$$\begin{array}{c} \text{Estimated} \\ \text{Capacity} \\ \text{(Volume)} \end{array} = \begin{array}{c} \text{Landfill} \\ \text{Acreage} \end{array} * \begin{array}{c} \text{Estimated} \\ \text{Landfill} \\ \text{Depth} \end{array}$$

The LandGEM's utilities can be used to perform this calculation as well. A utility for estimating refuse in place from landfill dimensions is available in the Windows™ version of the program.

- If calculating volume is not practical from available data, determining weight and converting this to volume can be done using the following from *AP-42*:
 - 1,100 to 1,400 lb/yd³ for compacted waste;
 - 1,700 to 1,900 lb/yd³ for waste that has undergone degradation and settling; or

- Use 1,160 lb/yd³ if it is unknown whether the waste has degraded, or been compacted.

For example:

$$\begin{array}{l} \text{Estimated} \\ \text{Capacity} \\ \text{(Weight)} \end{array} = \begin{array}{l} \text{Estimated} \\ \text{Capacity} \\ \text{(Volume)} \end{array} * 1,160 \text{ lb/yd}^3$$

Another method of estimating the waste-in-place, which is needed for the emissions equation, is by using an estimate of the percentage filled. Alternatively, fill can be estimated by proportioning the estimated capacity by the years that the landfill has accepted or is expected to accept waste.

If opening and closure dates are known, then closed landfills can be assumed to have filled their capacity. Waste in place for landfills that are still accepting waste can be estimated by dividing the capacity by the number of years the landfill is accepting waste (closing year - opening year +1). Multiply the annual acceptance rate by the number of years that the landfill has been open.

If opening and closure dates for the landfills are not available, assume that the landfill is still accepting waste, and opened 25 years before the inventory year. This is a conservative assumption, and will assign most of the emissions to the inventory year. If only the closing date is known, assume that the landfill accepted waste for 10 years. This is also a conservative assumption.

Use the *AP-42* defaults for L_0 and k in the equation. Calculate VOC or HAP emissions using the default concentrations and equations in *AP-42*.

This alternative method should allow inventory preparers the opportunity to prepare fairly reliable estimates for the largest landfills in the inventory area and more uncertain, but conservative estimates for the smaller landfills.

5.2 ALTERNATIVE TWO: REGRESSION MODEL

This method uses information gathered about a sample of the landfills in an inventory area to develop a regression model that can be used to estimate the waste in place for all of the landfills in the inventory region. Regression is used to analyze how a dependant variable is affected by the values of one or more independent variables. The dependant variable in this case is landfill

waste in place, and the independent variables are the surrogate factors that will be used to calculate waste in place estimates for other counties within the inventory area.

This method can be used as an alternative to the more detailed data collection of the preferred method when the number of counties in the inventory area is large (>10). If there are fewer than 10 counties or other geographic units in the inventory area, then this method is not suitable and the first alternative method should be used. This approach uses regression analysis to relate surrogate factors to landfill attributes. Because this method uses a survey of an inventory area subset, and the regression output includes statistical indicators of the model validity, personnel working on this method should have enough training in statistics to ensure that the results of the survey and the model are valid.

The steps taken to develop a regression model are as follows:

- Define the scope of the landfill population in the inventory area. Identify counties or other geographical units that can be efficiently surveyed and that, when combined, represent a reasonable cross section of a statistically valid size. More data points (landfills) will result in a more reliable model.
- Develop a survey approach. A mail out with written forms may be designed, a telephone survey, or a combination of the two approaches may be used. See the discussion of surveys in Chapter 1, *Introduction to Area Source Emission Inventory Development*, and in Volume I of this series.
- Define what information can be reasonably requested. The information needed can be used to develop an emissions estimate, such as the amount of waste in place (or information that allows an estimate of waste in place) and the opening and closure dates, and information that can be used to develop a surrogate, such as population, population density, rural/urban population mix, property values, and land use. The information for the emission estimation will be collected from the landfill operators or the government agency that oversees landfills for that area. The surrogate information can come from U.S. Bureau of the Census data sources, tax records, and county planners. Review the first alternative method for options when incomplete data are available.
- Distribute the survey and compile the results. If information about waste in place could not be directly collected, then use the methods discussed in the first alternative method to estimate waste in place for the surveyed landfills.
- Use the waste-in-place numbers and the surrogate values to develop a regression model of the relationship between those variables. Develop a regression model of

the relationship between the landfill age and the surrogate factors as well. Spreadsheet programs such as Lotus® 1-2-3, Quattro® Pro and Microsoft® Excel provide regression analysis as a function.

The results of the regression analysis should be reviewed for validity.

- Collect the surrogate information from the unsurveyed counties and apply the regression model factors.
- Use the *AP-42* equation or LandGEM to calculate emissions using the estimated waste in place and the estimated landfill age for each county.

5.3 ALTERNATIVE THREE: POPULATION-BASED WASTE GENERATION FACTOR

This method should be used only if there are no other means with which to calculate landfill emissions. Emissions are based on total waste in place, so waste generation must be calculated for years previous to the inventory year. Although landfills can generate emissions for many years, the greatest emissions can be assumed to be emitted from waste 25 years old or less. The steps for calculating waste in place are:

- Collect population figures for the inventory year and the 24 years previous for a total of 25 years of population data.
- Multiply the waste generation factor of 0.69 tons/person/year times the population for each year (EPA, 1996c).
- Multiply tons by 0.9072 to get megagrams (tonnes).
- Use the annual waste estimates in the LandGEM, or calculate the average annual waste estimates and use that value in the *AP-42* equation.

Because this method uses no landfill-specific information, control factors cannot be applied to these estimated emissions.

The per capita waste generation factor supplied here is from the U.S. EPA Office of Solid Waste and Emergency Response annual publication, *Characterization of Municipal Solid Waste in the United States: 1995 Update*, and represents the estimated average generation of all types of MSW in 1994. Waste types include yard trimmings, paper, glass, metals and plastics which may

be composted or recycled in some areas.² The major uncertainty of this method is that it does not account for the amount of waste shipped into or out of a county.

² The EPA Office of Solid Waste maintains a World Wide Web page at: <http://www.epa.gov/epaoswer/osw/index.htm>, can be reached by telephone through the RCRA hotline at 1-800-424-9346 or 1-800-553-7672, and by mail at: RCRA Information Center, U.S. EPA, 401 M Street, SW (5305W), Washington, DC 20460.

6

QUALITY ASSURANCE/QUALITY CONTROL

During the inventory planning process, the agency should define the data quality objectives for the inventory and set data quality goals for the emission estimates developed for this source category. QA and QC methods may vary based on the data quality objectives for the inventory. The Quality Assurance Procedures Volume (Volume VI) of the EIIP series discusses methods to be used to ensure the development of a quality inventory. QA for area source inventories is also discussed in Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development*.

When using the preferred method, the survey planning, sample design, and data handling should be planned and documented in the inventory QA/QC plan. Refer to the discussion of survey planning and survey QA/QC in Chapter 1 of this volume, and Volume VI of the EIIP series.

Data handling for the data collected using all of the methods should also be planned and documented in the inventory QA/QC plan. Other than the conversion of the waste-in-place estimates from volume to weight units, data handling does not involve any category-specific issues. However, the first and second alternative methods require decision making and assumptions in order to develop emission estimates. All of these decisions and assumptions should be clearly documented, supported in writing, and reviewed as the estimates are developed. Please consult the Emission Inventory Improvement Program (EIIP) volume on inventory QA/QC for more information about data handling and documentation.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

Surveys are theoretically the most accurate approach for estimating emissions, but also are the most expensive. The advantage to using a survey is that specific information about the landfills in an area are collected in terms of the landfill fill and age, controls in place are more accurately reflected with actual data, and the local practices in waste disposal are reflected. The level of detail that is possible to collect with a survey is not available when using the alternative methods.

However, following the preferred method does not necessarily require a survey. Information that is current and reliable may be available to state and local agencies for some landfills (especially larger landfills) from permits and reports required under RCRA, the NSPS, or the State or Federal plan that implements the Emission Guidelines.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The Data Attribute Rating System (DARS) has been developed as a tool to rate emission inventories. A description of the system and the EIIP recommendations for its use can be found in Appendix F of EIIP Volume VI, Quality Assurance Procedures. The following discussion uses the DARS rating system as a way to compare the estimation approaches presented in this chapter and analyze their strengths and weaknesses.

The DARS scores for each method are presented in Tables 15.6-1 through 15.6-4. Table 15.6-5 is a summary of all of the methods' composite scores. A range of scores is given for the first and second alternative method to reflect variability in survey techniques and the validity of the assumptions that have been made in the course of data gathering. More information about DARS scoring can be found in Appendix F of EIIP Volume VI.

TABLE 15.6-1

**PREFERRED METHOD DARS SCORES:
USING INFORMATION COMPILED AS PART OF A PERMIT**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5	0.8	0.4
Source Specificity	0.5	1.0	0.5
Spatial	0.3	1.0	0.3
Temporal	0.8	1.0	0.8
Composite Scores	0.53	0.95	0.5

TABLE 15.6-2

**ALTERNATIVE METHOD 1 DARS SCORES:
GUIDELINES FOR USING ASSUMPTIONS WITH LANDFILL DATA**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5	0.3 - 0.6	0.15 - 0.30
Source Specificity	0.5	0.7 - 0.9	0.35 - 0.45
Spatial	0.3	1.0	0.3
Temporal	0.8	0.8 - 1.0	0.64 - 0.8
Composite Scores	0.53	0.7 - 0.88	0.36 - 0.46

TABLE 15.6-3

ALTERNATIVE METHOD 2 DARS SCORES: REGRESSION MODEL

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5	0.5 - 0.6	0.25 - 0.30
Source Specificity	0.5	0.7	0.35
Spatial	0.3	0.7 - 0.9	0.21 - 0.27
Temporal	0.8	0.9	0.72
Composite Scores	0.53	0.7 - 0.78	0.38 - 0.41

TABLE 15.6-4**ALTERNATIVE METHOD 3 DARS SCORES: POPULATION-BASED WASTE FACTOR**

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5	0.6	0.30
Source Specificity	0.5	0.1	0.05
Spatial	0.3	0.3	0.09
Temporal	0.8	0.5	0.40
Composite Scores	0.53	0.38	0.21

TABLE 15.6-5**COMPOSITE DARS SCORES: SUMMARY FOR ALL METHODS**

Method	Scores		
	Factor	Activity	Emissions
Preferred Method	0.53	0.95	0.5
Alternative Method 1	0.53	0.7 - 0.88	0.36 - 0.46
Alternative Method 2	0.53	0.7 - 0.78	0.38 - 0.41
Alternative Method 3	0.53	0.38	0.21

All of the DARS scores for the factor ratings are the same. This is because all of the methods use the same emission estimation method, the *AP-42* equation for landfill gas emissions. The difference between the methods is in the data collection for the variables used in the *AP-42* equation: waste in place, landfill opening and closure dates, k , L_0 , and the concentration of NMOC in the landfill gas. The data collection methods are scored as activity ratings.

Scores for all methods are limited by the fact that emissions from this source category depend on a number of variables that cannot be adequately modeled in a single, fairly simple equation. The most significant limitation to the emission equation is that without detailed understanding of the

types of wastes being landfilled (expressed as the generation potential, L_0) and the impact of climate on landfills (expressed as the methane generation constant, k), local variables are not reflected in the calculation. It is difficult to generalize landfill emissions from region to region because local waste management will determine how much of the waste is recycled and what types of wastes are landfilled, and local rules will determine landfill construction and the use of controls.

Activity data, if it is understood to be the waste in place, landfill age, and control information, can be collected with a satisfactory amount of detail. The preferred method collects data for each landfill for the time period of the inventory. All scores assume that adequate QA/QC measures are performed and that no significant deviations from the prescribed methods have been made. If these assumptions are not met, new DARS scores should be developed according to the guidance in Appendix F of the EIIP QA Procedures volume.

DARS scores vary for Alternative Method One depending on how many of the landfills must have assumptions made about their capacity or age, and how significant their emissions are compared to those for which the detailed information is available. The scores for Alternative Method Two will vary based on how many counties the survey portion of the study can cover, and how closely the surveyed counties represent the estimated counties. Alternative Method Three has the lowest scores of all of the methods because using a per capita estimate of waste generation as a surrogate for waste in place will not reflect the local variables of waste reduction and recycling, incineration, or shipping the waste out of or into the area. Also, population can be a poor surrogate because it will not include waste generated by people that live outside of the area but work in the area. This method also will not include the effect of controls.

6.1.2 SOURCES OF UNCERTAINTY

Estimates generated using any of these methods are relatively uncertain. A variety of chemical, biological, and physical factors affect the rate of landfill emissions. The only reliable way to determine emissions is by direct, continuous measurement. Source testing can provide a snapshot of emissions at a given time period, but landfill emissions can fluctuate over time. Therefore, source testing results are not always a reliable estimator of average or future emissions without a large number of repeated samples. Even with repeated testing, it is still necessary to predict future emissions using AP-42 equations and the site-specific measured methane generation rate constant (k), and NMOC or and HAP concentrations. This is because mass emission rates from landfills change from year to year as additional waste is added, and as the initial waste gets older.

The preferred method gives higher-quality estimates than any of the alternative methods but requires more effort. The level of effort required to calculate emissions using the preferred method will vary depending on the availability of information from permitting agencies and the

form in which it can be retrieved. Readers are reminded that the goal of the inventory is to locate and estimate the largest share of landfill emissions possible within the budget for this source category. Small landfills that closed before 1987 (for Emission Guidelines and RCRA States should have a list of landfills that accepted waste since 1987) may require more time and effort than their proportionate contribution to the source category emissions total. It is possible to estimate a range of error that results from not including those landfills in the inventory. Landfill emissions depend on a complex combination of variables and, even with the most accurate data for waste in place and the landfill age, emissions cannot be characterized as accurately as those for other source categories may be.

The first alternative method is similar to the preferred method, but uses assumptions that introduce uncertainty to the estimates. This uncertainty cannot be quantified. Statistics describing the error and the uncertainty of the activity for the second alternative method are calculated with the regression model. This second method will require a similar amount of effort to collect and compile the survey information from the selected counties as that needed for the preferred method, but the remaining portion of the inventory area requires much less effort. The uncertainty of the emission estimates and the activity information developed through the preferred and second alternative methods may be quantified (see QA Procedures volume, Chapter 4). However, the statistics needed to quantify the uncertainty of the first and third alternative methods are incomplete. Activity for the third alternative method is based on the use of population as a surrogate, which does not take into account local waste management practices or possible controls being used in the inventory area.

7

DATA CODING PROCEDURES

The inventory preparer should check the EPA website (<http://www.epa.gov/ttn/chief/>) for the latest information (codes) available to characterize emission estimates from landfills. A complete list of Source Classification Codes (SCC) can be retrieved at <http://www.epa.gov/ttn/chief/codes/>. Table 15.7-1 lists the applicable SCCs for landfills.

Available codes and process definitions influence and help guide the preparation of emission estimates for this category. Data transfer formats should be taken into account when an inventory preparer plans for data collection, calculation, and inventory presentation. Consistent categorization and coding will result in greater continuity between emission inventories for use in regional and national scale analyses.

7.1 NECESSARY DATA ELEMENTS

If the category emissions data will be transferred to EPA for incorporation into the national criteria and toxics air pollutant inventory, specific data transfer formats are acceptable. The acceptable data transfer format(s) are described and available for download at <http://www.epa.gov/ttn/chief/net/>. The acceptable data transfer formats contain the data elements necessary to complete the data set for use in regional or national air quality and human exposure modeling. The inventory preparer should review the area source portion of the acceptable file format(s) to understand the necessary data elements. The EPA describes its use and processing of the data for purposes of completing the national inventory, in its Data Incorporation Plan, also located at <http://www.epa.gov/ttn/chief/net/>.

TABLE 15.7-1**AREA AND MOBILE SOURCE CATEGORY CODES FOR
MUNICIPAL SOLID WASTE LANDFILLS**

Process Description	Source Category Code
Landfills: All Categories	26-20-000-000
Landfills: Industrial	26-20-010-000
Landfills: Commercial/Institutional	26-20-020-000
Landfills: Municipal	26-20-030-000

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APPENDIX A

Landfill Gas Emissions Model

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APPENDIX A

This appendix is organized into the following sections:

- 15.A-1 Abstract
- 15.A-2 Introduction
- 15.A-3 System Utilities
- 15.A-4 Examples: Steps for Running a Study Using the Model
- 15.A-5 Potential Operational Errors

Attachments

15.A-1 ABSTRACT

This document is an abridged user's guide for a computer model, the Landfill Gas Emissions Model (LandGEM), for estimating air pollutant emissions from municipal solid waste (MSW) landfills. The model was developed by the Control Technology Center. This manual provides step-by-step guidance for using this model. The Landfill Gas Emissions Model can be used to estimate emission rates for methane, carbon dioxide, nonmethane organic compounds, and individual air pollutants from landfills for emission inventories. The program can also be used by landfill owners and operators to determine if a landfill is subject to the control requirements of the federal New Source Performance Standard (NSPS) for new MSW landfills (40 CFR 60 subpart WWW) or the Emission Guidelines for existing MSW landfills (40 CFR 60 Subpart Cc).

The model is based on a first order decay equation. The model can be run using site-specific data for the parameters needed to estimate emissions or, if no site-specific data are available, using default values. There are two sets of default values. One set is based on the requirements of the NSPS and Emission Guidelines. This set of default values produces conservative emission estimates and can be used to determine whether the landfill is subject to the control requirements of the NSPS and Emission Guidelines. The other set of default values is based on emission factors in the U.S. Environmental Protection Agency's (EPA's) *Compilation of Air Pollutant Emission Factors, AP-42* (EPA, 1998a). This set of default values produces more representative emission values and can be used to produce typical emission estimates to be used in emission inventories. The default values presently in the model are the parameter values recommended by the NSPS and *AP-42* as of September 1997. However, these parameter values may be revised in future updates of the model based on new information collected by the EPA.

15.A-2 INTRODUCTION

The Landfill Gas Emissions Model (LandGEM) provides an automated estimation tool for quantifying air emissions from municipal solid waste (MSW) landfills. This document provides an introduction to the model and step-by-step instructions for using it. The model was developed by the Control Technology Center (CTC) of the U.S. Environmental Protection Agency and can be obtained by downloading from the TTN Web (<http://www.epa.gov/ttn/catc/>). A glossary of terms is available as Attachment 15.A-1.

Air emissions from landfills come from landfill gas, generated by the decomposition of refuse in the landfill. Landfill gas is assumed by this model to be roughly half methane and half carbon dioxide, with additional, relatively low concentrations of other air pollutants. The following information is needed to estimate emissions from a landfill:

- The design capacity of the landfill,

- The amount of refuse in place in the landfill, or the annual refuse acceptance rate for the landfill,
- The methane generation rate (k),
- The potential methane generation capacity (L_o),
- The concentration of total nonmethane organic compounds (NMOC) and speciated NMOC found in the landfill gas,
- The years the landfill has been in operation, and
- Whether the landfill has been used for disposal of hazardous waste (codisposal).

Default values are available for k , L_o , NMOC concentration, and toxic air pollutant concentrations.

The estimation method used by the model is a simple first-order decay equation. Because the data available for landfills, such as data on the quantity, age, and composition of the refuse in the landfill are limited, using a more sophisticated calculation method was not justified. The Landfill Gas Emissions Model estimates emissions of methane, carbon dioxide, nonmethane organic compounds, and selected air pollutants. A list of the air pollutants for which the model will calculate emissions is included as Attachment 15.A-2.

Information on the assumptions used in the model can be found in the background information document (NTIS-PB91-197061) written to support the Standards of Performance for New Stationary Sources (40 CFR 60 Subpart WWW) and Emission Guidelines for Control of Existing Sources (40 CFR 60 Subpart Cc) and in the public docket (Docket A-88-09).

The Landfill Gas Emissions Model can be used with site-specific data for all the information needed to generate emission estimates, or it can be used with two different sets of default values. One set of default values (the CAA defaults) is for estimating emissions to determine the applicability of the Clean Air Act (CAA) regulations for MSW landfill emissions, specifically the New Source Performance Standards (NSPS) for new MSW landfills and the Emission Guidelines for existing MSW landfills. The CAA default values in the model provide emission estimates that would reflect the expected maximum emissions and generally would be used only for determining the applicability of the regulations to a landfill. To estimate emissions for an air emissions inventory in the absence of site-specific data, a second set of default values (the *AP-42* defaults) is provided in the model. The *AP-42* default values in the model are based on emission factors from the U.S. Environmental Protection Agency's *Compilation of Emission Factors, AP-42* (EPA, 1998a). The *AP-42* default values provide emission estimates that should reflect typical landfill emissions and are the values suggested for use in developing estimates for state inventories.

15.A-3 SYSTEM UTILITIES

The landfill model is designed as a tool to estimate landfill emissions. To aid in estimation, the landfill model has been equipped with Help screens to describe and explain features of the model and its functions. In addition, the model has been equipped with utility functions to assist the user. Like Help screens, the utilities for this program are available when any of the model windows (i.e., the Operating Parameters window or a Report window) is being used. There are three utilities: a Unit Conversion utility, a Refuse Estimator utility, and an Autocalc function. These utility functions are described in the succeeding sections.

15.A-3.1 The Unit Conversion Utility

This program uses metric units (such as megagrams of refuse) rather than English units (such as tons of refuse), because metric units are used by the federal government and for the CAA regulations for MSW landfills. However, users of the model who prefer to use English units can use the conversion utility to convert English units to metric units, or vice versa.

To use the Unit Conversion utility:

1. Choose Unit Conversions from the Utilities menu.
2. Type the units to be converted in the "To convert from" text box. The units should be in a format specified by the program. This format is explained in the Help for the Unit Conversion utility. Select [Help], then choose Unit Formulas in the topics list on the main Help screen. For example, use the symbol ^ to indicate an exponent, * to indicate multiplication, and / to indicate division. The following are several examples of units in formats that will be accepted by the system: kg/m³; 1.25 kg/m/s; 1.25 kg(m*s)².
3. Type the units to convert to in the "to" text box.
4. Select [Convert] and the units will be converted. If the units you typed in were units only, with no value, the result of conversion will be a factor by which to multiply the value. If the units you typed in were accompanied by a value (e.g., 35,000 tons) the result will be a converted value (e.g., 31,751 Mg).
5. [Update] will update the units conversion database by adding new units or editing units already included in the conversion database. See below.
6. To exit the Unit Conversion utility, select [Cancel] or double click on the close button in the upper right corner of the Utility window.

You can add new units and delete or edit existing unit conversion factors in the Unit Conversion utility with the Unit Database Maintenance facility.

To update the Unit Conversion Utility:

1. Choose Unit Conversions from the Utilities menu.

2. In the Unit Conversions screen, select [Update]. A Unit Database Maintenance dialog box will come up.
3. Type the unit to add to the unit conversion database in the "Unit" text box.
4. Specify whether the unit is case dependent. Metric units, for example, are generally case dependent; mg and Mg are different units. English units are generally not case dependent; ton and Ton are the same unit.
5. Select [Locate] to locate a unit in the database, to be sure the unit is not already there.
6. Type the conversion factor for the unit in the "Factor" text box.
7. Type the metric unit into which the English unit will be converted in the "Base Unit" text box. The base units should be base units in the metric system, if possible (that is, you would use g rather than Mg as a base unit). The base units of the metric system are listed in Help. To access, select [Help]. Choose Search Method in the topics list on the main Help screen and "base quantity" highlighted in the Help text. A list of the metric base units and abbreviations for them will appear.
8. Select [Add] or [Delete] to add a unit to or delete it from the conversion database.
9. Updating the conversion database is explained in the Help for the Unit Conversion Utility. To access help for updating the conversion database, select Help. Choose Adding Units or Database Maintenance from the topics list on the main Help screen.

15.A-3.2 The Refuse Estimator Utility

This program requires refuse in place or refuse acceptance rates, and calculates emissions using refuse in place. The Refuse Estimator utility allows a user to estimate emissions using this program even if no refuse in place data are available other than the dimensions of the landfill.

To use the refuse estimator:

1. Select Refuse Estimator from the Utilities menu.
2. In the Refuse Estimator dialog box, select the Landfill Size (Acres) text box. If you do not have the size of the landfill in acres, use the Unit Conversion utility to convert to acres.
3. Enter the acreage of the landfill.
4. Select the Landfill Depth (Feet) text box. Enter the depth of the landfill in feet. Use the Unit Conversion utility if necessary to convert the depth to feet.
5. Select [Estimate]. The estimator will estimate the refuse in place in Mg and the value will appear in the Estimated Refuse in Place (Mg) text box.
6. Select [OK] to exit the Refuse Estimator.

15.A-3.3 The Autocalc Function

The Autocalc function is located under the Edit menu. This function can be used to assist the user in calculating either waste acceptance rates or refuse in place for the years of operation of the model. The Autocalc function is easy to use and allows the user either to enter an average acceptance rate for a period of operation or to linearly interpolate refuse data between two years (e.g., year 1 and year 10 of a given period of uniform or linearly increasing or decreasing waste acceptance). Examples of how to use the Autocalc function are available in Attachment 15.A-3.

The user should take caution: The Autocalc function does not recognize the landfill capacity as the upper limit which the refuse in place cannot exceed. It is possible to use the Autocalc function to calculate values for the acceptance rates or the refuse in place that cause the final values for the accumulated refuse to exceed the landfill capacity. If accumulated refuse exceeds the landfill capacity, the data must be erased or adjusted before a report can be generated.

15.A-4 EXAMPLES: STEPS FOR RUNNING A STUDY USING THE MODEL

This section outlines a step-by-step example of how to operate the emission estimation model for a standard case. Section 4.1 of this document describe the basic operation of the model. The methodology for modifying the parameters to run specific scenarios are described in section 4.3.

The following steps need to be followed to run a model:

- Open or Create a New Landfill Study,
- Select Model Parameters for Calculating Emissions,
- Define the Operating Parameters of the Landfill,
- Adapt the Model for a Specific Scenario,
- Generate a Report, and
- Save the Landfill Study.

The following *Model Parameters* are needed to estimate emissions from a landfill:

- The methane generation rate (k),
- The potential methane generation capacity (L_o),
- The estimated percentage composition of methane and carbon dioxide in the landfill gas (the default value is a 50/50 split),
- The concentration of nonmethane organic compounds (NMOC) and speciated NMOC found in the landfill gas,
- The concentrations of toxic air pollutants found in the landfill gas, and
- Whether the landfill has been used for disposal of hazardous waste (codisposal).

The following *Operating Parameters* are needed to estimate emissions from a landfill:

- The years the landfill has been in operation (including the Closure Year),
- The design capacity of the landfill, and
- The amount of refuse in place in the landfill, or the annual refuse acceptance rate for the landfill.

The following data entry pattern is recommended when entering operating parameters into the computer model:

- Select the Year Opened;
- Select the final year for which information is available (Current Year);
- Make any changes to the Closure Year that are needed;
- Enter the Landfill Capacity; and
- Enter the Acceptance Rate or Refuse In Place data.

With the exception of the requirement that the landfill capacity must be entered before any waste data, this recommended order of entry is not required.

15.A-4.1 An Example User Session

This section describes a step-by-step procedure for estimating landfill emissions using the model, which can be operated in Windows 3.1, Window 3.11, or Windows 95. The data provided below are for a generic landfill and a generic study.

Landfill Scenario Model Parameter Data:

Methane Generation Rate (k):	AP-42 default
Methane Generation Potential (L ₀):	AP-42 default
Percentage Composition of CO ₂ and CH ₄ :	50%/50%
Concentration of NMOC:	AP-42 default
Selected Air Pollutant:	add <i>Ethyl Mercaptan</i> (MW = 62.13; concentration = 0.86)
Landfill Type:	Codisposal

Landfill Scenario Operating Parameter Data:

Year Opened:	1975
Current Year:	1995
Landfill Design Capacity:	3,000,000 Mg

Refuse in Place in 1980:	330,500 tons
Annual Refuse Acceptance Rate:	109,890 ton/yr from 1980 to 1994
Autocalc:	(Refuse in place from 1975 to 1979)
Closure Year:	2001

Steps

I. Open or Create a New Landfill Study

1. Launch the program (either by double-clicking on the program icon or selecting landwin.exe from the Program Manager).
2. The Landfill Gas Emissions Model will open with an abbreviated set of menus. From the File menu, select [New] or [Open] to run a landfill study. A landfill study window (the Operating Parameters window) will open. A new landfill study is assigned the default name *landfill.000*. This name will be replaced by a user-supplied name when the landfill study is saved and named.

II. Select Model Parameters for Calculating Emissions

A. Methane Generation Rate (k) and Methane Generation Potential (L_o)

1. To set the default values for k, L_o, and NMOC concentration used to calculate emissions, select the Defaults menu.
2. To set the system for estimating emissions for emission inventories for municipal solid waste landfills, select AP-42.

B. Percentage Composition of CO₂ and CH₄

1. From the Parameters menu, select Air Pollutants. An Air Pollutant Compound Parameters dialog box will appear.
2. Methane and carbon dioxide are assumed to make up 50 percent each of the landfill gas. Leave these percentages as they are.

C. Concentration of NMOC

1. From the Parameters menu, select Air Pollutants. An Air Pollutant Compound Parameters dialog box will appear.
2. Because the AP-42 defaults were selected from the Defaults menu (see step A.2.) the NMOC concentration has already been set as the AP-42 default; the other options (i.e., CAA defaults and User Specific defaults) are dimmed and cannot be

selected. Only when the User Specific option is selected from the Defaults menu can the value for the NMOC concentration be changed.

D. Concentrations of Toxic Air Pollutants

1. A total of 47 air pollutants expected to be emitted from landfills is included in the program. Air pollutants that are designated as HAP and/or VOC are indicated as so in parentheses. Additional air pollutants can be added or inappropriate ones can be deleted. To edit the list of toxic air pollutants for which emissions will be estimated, select Air Pollutants from the Parameters menu. In the Air Pollutant Compound Parameters dialog box that opens, select [Edit Air Pollutants]. A Selected Air Pollutants dialog box will open.
2. To add an additional entry for Ethyl Mercaptan, type over the existing data that appear for a pollutant in the box. Start by selecting the name of the chemical in the text box. Delete this information and type in *Ethyl Mercaptan*.
3. Select the molecular weight text box. Delete the information in the box and type in *62.13*.
4. Select the Concentration, Codisposal, text box. Delete the information in the box and type in *0.86*. Repeat this step for the concentration, no codisposal, text box.
5. Choose [Append] to add the record for Ethyl Mercaptan.
6. Select [OK] to accept these data and to add Ethyl Mercaptan to the list of air pollutants for which emissions will be estimated. In the Air Pollutants Parameters dialog box, select [OK] to accept the set values for pollutant concentrations.

E. Landfill Type

1. Select Parameters from the Main Menu.
2. Select Landfill type.
3. Select Codisposal. This option should be used when the landfill has been used to dispose of hazardous waste.

III. Define the Operating Parameters of the Landfill

A. Enter Year Opened and Design Capacity

1. Select the Year Opened text box in the data entry box. The year opened defaults to 10 years before the current year (determined from the computer's clock).
2. Delete the default Year Opened. Enter 1975.
3. Delete the default Current Year. Enter 1995.
4. Select the Capacity text box and type in 3.0E+06 for 3,000,000 Mg refuse capacity. Press Enter to accept this value.

B. Enter Refuse In Place for the First Year of Accepting Refuse

1. Because the refuse in place in 1980 and annual refuse acceptance rate values for this landfill are recorded in tons and the program calls for megagrams, the units of measure need to be converted.
 - 1(a). From the Main Menu, select Utilities.
 - 1(b). Select Unit Conversions to bring up the dialog box for the unit conversion utility.
 - 1(c). Select the "To convert from" text box. Type in the refuse in place value, including the units: *330,500 tons*.
 - 1(d). Select the "to" text box. Type in the units to which you want to convert: *Mg*.
 - 1(e). Select [Convert].
 - 1(f). The box with the result (the "multiply quantity in source unit by" text box) will give the value of the refuse in place in Mg. This value rounds to 300,000 Mg. Record this value to use later.
 - 1(g). To convert the annual acceptance rate to Mg, select the "To convert from" text box. Delete the value in it and type in *109,890 tons*.
 - 1(h). Select the "to" box and type in *Mg*.
 - 1(i). Select [Convert]. The annual acceptance rate in Mg rounds to 100,000 Mg. Record this value to use later.
 - 1(j). To exit the unit conversion utility, Select [Cancel] or double-click on the close box in the upper right corner of the conversion utility dialog box.
2. In the Operating Parameters table, select the year 1980. The cells in the Acceptance Rate/Refuse in Place column for 1980 will be highlighted by a bold box around them.
3. Select the button in the data entry box for Refuse in Place.
4. Select the Waste Value text box.
5. Type in 3.0E+05 (300,000) for the refuse in place in 1980. Press Enter to accept the value. The program will enter 3.0E+04 as the refuse in place for all following years up to the current year until you enter specific values for specific years. The table represents refuse in place, which is cumulative.
6. Highlight the Refuse in Place cells from 1975 through 1980. Choose the Autocalc function from the Edit menu. By using the Autocalc function, you will assume that waste has been received at a uniform rate of 60,000 Mg/yr since the landfill opened. You will see this change reflected in the refuse acceptance rates from 1975 through 1979.

C. Enter Refuse Acceptance Rates for Following Years

1. Enter a refuse acceptance rate for 1980 of 100,000 Mg. Do this by selecting the Acceptance Rate (Mg) cell in the row for 1980. This selection will select the Acceptance Rate (Mg/yr) check box on the toolbar. Highlight the entry in the Waste Value box on the toolbar and type 100,000. Press Enter to accept this value. [Note: Refuse in place values in this model are calculated at the beginning of the year. That is, the refuse in place for a landfill is a total of the previous year's refuse in place and the previous year's refuse acceptance rate. By entering a value of 100,000 Mg received in 1980, you will not have altered the Refuse in Place value for that year (i.e., the value will remain 300,000 Mg). However, the Refuse in Place value for 1981 will be changed to 400,000 Mg.]
2. The refuse acceptance rate remains constant from 1980 through 1994. Using the Autocalc function will help to speed the data entry rather than repeating step 1 for each year from 1980 to 1994. To do this, repeat step C.1 for the year 1994 (i.e., enter a refuse acceptance rate for 1994 of 100,000 Mg). Highlight the refuse acceptance rate cells from 1980 through 1994. Then select the Autocalc function from the Edit menu. This action will change the refuse acceptance rates for these years from their default values to 100,000 Mg/yr. Consequently, the refuse in place values will increase by 100,000 Mg each year from 1981 through 1995. The refuse in place in 1995 should total 1,800,000 Mg.

D. Closure Year

1. To set the closure year of the landfill, select the Closure Year item from the Parameters menu.
2. Click on the check box User Specified to permit entry of a certain closure year.
3. Type in 2001. Select [OK]. [Note: When a report is generated the program will calculate, based on this selection, the difference (1,200,000 Mg) between the landfill design capacity (3,000,000 Mg) and the refuse in place (1,800,000 Mg) for the last year for which information has been entered (i.e., 1995). The program will divide this value by the number of years (6) between the current year (1995) and the closure year (2001). When a report is generated, the quotient (200,000 Mg/yr) will be entered as the acceptance rates for the years in which no data have been entered.]

IV. Adapt the Model for a Specific Scenario

Models can be adapted to specific scenarios to account for non-biodegradable waste or areas of the landfill for which the emissions are collected and controlled. For this study it was assumed that none of the waste in the landfill is non-biodegradable and that none of the

emissions from the landfill are collected and controlled. These topics are discussed in more detail in section 4.3.

V. Generating a Report, Saving a Study, and Exiting the Program

A. Generate a Textual Report of Emissions

1. To see the emissions generated based on the operating parameters, program defaults, and pollutant concentrations selected, select Reports from the Main Menu. To generate a textual report of emissions, select Text. A dialog box titled *Select an Emitted Substance* will appear.
2. Select *Ethyl Mercaptan* as the pollutant to report. Select [OK] to generate the emission report for all the years the landfill is open, plus 200 years past closure. A report will appear in the landfill study window.
3. To print the report, select Print from the File menu. A Print dialog box will come up, with a list of variable printers.
4. Select a printer. Select [Print].
(A copy of the text report is included as Attachment 15.A-4).

B. Generate a Graphical Report of Emissions

1. To generate a graphical report of emissions, select Graphics from the Reports menu.
2. Select *Ethyl Mercaptan*. Select [OK].
3. Select Print from the File menu. Select [Print].
(A copy of the graphical report is included as Attachment 15.A-5.)

C. Save the Landfill Study

1. To save the landfill study and assign a filename, select Save As from the File menu. A dialog box for Save As Landfill Study will appear, with a list of the landfill study files, if there are any (landfill study files are assigned a .PRM file extension), in the working directory for the program. The landfill study will be filed in the working directory of the program unless you specify another directory.
2. Select the File Name text box. Type *test*. The program will add the .PRM extension to the filename. This study will be saved in the working directory for the program as test.PRM. Select [OK].

D. Exit the Program

1. Select Exit from the File menu.

15.A-4.2 Adapting the Model for a Specific Scenario

Whenever possible, actual landfill data should be used to run the emissions estimation model. However, sometimes landfill data may be incomplete or unavailable, or a landfill owner or operator may wish to estimate the emissions for a landfill that has not yet opened. In such cases, the model can be used to forecast landfill emissions.

15.A-4.2.1 Forecasting Landfill Emissions

When forecasting emissions, it is best to use any actual data that are available. Even if a complete set of data is not available, any partial data sets should be put into the model. In cases where data are not available, the model can be used to give reasonable estimates of the landfill waste to forecast emissions.

Using the model to forecast emissions is similar to calculating past waste acceptance rates and refuse in place. The same general methodology described in the previous sections is used: select the model parameters, identify the length of operation of the landfill, enter the refuse in place or the acceptance rates of refuse, and run a report.

The principal difference between modeling emissions for existing landfill wastes and forecasting emissions for future landfill wastes is that, instead of actual data, estimates are needed for the length of operation, landfill capacity, and landfill waste when forecasting emissions. The following paragraphs describe the modified approach to use when forecasting emissions.

Length of Operation: Specifying the length of operation of the landfill can be more complicated when forecasting emissions. If precise years of operation (e.g., 1950, 1990, 1991) are known, they can be entered for the time variables (e.g., Year Opened, the Current Year, and the Closure Year), and the model functions normally. However, when precise dates are not known, the length of operation of the landfill can be specified with generic year numbers, such as 0001 (Year Opened), 0015 (Current Year), and 0016 (Closure Year).

Begin entering the length of time in which the landfill operates by entering a value for the Year Opened. Then choose a value for the Current Year that allows you to input refuse data for as many years past opening as you desire. The current year is the last year for which you will be able to input refuse data into the model. If the landfill will be open and accepting waste after the current year, then the user can choose a value for the Closure Year, or the computer model will automatically calculate it. However, if the

current year is the year in which the landfill will reach its capacity, the user should either allow the computer to automatically calculate the closure year or specify a closure year value that is one year in the future of the current year.

Landfill Capacity: The model algorithms and validation procedures require that a design capacity be entered prior to entering yearly refuse data. That is, even for a landfill not yet in operation, the total landfill capacity must be specified before any other information about the refuse in the landfill can be entered. If necessary, the user may use the Refuse Estimator to determine the landfill capacity from estimated landfill dimensions.

Landfill Waste: For each year of operation, the amount of landfill refuse must either be entered as a refuse in place or an acceptance rate. If data are available for either refuse parameter, they should be entered into the model. For years in which no such data are available, estimates must be provided. The Autocalc Function can assist the user in entering estimates for years in between those in which refuse acceptance rate or the amount of refuse in place is known.

15.A-4.2.2 Compensating for Non-biodegradable Debris, Areas with Emission Controls, and Areas Outside the Radius of Influence of Emission Controls

In certain cases, there are sections of a landfill that contain largely non-biodegradable debris (e.g., concrete, rocks, asphalt or other demolition debris) and do not produce emissions that other landfill refuse does. If records are available documenting such a quantity of waste and the regulatory agency is in agreement with this judgement, this amount of waste can be subtracted from the accumulated waste and the landfill capacity.

Similarly, when an area of the landfill is operated with a gas collection system and emission controls, this area of the landfill and the subsequent landfill waste will not release emissions at the same rate as an uncontrolled area of the landfill. In the case of a landfill with such emission controls, the user must estimate the quantity of the waste for which gas is collected and controlled. The controlled and uncontrolled portions of the landfill can then be modeled separately. Application of controls are discussed in Section 3.3.2 of this chapter.

15.A-5 POTENTIAL OPERATIONAL ERRORS

Some inputs can cause problems in the operation of the program. The following sections describe how to avoid them.

15.A-5.1 The Autocalc Function

The Autocalc function is located under the Edit menu and assists the user in calculating waste acceptance rates or refuse in place for the years of operation of the model. The Autocalc function will not recognize the landfill capacity as the upper limit for the accumulated refuse. When this occurs, calculated values for accumulated refuse will exceed the landfill capacity.

The user should compare the amount of accumulated refuse as calculated by the Autocalc function to the landfill capacity value prior to entering the data into the model to be certain that the refuse in place does not exceed the landfill capacity. If the calculated accumulated refuse amounts do exceed landfill capacity, then the user should adjust the acceptance rate data in the Autocalc function to reduce the calculated accumulated refuse amount. Please note that the program will continue to run if the entered value for landfill capacity has been exceeded.

15.A-5.2 The Closure Year

The Closure Year function is located under the Parameters menu and allows the user either to calculate the closure year automatically or to specify an actual closure date for the landfill. In either case, the closure year is the year in which the landfill waste accumulated reaches the capacity of the landfill. The default option is for the model to calculate the closure year automatically. The following is a brief description of the two options and an explanation of how the closure variable choice affects operation of the model.

System Calculated Closure Year: The computer model will project the closure based on the last non-zero acceptance rate and the capacity of the landfill. The model will project waste acceptance at the last non-zero acceptance rate until the year in which the accumulated refuse in place reaches the landfill capacity. This year becomes the closure year.

User-specified Closure Year: If the user does not know the refuse acceptance rates for the final years of the landfill's operation, the user may specify the closure year for the landfill and allow the computer to calculate the acceptance rates until closure. The model will calculate the acceptance rates for the final years of operation by dividing the remaining capacity of the landfill by the number of years between the current year and the user-specified closure year.

The user must take caution when specifying the closure year because of the model's method of calculation. If a closure year is chosen that is the same as the current year, the model's calculation routine will not be able to estimate emissions correctly. To avoid this problem, the user should always specify a closure year that is at least one year beyond the current year even if the current year is the year in which the refuse in place reaches the capacity of the landfill (i.e., a case in which the current year is, by definition, the closure year). If the current year is the

closure year, we recommend allowing the model to automatically calculate the closure year (i.e., use the default System Calculated Closure Year).

15.A-5.3 Cut, Copy, and Paste

The Cut, Copy, and Paste commands, which function similarly as in other Windows software programs, are designed to be implemented in the following way: highlight the contents of the origin cell (i.e., drag the cursor across the cell with the primary mouse button depressed); select the Cut or Copy command; highlight the contents of the destination cell; and then select the Paste command.

**ATTACHMENT 15.A-1
GLOSSARY OF TERMS**

Term	Definition
Codisposal	Disposal of hazardous waste as well as other kinds of waste in a landfill.
Landfill Capacity	The total amount of refuse that can be disposed of in the landfill.
Landfill Gas	Landfill gas is a product of biodegradation of refuse in landfills and consists of primarily methane and carbon dioxide, with trace amounts of NMOC and air pollutants.
Methane Generation Rate Constant (k)	k is a constant that determines the rate of landfill gas generation. The first-order decomposition model assumes that k values before and after peak landfill gas generation are the same. k is a function of moisture content in the landfill refuse, availability of nutrients for methanogens, pH, and temperature.
Nonmethane Organic Compounds (NMOC)	NMOC are specified in this program as the fraction of landfill gas containing nonmethane organic compounds, expressed as hexane. NMOC include air pollutants and volatile organic compounds. NMOC concentration can be measured using guidance provided by the proposed EPA Method 25C.
Potential Methane Generation Capacity (L_o)	L_o is a constant that represents the potential capacity of a landfill to generate methane (a primary constituent of landfill gas). L_o depends on the amount of cellulose in the refuse.
Air Pollutants	Compounds found in landfill gas or emitted with landfill gas, some of which are listed as air pollutants under section 112 of the Clean Air Act. A total of 47 air pollutants emitted from landfills are included in the model.
Closure Year	The year in which the landfill ceases, or is expected to cease, accepting waste.

ATTACHMENT 15.A-2. POLLUTANTS INCLUDED IN THE LANDFILL GAS EMISSIONS MODEL

Chemical	Molecular Weight	Concentration (ppmv)	
		Codisposal	No Codisposal
1,1,1-Trichloroethane (HAP)	133.41	0.48	0.48
1,1,2,2-Tetrachloroethane (HAP/VOC)	167.85	1.11	1.11
1,1,2-Trichloroethane (HAP/VOC)	133.41	0.1	0.1
1,1-Dichloroethane (HAP/VOC)	98.96	2.35	2.35
1,1-Dichloroethene (HAP/VOC)	96.94	0.2	0.2
1,2-Dichloroethane (HAP/VOC)	98.96	0.41	0.41
1,2-Dichloropropane (HAP/VOC)	112.99	0.18	0.18
2-Propanol (VOC)	60.11	50.1	50.1
Acetone	58.08	7.01	7.01
Acrylonitrile (HAP/VOC)	53.06	6.33	6.33
Benzene (HAP/VOC)	78.12	11.1	1.91
Bromodichloromethane (VOC)	163.83	3.13	3.13
Butane (VOC)	58.12	5.03	5.03
Carbon Disulfide (HAP/VOC)	76.14	0.58	0.58
Carbon Monoxide	28.01	141	141
Carbon Tetrachloride (HAP/VOC)	153.84	0.004	0.004
Carbonyl Sulfide (HAP/VOC)	60.07	0.49	0.49
Chlorobenzene (HAP/VOC)	112.56	0.25	0.25
Chlorodifluoromethane (VOC)	86.47	1.3	1.3
Chloroethane (HAP/VOC)	64.52	1.25	1.25
Chloroform (HAP/VOC)	119.38	0.024	0.024
Chloromethane (HAP/VOC)	50.49	1.21	1.21
Dichlorobenzene (VOC/HAP for 1,4 isomer)	147	0.21	0.21
Dichlorodifluoromethane (VOC)	120.91	15.7	15.7
Dichlorofluoromethane (VOC)	102.92	2.62	2.62
Dichloromethane (HAP)	84.93	14.3	14.3
Dimethyl Sulfide (VOC)	62.13	7.82	7.82
Ethane	30.07	889	889
Ethanol (VOC)	46.08	27.2	27.2
Ethylbenzene (HAP/VOC)	106.17	4.61	4.61
Ethyl Mercaptan (VOC)	62.13	1.25	1.25
Ethylene Dibromide (HAP/VOC)	187.88	0.001	0.001
Fluorotrichloromethane (VOC)	137.37	0.76	0.76
Hexane (HAP/VOC)	86.18	6.57	6.57
Hydrogen Sulfide	34.08	35.5	35.5
Mercury (HAP)	200.61	0.000253	0.000253
Methyl Ethyl Ketone (HAP/VOC)	72.11	7.09	7.09
Methyl Isobutyl Ketone (HAP/VOC)	100.16	1.87	1.87
Methyl Mercaptan (VOC)	48.11	2.49	2.49
Pentane (VOC)	72.15	3.29	3.29
Perchloroethylene (HAP/VOC)	165.83	3.73	3.73
Propane (VOC)	44.1	11.1	11.1
Toluene (HAP/VOC)	92.14	165	39.3
Trichloroethene (HAP/VOC)	131.38	2.82	2.82
t-1,2-Dichloroethene	96.94	2.84	2.84
Vinyl Chloride (HAP/VOC)	62.5	7.34	7.34
Xylene (HAP/VOC)	106.17	12.1	12.1

Note: Technical support information for the above pollutant data is located in the *Compilation of Air Pollutant Emission Factors, AP-42, Volume 1: Stationary Point and Area Sources* (EPA, 1998a) which can be obtained from the TTN website (<http://www.epa.gov/ttn/chief/ap42back.html>) or from the National Technical Information Service.

ATTACHMENT 15.A-3 EXAMPLES OF THE AUTOCALC FUNCTION

Example 1: Using the Autocalc Function When Only Partial Data Are Available

If refuse information is available for only certain years of landfill operation and assumptions can be made about acceptance rates in the years for which there is no information, the Autocalc function can be useful to estimate and enter acceptance rate data. In this example, the user will have two periods of acceptance rates for which the Autocalc function will be used: one in which the user will assume that the acceptance rate increases linearly over time and one in which the acceptance rate is constant for a number of years. In this example, the landfill will open in 1971, and the current year will be 1986.

To input an increasing refuse acceptance rate, an acceptance rate must be entered for the beginning and ending points. Assume that the landfill capacity is 2,000,000 Mg, the refuse acceptance rate in the first year (1971) is 10,000 Mg/yr, and the refuse acceptance rate in the tenth year (1980) is 100,000 Mg/yr. To use the Autocalc function to interpolate between the two rates, select the waste acceptance rate for the year 1971. Click and drag the mouse until all the cells from years 1971 through 1980 are highlighted. Then, from the Edit menu, select the Autocalc function. The computer model will linearly interpolate the acceptance rate for the years between 1971 and 1980. In this case, the rate increases from 10,000 Mg/yr to 100,000 Mg/yr in 10,000 Mg/yr increments.

To enter a constant refuse acceptance rate, the same value for the acceptance rate must be entered for the beginning and end points of the period throughout which refuse is received at a uniform rate. In this case, assume that the acceptance rate remains constant at 100,000 Mg/yr from 1980 through 1985. Start by entering 100,000 Mg/yr in the acceptance rate cell for the year 1985. (A value of 100,000 Mg/yr should have already been entered for 1980 based on the directions in the previous paragraph). Then highlight all the cells from years 1980 through 1985. From the Edit menu choose the Autocalc function. The computer model will enter the acceptance rate of 100,000 Mg/yr for each year between 1980 and 1985. Note that, in both cases, entering acceptance rate values with the Autocalc function caused the estimates for the refuse in place to change accordingly.

Example 2: Using the Autocalc Function With No Data for Early Periods of Operation

This example will begin with a new study. Assume that a landfill with a capacity of 5,000,000 Mg opens in the year 1971 and the current year is 1980. For the last two years (i.e., 1979 and 1980) the amount of refuse in place has been recorded. In 1979 the refuse in place

totaled 2,000,000 Mg, and in 1980 it was 2,350,000 Mg. However, there are no records to indicate what the refuse in place was for 1971 through 1978.

The Autocalc function can be used to estimate the refuse in place for the years between 1971 (the year the landfill opened) and 1978. The refuse in place in 1971 must be zero because 1971 is the year the landfill opened. Assuming that refuse acceptance rates were constant between 1971 to 1978, the Autocalc function can be used to linearly interpolate backwards to produce estimates of the refuse between 1971 and 1978. As in the previous example, begin by selecting the cell with the earlier date (i.e., move the active cell to the refuse in place for 1971). Click and drag the mouse until all the cells between 1971 and 1979 are highlighted. Then choose the Autocalc function from the Edit menu. The values in both the refuse acceptance rate and refuse in place column will be calculated. The refuse acceptance rate for years 1971 through 1978 will be 250,000 Mg/yr, and the refuse acceptance rate for 1979 will be 350,000 Mg/yr. The refuse in place estimates will be adjusted accordingly from 1971 (0 Mg in place) to 1979 (2,000,000 Mg in place).

ATTACHMENT 15.A-4 **A COPY OF THE TEXT REPORT FROM THE EXAMPLE STUDY IN SECTION 4.1**

Source: C:\LANDFILL\TEST.PRM

Model Parameters

Lo: 100.00 m³ / Mg
 k : 0.0400 1/yr
 NMOC : 2420.00 ppmv
 Methane : 50.0000 % volume
 Carbon Dioxide : 50.0000 % volume
 Air Pollutant : Ethyl Mercaptan
 Molecular Wt = 62.13 Concentration = 0.860000 ppmV

Landfill Parameters

Landfill type : Co-Disposal
 Year Opened : 1975 Current Year : 1995 Closure Year: 2001
 Capacity : 3000000 Mg
 Average Acceptance Rate Required from
 Current Year to Closure Year : 200000.00 Mg/year

Model Results

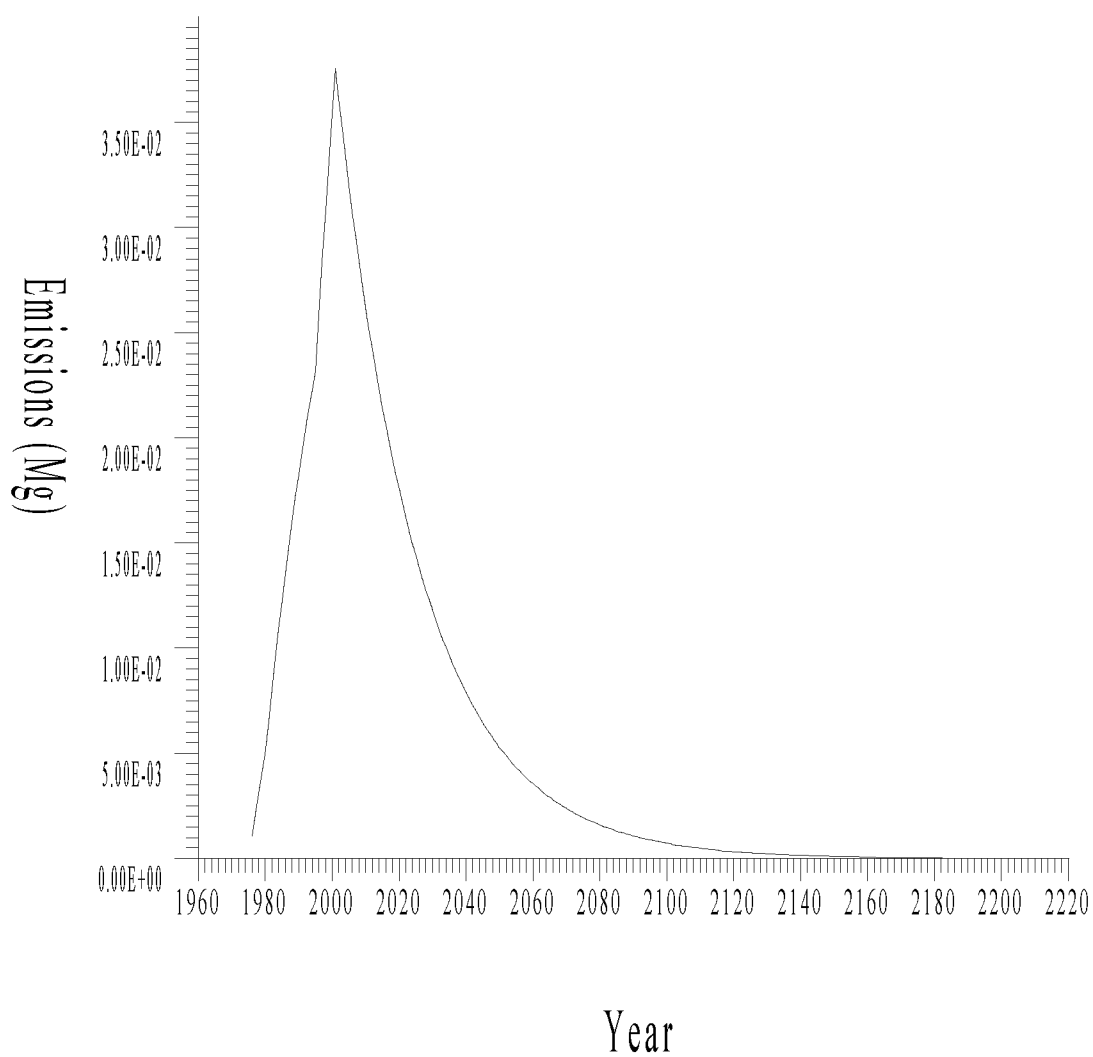
Year	Refuse In Place (Mg)	Ethyl Mercaptan Emission Rate (Mg/yr)	(Cubic m/yr)
1976	6.000E+04	1.067E-03	4.128E-01
1977	1.200E+05	2.092E-03	8.094E-01
1978	1.800E+05	3.076E-03	1.190E+00
1979	2.400E+05	4.022E-03	1.557E+00
1980	3.000E+05	4.932E-03	1.908E+00
1981	4.000E+05	6.516E-03	2.522E+00
1982	5.000E+05	8.038E-03	3.111E+00
1983	6.000E+05	9.501E-03	3.677E+00
1984	7.000E+05	1.091E-02	4.221E+00
1985	8.000E+05	1.226E-02	4.743E+00
1986	9.000E+05	1.355E-02	5.245E+00
1987	1.000E+06	1.480E-02	5.727E+00
1988	1.100E+06	1.600E-02	6.191E+00
1989	1.200E+06	1.715E-02	6.636E+00
1990	1.300E+06	1.825E-02	7.064E+00
1991	1.400E+06	1.932E-02	7.475E+00
1992	1.500E+06	2.034E-02	7.870E+00
1993	1.600E+06	2.132E-02	8.249E+00

1994	1.700E+06	2.226E-02	8.614E+00
1995	1.800E+06	2.316E-02	8.964E+00
1996	2.000E+06	2.581E-02	9.989E+00
1997	2.200E+06	2.836E-02	1.097E+01
1998	2.400E+06	3.080E-02	1.192E+01
1999	2.600E+06	3.315E-02	1.283E+01
2000	2.800E+06	3.540E-02	1.370E+01
2001	3.000E+06	3.757E-02	1.454E+01
2002	3.000E+06	3.610E-02	1.397E+01
2003	3.000E+06	3.468E-02	1.342E+01
2004	3.000E+06	3.332E-02	1.290E+01
2005	3.000E+06	3.202E-02	1.239E+01
2006	3.000E+06	3.076E-02	1.190E+01
2007	3.000E+06	2.955E-02	1.144E+01
2008	3.000E+06	2.840E-02	1.099E+01
2009	3.000E+06	2.728E-02	1.056E+01
2010	3.000E+06	2.621E-02	1.014E+01
2011	3.000E+06	2.518E-02	9.746E+00
2012	3.000E+06	2.420E-02	9.364E+00
2013	3.000E+06	2.325E-02	8.997E+00
2014	3.000E+06	2.234E-02	8.644E+00
2015	3.000E+06	2.146E-02	8.305E+00
2016	3.000E+06	2.062E-02	7.979E+00
2017	3.000E+06	1.981E-02	7.666E+00
2018	3.000E+06	1.903E-02	7.366E+00
2019	3.000E+06	1.829E-02	7.077E+00
2020	3.000E+06	1.757E-02	6.799E+00
2021	3.000E+06	1.688E-02	6.533E+00
2022	3.000E+06	1.622E-02	6.277E+00
2023	3.000E+06	1.558E-02	6.031E+00
2024	3.000E+06	1.497E-02	5.794E+00
2025	3.000E+06	1.439E-02	5.567E+00
2026	3.000E+06	1.382E-02	5.349E+00
2027	3.000E+06	1.328E-02	5.139E+00
2028	3.000E+06	1.276E-02	4.937E+00
2029	3.000E+06	1.226E-02	4.744E+00
2030	3.000E+06	1.178E-02	4.558E+00
2031	3.000E+06	1.132E-02	4.379E+00
2032	3.000E+06	1.087E-02	4.207E+00
2033	3.000E+06	1.045E-02	4.042E+00
2034	3.000E+06	1.004E-02	3.884E+00
2035	3.000E+06	9.643E-03	3.732E+00

2036	3.000E+06	9.265E-03	3.585E+00
2037	3.000E+06	8.902E-03	3.445E+00
2038	3.000E+06	8.553E-03	3.310E+00
2039	3.000E+06	8.217E-03	3.180E+00
...
2198	3.000E+06	1.421E-05	5.499E-03
2199	3.000E+06	1.365E-05	5.284E-03
2200	3.000E+06	1.312E-05	5.076E-03

**ATTACHMENT 15.A-5 A COPY OF THE GRAPHICAL REPORT FROM THE EXAMPLE
STUDY IN SECTION 4.1**

Projected Ethyl Mercaptan Emissions



VOLUME III: CHAPTER 16

OPEN BURNING

**Revised Final
January 2001**



Prepared by:
Eastern Research Group, Inc.

Prepared for:
Area Sources Committee
Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

This chapter is one of a series of documents developed to provide cost-effective, reliable and consistent approaches to estimating emissions for area source inventories. Multiple methods are provided in the chapters to accommodate needs of state agencies with different levels of available resources and skills; and different levels of needs for accuracy and reliability of their estimates. More information about the EIIP program can be found in Volume 1 of the EIIP series, *Introduction and Use of EIIP Guidance for Emissions Inventory Development*.

Throughout this chapter and other EIIP area source methods chapters, we stress that area source categories should be prioritized by the inventory planners so that resources can be spent on the source categories that are the largest emitters, most likely to be subject to regulations or are already subject to regulations, or require special effort because of some policy reason. Prioritization is particularly important for area source inventories, because in some cases, a difficult to characterize source category may contribute very little to overall emissions and attempting a high quality estimate for that source category may not be cost effective.

EIIP chapters are written for the state and local air pollution agencies, with their input and review. EIIP is a response to EPA's understanding that state and local agency personnel have more knowledge about their inventory area's activities, processes, emissions, and availability of information; and require flexible inventory methods to best use their sometimes limited resources. These EIIP area source chapters are written as a set of options presented to inventory professionals capable of using their own experience and judgement to apply the method that best fits their overall needs and constraints.

This chapter describes the procedures and recommended approaches for estimating emissions from open burning of residential municipal solid waste, land clearing debris, and yard wastes. Section 2 of this chapter contains descriptions of open burning subcategories, their associated pollutants, and restrictions to their occurrence. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation methods for each of the open burning subcategories, and Section 5 presents alternative emission estimation techniques. Quality assurance and quality control procedures are described in Section 6. Data coding procedures are discussed in Section 7, and Section 8 lists all references cited in this chapter.

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2

SOURCE CATEGORY DESCRIPTION

Open burning is the purposeful burning of materials in outdoor areas such as forests and yards. The types of open burning included in this chapter are fires that: (1) result from anthropogenic activities; and, (2) are intentionally set in order to dispose of non-hazardous wastes by burning. This category excludes burning in dedicated combustion devices and buildings, and fires that are accidental, such as forest wildfires or structure fires. Open burning subcategories included in this chapter are open burning of residential municipal (household) solid wastes (MSW), land clearing wastes, and yard wastes. In many cases, however, the approaches for preparing emission estimates for some of the accidental fires may be very similar to the approaches presented here for intentional fires.

2.1 OPEN BURNING SUBCATEGORIES

A description of each of the anthropogenic open burning subcategories is provided in the following text:

- **Residential Municipal Solid Wastes (MSW).** Residential MSW is the nonhazardous refuse produced by households. MSW includes paper, plastics, metals, wood, glass, rubber, leather, textiles, and food wastes. Open burning of MSW at municipal landfills was prohibited by federal law in 1979 (40 CFR 257), therefore, burning of residential MSW is practiced only by private individuals. Most municipalities and some states have laws that prohibit on-site burning of residential MSW. Open burning of residential MSW is a concern mostly in rural areas, where burning is seen as an easier or cheaper alternative to landfilling.
- **Land Clearing Wastes.** The clearing of land for the construction of new buildings and highways often results in debris consisting of trees, shrubs, and brush. This debris may be burned in place but it is usually collected in piles for burning. The burning of land clearing wastes may be practiced by private individuals, corporations, and government agencies (e.g., highway construction department). There are no federal laws restricting the open burning of land clearing wastes, although state or local laws may exist.
- **Yard Wastes.** Yard waste burning is the open burning of materials such as grass clippings, leaves, and trimmings from trees and shrubs. Yard waste burning

takes place where the waste is generated (i.e., residences, parks, institutions such as universities or hospitals, office complexes or other areas where grounds maintenance generates this type of waste) or waste disposal sites where wastes have been collected. Although there are no federal regulations restricting the open burning of yard wastes, many municipalities prohibit or restrict the burning of yard wastes, and promote composting as an alternative.

Previous efforts to estimate emissions from open burning, such as the 1990 base year State Implementation Plan (SIP) inventories for ozone precursors, estimated emissions for the subcategories described in the document *Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone* (EPA, 1991). The open burning subcategories described in that document are forest fires, slash/prescribed burning, agricultural burning, structure fires, rural residential MSW burning, rural commercial/institutional MSW burning, and industrial MSW burning. This chapter does not include agricultural burning prescribed burning, forest fires, structure fires, rural commercial/institutional or industrial MSW. Forest fires and structure fires are outside of this chapter's scope, because these fires are not intentionally set. Emission estimation methods can be found in Chapter 18, Accidental Fires, of this volume. Unless there is evidence of open burning of MSW by commercial/institutional or industrial generators within the inventory area, that source does not need to be included in an inventory.

Open burning practices have changed considerably since the factors in the *Procedures* document were prepared, and the reader should keep in mind that they will likely continue to change. For example, landfilling and recycling policies will affect burning practices. Materials that were previously burned may be landfilled or recycled, resulting in a decrease in open burning emissions. On the other hand, if a landfill closes, raises fees, or no longer accepts certain types of wastes that are combustible, residents may choose to dispose of the material by burning, legally or illegally, resulting in an increase in open burning emissions.

2.2 FACTORS INFLUENCING EMISSIONS

2.2.1 PROCESS FACTORS

Emissions from open burning depend mainly on the type of waste, type of fire, and fuel loading (the weight of the material to the measured volume of the material or the area burned). Residential MSW may include paper, plastics, and other man-made products. Wastes from land clearing and yard debris consist almost entirely of naturally occurring vegetative materials. Emission factors presented in this chapter will reflect the difference in the materials burned for each type of burning. In some cases, different emission factors will be provided for many

different types of fuels for the same type of fire. For example, land clearing emission factors are provided for different vegetation types and burning configurations.

In the case of land clearing burning, the combustion process is important because the different phases of combustion greatly affect the amount of emissions produced. The phases of the combustion process include preheating, flaming and smoldering. Preheating is the first stage, where water and highly volatile hydrocarbons are volatilized. Flaming combustion is the rapid oxidation of the fuel cellulose, lignin, and volatile hydrocarbons, usually consuming fine fuels and surface fuels. As less oxygen is available either from the fuel or from the atmosphere, flaming combustion is harder to maintain and smoldering occurs. Emissions occur at all phases, but individual pollutants are emitted in different proportions during different phases and emissions are related to the rate of fuel combustion (Peterson and Ward, 1993).

AP-42 Section 13.1, Table 13.1-3 (EPA, 1995a) presents emission factors for the flaming and smoldering phases of combustion of forest materials, and a more general factor for the entire fire. The emission factors labeled “fire” for a material type should be used for area source inventories.

The configuration of the burned material will also affect emissions. Land clearing wastes may be piled, collected in windrows (material heaped or collected in rows), or spread out at the time of burning. Land clearing waste burning emission factors are available for different fuel configurations, and these should be used when fuel configuration information is available. When fuel configuration information is not available, recommendations for appropriate emission factors are provided in Sections 4 and 5 in the descriptions of specific methods.

Open burning emissions are also affected by combustion efficiency. Combustion efficiency is the proportion of the waste that is actually burned out of the total amount of waste that is subjected to burning. In a more detailed approach to estimating emissions, it may be appropriate to estimate combustion efficiency. Although combustion efficiency is not discussed in the method descriptions in this section, the inventory preparer may decide that it should be included in emissions calculations.

A fuel loading factor is the final component of an emissions calculation for land clearing burning. Fuel loading factors are provided for these burning types in the descriptions of the preferred and alternative methods.

2.2.2 OTHER FACTORS

Weather affects open burning practices. During extremely dry periods, most regions prohibit any type of open burning, even though it is allowed during normal weather periods. An inventory of open burning emissions for a dry period should result in lower than normal

emission levels. Weather-related catastrophes may cause an increase in open burning emissions. For example, a region may temporarily suspend restrictions on burning of land clearing debris after a hurricane has occurred and a lot of trees have been downed.

2.2.3 CONTROL TECHNIQUES

The most effective control technique for open burning emissions is to ban open burning and require disposal of the wastes by other methods. Composting of land clearing or yard wastes, increasing household waste pickups in an area, or improving recycling rates will reduce burning of these wastes. Another means of disposal is by combustion or incineration in a dedicated furnace or incinerator with emissions control devices. Although incineration also results in emissions, they are generally much lower per unit of mass than emissions from open burning.

Air curtain incinerators may be used to control emissions from open burning. An air curtain incinerator consists of a burn pit and a device that blows air across and into the pit. The effectiveness of these devices in controlling emissions, compared to burning the wastes in a pit without the blower, has been questioned, but they do decrease the amount of time required to burn the waste.

3

OVERVIEW OF AVAILABLE METHODS

Emissions from open burning are estimated by multiplying activity data and emission factors. Emission factors for open burning categories are available from a number of sources. The primary source is *AP-42*, but other EPA documents and documents produced by the USDA Forest Service are good information resources. Emission factors are provided in the preferred methods section of this chapter for each source category, but inventory preparers can use emission factors from other sources if the factors better characterize local conditions.

Activity data used with an emission factor should be specific to the inventory area. One of the particular difficulties with this source category is the frequent lack of activity information. This category requires a number of variables for the emission equation, and some of those variables may not be well defined or available. Inventory preparers will need to be prepared to make well-educated assumptions in some cases. Preferred and alternative methods in this chapter differ mainly in how activity data are collected, and how detailed and area-specific those data are.

Selection of the appropriate estimation method depends on the relative significance of emissions from this source in the inventory area and the data quality objectives (DQOs) of the inventory plan. Refer to EIIP Volume VI, Quality Assurance Procedures, Sections 2.1 and 2.4 for discussions of inventory categories and DQOs.

Each method has advantages and disadvantages in terms of the expense and labor required by the method and the resulting quality of the emission estimate. The inventory preparer must select a method based on the desired accuracy of the emissions inventory and the resources available to develop the inventory.

There are many factors to consider when deciding which open burning subcategories to inventory in a particular area. The selection of the subcategories depends on the data quality objectives (DQOs) of the inventory, the burning practices that take place in the inventory area, the temporal scale of the inventory, and the pollutants of interest. Some types of open burning may simply not be practiced in an area (e.g., prescribed burning of forests in a strictly urban area), or there may be regulations that prohibit or discourage its use. If an inventory is for a specific season or period of the year, it may be that some types of open burning do not occur during that period, although they occur during other seasons of the year. When an inventory is to be pollutant specific, the inventory preparer should determine if any of the open burning subcategories are sources of emissions of that pollutant. If so, the preparer must decide if the

emissions are likely to be significant enough, relative to other sources of that pollutant in the inventory area, to warrant inclusion in the emissions inventory.

3.1 PLANNING

As noted above, open burning may not be practiced or may not be a source of significant emissions in all inventory areas. During the planning stage of the inventory, the open burning subcategories discussed in this chapter should be investigated before they are included in the inventory or methods are chosen to estimate emissions from them. If a type of open burning takes place during the time period of interest for the inventory and if the potential emissions could provide a detectable addition to the total area source emissions, the subcategory should be included in the inventory, and an appropriate estimation method chosen based on the potential level of emissions, inventory budgets, and schedules. However, if a type of open burning is rarely, if ever, practiced in the inventory area, or all or most of the activity occurs outside of the inventory period, then there is no need to estimate emissions from this category. Also, before an estimation method can be chosen, inventory personnel should have researched and made certain that the source of activity information recommended for the estimation method is available and is at a sufficient level to satisfy the DQOs of the inventory. The following paragraphs list the agencies and organizations that can be contacted for the preliminary data collection step.

3.1.1 MUNICIPAL SOLID WASTE (MSW) BURNING

County sanitation, health, and fire departments are most likely to monitor open burning of household wastes. One of these departments or local or state air agencies should be able to indicate whether this type of open burning occurs frequently in the inventory area. In most cases, this activity is not legal or requires a permit.

Factors most likely to increase activity for this subcategory are the lack of garbage pickup, high costs for pickup or disposal, or drop off points that are difficult to reach. Inventory planners should consider these factors when deciding if the subcategory is important to include in their inventory, and if it may become more or less important in the future. If yard waste burning emissions are also being estimated, information about yard waste pickup and composting programs should be collected at the same time as information about MSW.

3.1.2 LAND CLEARING WASTE BURNING

Permits for the burning of land clearing wastes may be issued by local or state air agencies, local fire departments, or local health departments. Other sources of information concerning land clearing activity would be landfill personnel, state departments of transportation (DOT) when a significant proportion of the clearing is for roads, and local planning departments. The number

of burning permits issued should provide an indicator of the scale of the activity in this source subcategory. These same agencies should also know if there are restrictions on burning at certain times of the year, or if there were restrictions during the specific inventory period. For instance, burning for this subcategory and others such as yard wastes can be banned during droughts. On the other hand, catastrophic events such as tornadoes, floods or hurricanes may result in burning of debris even though such burning is ordinarily banned. These agencies should also be aware of alternative disposal methods such as landfilling or composting that are practiced in their area.

Data collection for the land clearing waste subcategory and the prescribed burning subcategory should be coordinated, because these two burning types will sometimes be reported together. These burning types will also rely on similar fuel loading data and will use the same emission factors.

3.1.3 YARD WASTE BURNING

State and local regulations and programs that provide pickup for leaves and other yard debris, or encourage composting of the material should be identified. Rules prohibiting or limiting open burning of yard wastes and the organization that enforces those rules should be identified. In 1996, 23 states had rules banning yard wastes from landfills (EPA, 1996b). Solid waste agencies should be contacted about rules currently in place for an inventory area. Composting programs are meant to reduce the burden on landfills and are typically run by local departments in charge of solid waste. These departments may also track reductions in burning and non-compliance with non-burning rules.

Inventory planners should also define the potential scope of the activity during the inventory time period and in the inventory area. Factors that may increase yard waste burning activity are high costs for pick up or tipping at local landfills, or not having a local landfill that will accept the waste. Some areas may limit burning to leaves and grass clippings only, or prohibit burning during certain times of the year, such as the summer months, or during droughts. Yard waste burning may take place primarily in the rural areas outside of the inventory area, or may take place during a different season than the inventory time period. Estimating emissions from this subcategory may not be necessary if there is little evidence of activity during the inventory time period and area.

Information gathering about the collection or composting of yard wastes should be coordinated with the information collection for MSW.

3.2 AVAILABLE METHODS AND DATA REQUIREMENTS

The following sections outline the preferred and alternative methods for this source category. Sections 4 and 5 of this chapter provide detailed descriptions of the methods.

3.2.1 MUNICIPAL SOLID WASTE BURNING

Table 16.3-1 presents the preferred and alternative methods for estimating emissions from open burning of municipal solid wastes. Emission factors from the most recent *AP-42* section on open burning, Chapter 2, Section 5, and an EPA document titled, *Evaluation of Emissions from the Open Burning Of Household Waste in Barrels*, (EPA, 1997), are used in all of the methods for this burning type. Methods for estimating residential burning of MSW vary in the way that activity data are collected. The preferred method requires a local estimate of the amount of waste burned. The first alternative method takes into account that it may be more convenient to estimate the fraction of waste generated that is not burned than it is to estimate the fraction of waste that is burned. The method provides an approach for estimating the amount of waste open burned in an area, using either locally-generated estimates of the total amount of MSW generated, or a national average per capita waste generation. The amount of waste known to be disposed of through landfilling, composting, incineration or other disposal methods is subtracted from this total, and the remainder is assumed to be open burned. The second alternative method uses emissions data from another area (similar area or an area that contains the inventory area) or tons of waste burned in another area extrapolated to the inventory area.

3.2.2 LAND CLEARING WASTE BURNING

The preferred and alternative methods for estimating emissions from the open burning of land clearing wastes are shown in Table 16.3-2. Emission calculations for all methods are based on determining the fuel type in order to estimate the fuel loading, and the emission factor. Data collection issues, assumptions and factors for fuel loading are provided in Section 4 of this chapter. The preferred method develops activity data through permit data for land debris burning. Estimates of the average tons of fuel burned in the permitted burns will need to be collected from state or local experts. The preferred method uses information that is specifically collected for the inventory area. The first alternative method estimates activity data by estimating the acres of land cleared, estimating the waste generated by the land clearing, and subtracting the waste that is known to be disposed of through other means, such as landfilling or composting. The second alternative method extrapolates emissions or the amount of waste burned from a similar area. Scaling the emissions or activity can be done by comparing rules between the two areas, and either population growth or building activity.

TABLE 16.3-1
SUMMARY OF AVAILABLE METHODS FOR
MUNICIPAL SOLID WASTE BURNING

METHOD DESCRIPTION	ACTIVITY DATA REQUIRED
<p>PREFERRED Collect a local estimate of MSW open burned. Calculation: Amount of waste burned in inventory area * Emission factor</p>	<ul style="list-style-type: none"> - Tons of waste burned in inventory area
<p>ALTERNATIVE 1 Collect a local estimate of the total amount of MSW generated in the inventory area (or estimate using the national per capita waste generation rate) and the amount of MSW that is disposed of by other means (landfilling, incineration). Calculation: (Amount of waste generated in inventory area - Amount of waste disposed of by other means in inventory area) * Emission factor</p>	<ul style="list-style-type: none"> - Tons of waste generated in inventory area - Tons of waste disposed of by other means (other than open burning) in inventory area
<p>ALTERNATIVE 2 Obtain data (emissions or amount of waste burned) from an area that is similar to the inventory area, extrapolate the data to the inventory area based on the ratio of the rural population of the inventory area to the rural population of the similar area, and multiply by an emission factor. Calculation: (Rural population of inventory area/Rural population of similar area) * Emissions from similar area</p>	<ul style="list-style-type: none"> - Emissions data from similar area (or tons of waste burned and emission factors) - Ratio of rural population of similar area to inventory area

TABLE 16.3-2

SUMMARY OF AVAILABLE METHODS FOR LAND CLEARING WASTE BURNING

METHOD DESCRIPTION	ACTIVITY DATA REQUIRED
<p>PREFERRED Collect local activity and fuel loading data.</p> <p>Calculation: Permits for land clearing waste burns in inventory area * Fuel loading factor for each burn * Emission factor</p>	<ul style="list-style-type: none"> - Permits for land clearing burns - Fuel loading factor (ton/burn) - Fuel type (for determining fuel loading and emission factor)
<p>ALTERNATIVE 1 Collect the total number of acres cleared and a local fuel loading factor, subtract the amount of debris that is disposed of by means other than burning.</p> <p>Calculation: [(Acres of land cleared * Fuel loading factor) - Amount of debris disposed of by other means] * Emission factor</p>	<ul style="list-style-type: none"> - Acres of land cleared in inventory area - Fuel loading factor (ton/acre) - Debris disposed of by other means in inventory area (tons)
<p>ALTERNATIVE 2 Obtain data (emissions or amount of waste burned) from an area that is similar to the inventory area, extrapolate the data to the inventory area based on a scaling surrogate.</p>	<ul style="list-style-type: none"> - Activity or emissions from a similar area - The scaling surrogate is a ratio between the similar area and the inventory area based on population growth, acres cleared, or building permits

3.2.3 YARD WASTE BURNING

The preferred and alternative methods for estimating emissions from open burning of yard wastes are presented in Table 16.3-3. The preferred approach is to identify and use locality-specific data, if it is available. This approach, however, may not be an option, and three alternatives are also available. The first alternative is to survey a subset of the inventory area, and scale that estimate up to the larger inventory area. The second alternative is to use information from a similar area and extrapolate the data to the inventory area. Suitable information would be collected using the methods described under the preferred or first alternative methods. The third alternative is to develop a local generation rate that can be scaled to the inventory area, corrected by estimates of the material that is landfilled or composted.

3.3 ADJUSTMENTS FOR CONTROLS

Air curtain incinerators are the only devices currently used to control emissions from open burning. In an air curtain incinerator, a rotating mass (“curtain”) of high velocity, high temperature air is circulated across an open chamber or pit in which burning occurs. The continued air flow over-oxygenates the fire and increases turbulence, resulting in more complete combustion. The effectiveness of air curtain incinerators in reducing emissions has not been fully established. Available factors for burning with air curtain incinerators are provided in Section 4.

Other controls on open burning emissions are regulations that prohibit or restrict open burning, and recycling practices in the inventory area. These controls are reflected in lower activities.

3.4 SPATIAL ALLOCATION

Spatial allocation of the activity data may be necessary in some cases. Spatial allocation is the assignment of an activity level or emission estimate to a smaller or larger geographic area than the area for which it was prepared. Allocation requires the identification of a surrogate indicator that can be used for extrapolation or scaling. In addition to scaling or extrapolating emissions or activity from one area to another, emissions or activity may need to be allocated within the inventory area. When a method uses a spatial surrogate, preferred and alternative surrogates are described as part of the method. Some spatial allocation surrogates would be land use in the area, distribution of rural population, and building permit activity.

TABLE 16.3-3

SUMMARY OF AVAILABLE METHODS FOR YARD WASTE BURNING

METHOD DESCRIPTION	ACTIVITY DATA REQUIRED
<p>PREFERRED Actual measurements of burned material, or existing locality-specific information, either from previous study or local expert.</p>	<ul style="list-style-type: none"> - Waste generated that is burned
<p>ALTERNATIVE 1 Use a study of a subset of the inventory area using permits to burn and violations of burning rules to estimate extent of burning. Scale to larger inventory area.</p> <p>Calculation: (Permits + Violations) * Fuel loading * Scaling factor * Emission factor</p>	<ul style="list-style-type: none"> - Permits to burn - Violations of burning rules - Estimates of fuel loading for each burn - Scaling factors for inventory area
<p>ALTERNATIVE 2 Obtain data (emissions or amount of waste burned) from an area that is similar to the inventory area, extrapolate the data to the inventory area based on a scaling surrogate.</p> <p>Calculation: Yard waste burned in a similar area/Scaling factor for similar area * Scaling factor for inventory area * Emission factor</p>	<ul style="list-style-type: none"> - Waste burned for a similar area (defined by population and land use) - Scaling factors for inventory area and similar area
<p>ALTERNATIVE 3 Develop a local per residence or per acre yard waste generation rate. Estimate total waste generation and subtract the waste that is landfilled or composted.</p> <p>Calculation: (Yard waste generated in small area)/(Scaling factor for smaller area) * (Scaling factor for inventory area) * Emission factor</p>	<ul style="list-style-type: none"> - Yard waste generation for small area within the inventory area - Scaling factor (rural residences, acres of rural residential land use)

3.5 TEMPORAL RESOLUTION

Open burning emissions can be seasonal or influenced by weather conditions. Land clearing waste and yard waste burning may occur only during certain times of the year, and may not take place during the season of interest for a particular inventory. For that reason, it has been emphasized in this chapter that the preparer must investigate the seasonal aspect of the activity before collecting other emission calculation data for these burning types. All of the burning types covered in this chapter may be limited or banned because of seasonal drought or wind conditions. These conditions should also be investigated before committing resources to inventory data collection.

3.5.1 SEASONAL APPORTIONING

The preferred method for allocating open burning emissions is to use local season-specific activity data. An alternative is to collect estimates of seasonal activity percentages from local experts.

3.5.2 DAILY RESOLUTION

Open burning can be expected to take place seven days a week.

3.6 OTHER FACTORS INFLUENCING EMISSIONS ESTIMATES

Natural disasters may affect open burning practices and the resulting emissions. Natural disasters such as hurricanes, tornadoes, or floods may generate wastes, and open burning rules may be suspended to dispose of those wastes. These special conditions should be identified as part of the planning process for an inventory.

3.7 PROJECTING EMISSIONS

A discussion about developing growth factors and projecting emission estimates can be found in Section 4 of Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development*. Projecting emissions for this source category usually will take into account only changes in burning activity because rules for reducing emissions are most likely to reduce activity. Burning of land clearing wastes may be affected by controls if air curtain incineration is used. Emission factors specific to this device should be used to calculate emissions in this case.

Activity and emissions can vary substantially from year to year for open burning types. Sources of variation will depend on the burning type, but some factors apply to all burning types:

- Change in population, either in total or as a population shift from urban to rural areas;
- Changes in cost or location of landfills or other methods of waste disposal; and
- Implementation of new laws that affect types of open burning.

Yard waste composting programs may reduce burning for this waste type.

4

PREFERRED METHOD FOR ESTIMATING EMISSIONS

Because the data collection for this source category can be difficult, the preferred methods presented here are in the form of a set of guidelines for identifying data sources and using assumptions in order to develop reasonable estimates. There is no universal data source that can be used for every inventory to estimate emissions for this source category. When lists of potential data sources are given as part of a method, one or more of these data sources may need to be contacted.

AP-42 is the primary source of emission factors for all of the types of burning covered here. Additional emission factors are presented in Ward, et al. (1989), and two EPA Control Technology Center reports, EPA (1996) and EPA (1997). There are only limited factors in these references for burning of land clearing wastes, but factors developed for prescribed burning can be used for the land clearing subcategory.

Drawbacks to using the preferred methods are that the activity information can be difficult to collect; the process may be expensive in terms of time and effort; and the resulting information may still be based on estimates of activity, rather than measured amounts of materials burned. However, previous estimates of this category were often based on dated waste generation rates, and emission estimates for the category may not have reflected current burning practices. Collecting local, period-specific data and applying reasonable assumptions should provide a much better estimate of the scale and importance of the category relative to the inventory area's air pollution problems.

As with all area source inventory categories, documentation should be maintained for data collected, assumptions, information contacts, and calculations. Because this source category does require making assumptions in order to develop activity levels, the basis for all assumptions should be well documented.

Costs and labor efforts are highest the first time that the preferred methods are used. Subsequent updates to the inventory may be done using a local activity adjustment factor, if a suitable scaling surrogate can be identified. Also, subsequent inventories should take advantage of the data handling and quality assurance/quality control (QA/QC) routines that were put into place

the first time the method was used. See discussions of surveys for area sources in Volume I of the EIIP series and in Chapter 1 of this volume for more information.

4.1 PREFERRED METHODS

4.1.1 MUNICIPAL SOLID WASTE BURNING

The preferred method for estimating emissions from burning MSW is to collect estimates of open burning of MSW, in weight units, from state or local experts, or a survey of a subset of the inventory area. The subset should be representative of the activity throughout the entire inventory area. For the preferred method, the information is collected specifically for the inventory area and the inventory time period. See the discussion of the alternative methods if this level of information is not available.

If activity data are available for a subset of the inventory area, then information will need to be identified that can be used to scale the activity to the entire inventory area. Section 3.1.2 of this chapter discusses factors that influence activity for this source category, such as a lack of garbage pickup services, high costs for pickup or disposal, or drop off points that are difficult to reach. The alternative scaling factor is rural population.

Emission Factors

Emission factors for open burning MSW come from two sources, *AP-42* (EPA, 1995a) and an EPA document *Evaluation of Emissions from the Open Burning Of Household Waste in Barrels*, (EPA, 1997).¹ The recommended emission factors are listed in Table 16.4-1, and the source of each factor is indicated in the table. *AP-42* factors are based on a 1967 study of emissions from two test burns of MSW (Gerstle and Kemnitz, 1967). No detail is provided about the make up of the MSW in that article. The emission factors are expressed in units of the emission rate for the entire refuse weight.

The more recent EPA factors are also based on two test burns, out of four done for the study. Differences between the two test burns are described in the next paragraph. The proportions of waste types are provided in the report. These emission factors are expressed in units of the emission rate for only the fuel that actually burned.

¹ *Evaluation of Emissions from the Open Burning of Household Waste in Barrels*, is available from the Clean Air Technology Center (CATC), on the EPA TTN Website, at: <http://www.epa.gov/ttnecat1/products.html#aptecrpts>.

TABLE 16.4-1

**EMISSION FACTORS FOR OPEN BURNING OF MUNICIPAL REFUSE
(EPA, 1997 AND EPA, 1995a)**

Pollutant	Emissions (lb/ton entire refuse weight)	Emissions (lb/ton actually burned)	Emission Factor Source
Sulfur Oxides	1.0		AP-42 (EPA, 1995a)
Carbon Monoxide	85		AP-42 (EPA, 1995a)
Methane	13		AP-42 (EPA, 1995a)
Nitrogen Oxide	6		AP-42 (EPA, 1995a)
VOCs ^a		8.556	EPA, 1997
PM ₁₀		38	EPA, 1997
PM _{2.5}		34.8	EPA, 1997
Chlorobenzenes		0.0008484	EPA, 1997
Benzene		2.48	EPA, 1997
Acetone		1.88	EPA, 1997
Styrene		1.48	EPA, 1997
Phenol		0.28	EPA, 1997
Dichlorobenzenes		0.00032	EPA, 1997
Trichlorobenzenes		0.00022	EPA, 1997
Tetrachlorobenzenes		0.000148	EPA, 1997
Pentachlorobenzene		0.000106	EPA, 1997
Hexachlorobenzene		0.000044	EPA, 1997
Total Polycyclic Aromatic Hydrocarbons (PAHs) ^b		0.132	EPA, 1997

TABLE 16.4-1

(CONTINUED)

Pollutant	Emissions (lb/ton entire refuse weight)	Emissions (lb/ton actually burned)	Emission Factor Source
Acenaphthylene		0.022	EPA, 1997
Naphthalene		0.036	EPA, 1997
Phenanthrene		0.0146	EPA, 1997
Total Polychlorinated dibenzo-p-dioxins (PCDD)		0.000076	EPA, 1997
Total Polychlorinated dibenzo furans (PCDF)		0.0000122	EPA, 1997
Total Polychlorinated biphenyls (PCB)		0.00572	EPA, 1997
Hydrogen chloride (HCl)		0.568	EPA, 1997
Hydrogen cyanide (HCN)		0.936	EPA, 1997

^a The component VOCs measured for this factor include acetone, which is not considered a reactive VOC for ozone inventories (40 CFR 51.100). Reactive VOC can be calculated by subtracting the separate acetone emission factor in this table from the listed VOC factor. The other component VOCs measured are: 1,3-butadiene, 2-butanone, benzene, chloromethane (methyl chloride), ethyl benzene, naphthalene, styrene, and toluene. More detail about measurements of VOC is available in the source document.

^b Total PAH includes emissions from acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, dibenzo(ah)anthracene, fluoranthene, fluorene, indeno(123cd)pyrene, naphthalene, phenanthrene, pyrene. Individual emission factors for acenaphthylene, naphthalene, and phenanthrene were provided in the source document and are listed in this table.

The mix of household wastes burned in the 1997 EPA study was based on a survey done by the New York State Department of Environmental Conservation's Division of Solid Waste and is based on waste stream characterizations for New York State. Sample waste mixes were prepared for the study for an "avid recycler," who removed the paper from the mix, and a

“non-recycler,” which included all household wastes. Both samples included noncombustables. Emission factors for test burns using the non-recycler’s waste are those recommended here. Test burns of the non-recycler’s waste resulted in about 50 percent of the total waste burned. The non-recycler’s waste included about 20 percent noncombustables, such as glass or metal.

The reader should note important differences in how the emission factors from the two documents can be used. The *AP-42* factors should be applied to the estimated total waste subjected to burning. However, the factors from the 1997 EPA document should be applied to the estimated amount of waste that actually burns. This means that when using factors from the 1997 EPA document, the amount of waste that actually burned must be estimated based on the estimate of the amount of waste subjected to burning. The proportions of waste actually burned to total waste from the 1997 EPA document, discussed above, are recommended.

Example 16.4-1 shows how the emission factors may be used, and what assumptions have to be made.

Example 16.4-1

Estimating emissions from open burning of household waste in County A:

Survey results

A survey has been completed of 1,000 households in a rural portion of County A in the inventory area. The survey area covered only locations where no public or private garbage pickup services are available, determined through telephone conversations with County A’s Planning Department. An average household size is 2.5 people determined from U.S. Census Bureau statistics. Average waste generation for a household is 6.75 lbs per day, and 1.38 lbs of the waste is noncombustible material. Thus, combustible waste per household is 5.37 lb/day. Sixty-seven of the 1,000 households use burn barrels to dispose of combustible household waste.

Survey scaling

U.S. Census Bureau data lists 17,502 households in the rural portion of County A, and 2,636 of the households are in areas where public or private garbage pickup services are available. This study assumes that only the remainder, 14,866 households, are likely to open burn their waste. Of that number, 6.7 percent (from the survey) are expected to actually burn their household waste (996 households).

Emissions calculations for CO and PM

Both of the following waste calculations assume that households that open burn generate the average amount of household waste, noncombustible material is not put in the burn barrels, and that all of the combustible was subjected to burning and not recycled.

Example 16.4-1 (continued)

The emissions calculation using an *AP-42* factor uses total combustable waste. Total combustable waste for County A:

$$\begin{aligned}
 \text{Total Waste} &= 996 * 5.37 \text{ lb/day} \\
 \text{Burned (lb/day)} &= 5349 \text{ lb/day} \\
 &= 2.68 \text{ ton/day} \\
 \\
 \text{CO emissions} &= 85 \text{ lb CO/ton total waste burned} * 2.68 \text{ ton/day} \\
 &= 227.8 \text{ lb CO/day}
 \end{aligned}$$

The emissions calculation using a factor from EPA (1997) uses waste actually burned. Fifty percent of the waste subjected to burning, burned in tests reported in *Evaluation of Emissions from the Open Burning Of Household Waste in Barrels*, (EPA, 1997). Twenty percent of that was noncombustable. In County A, 50 percent of the total household waste generated by household is:

$$\begin{aligned}
 \text{Waste Actually} &= 6.75 \text{ lb/day} * 50\% \\
 \text{Burned (lb/day)} &= 3.38 \text{ lb/day}
 \end{aligned}$$

The waste actually burned for County A is:

$$\begin{aligned}
 \text{Waste Actually} &= 996 * 3.38 \text{ lb/day} \\
 \text{Burned (lb/day)} &= 3366 \text{ lb/day} \\
 &= 1.68 \text{ ton/day}
 \end{aligned}$$

Emissions calculation using factors from EPA (1997):

$$\begin{aligned}
 \text{PM}_{2.5} \text{ emissions} &= 34.8 \text{ lb PM}_{2.5}/\text{ton waste actually burned} * 1.68 \text{ ton/day} \\
 &= 58.5 \text{ lb PM}_{2.5}/\text{day}
 \end{aligned}$$

Activity Level Data Collection

Potential information sources for MSW open burning activity are:

- State solid waste agencies -- these agencies track waste types, generation of wastes and their treatment and disposal.

- Local or state air quality agencies -- these agencies should have information about the rules in place concerning open burning, and they may track violations of the rules, and generate estimates of the activity.
- Local health sanitation departments -- these departments manage waste pickup and disposal, and may have estimates of the amount of household waste (MSW) burned, or estimates of the entire amount generated.
- Local fire and public safety departments -- these departments may track reports of violations of open burning rules. Reports may include burning of MSW, yard wastes and land clearing wastes.

4.1.2 LAND CLEARING DEBRIS

Land clearing debris burning and prescribed burning are similar processes and burn similar fuels. However, only land clearing debris burning is covered in this chapter. In some cases, the distinction between the two subcategories will be the source of the activity data and the purpose of the burning. Some inventories may combine these two subcategories. Care should be taken not to double count activity between land clearing debris burning and prescribed burning.

Land clearing debris is typically piled and then burned, but can also be applied to material collected in windrows, or to broadcast debris (material left undisturbed before burning) over an area. The term slash is used for the debris that is left after logging or clearing.

The preferred method for estimating emissions from burning land clearing debris is to collect permit data for land debris burning from the permitting agency. Estimates of the average tons of fuel burned in the permitted burns of land clearing debris (the fuel loading per burn) will need to be collected from state or local experts. In some cases, the permit may contain enough information to estimate an average or typical amount of fuel burned. However, this method may need to be supplemented with information such as the number of acres cleared for a sample of permits, which would be collected from planning departments or building permits. This method uses information specifically collected for the inventory area.

The amount of land clearing wastes burned can vary from year to year, usually depending on local building and development, and by how much of the material cleared is either sold or disposed of in some other manner. Other factors that may increase activity levels are natural events such as tornadoes or insect infestations that create fallen wood that needs to be disposed of.

Activity Level Data Collection

Potential information sources for land clearing debris burning activity are:

- Local or state air quality agencies -- These agencies should have information about the rules in place concerning debris burning. They may be responsible for permits and may track violations of the rules, and generate estimates of the activity.
- Federal, state and local forest service and agricultural extension agents -- Some land clearing may result from the harvest of commercial timber, or removal of stands of timber that have become diseased. The remaining material may be disposed of by burning. See comments about sources of information about fuel loading.
- Local planning departments -- These departments track building permits and development of land that will result in clearing, and register changes in land use.
- State or local transportation departments -- These departments can estimate the amount of clearing that took place for building new roads. If clearing did take place, the transportation department may also have records that can be used to estimate how much of the clearing debris was landfilled, composted, or burned.
- State solid waste agencies -- These agencies may track or estimate land clearing debris generation, and may maintain records about what happens to the debris. These agencies are most likely to enforce rules about illegal dumping of wastes, and may have estimates of the amount of waste illegally dumped that is from land clearing.
- Local health and sanitation departments -- These departments may have estimates of the amount of land clearing debris generated, or estimates of the amount burned. In some cases, these departments may be responsible for some of the debris burning. These agencies should also be contacted about land clearing debris that is landfilled or composted.
- Local fire and public safety departments -- These departments may track reports of violations of burning rules. Reports may include burning of MSW, yard wastes and land clearing wastes, with no clear distinction between types.

Many areas require that permits be obtained before burning land clearing debris. Although the permits may not include any estimates of the amount of waste burned, local experts may provide

some estimates of typical size piles, or the amount of land cleared for each pile of debris. If permit information is not available, if not all burning requires a permit, or if the information needed for fuel loading is not available, this method cannot be used.

Emission Factors

At the time of this writing, there are no emission factors available that have been developed specifically for land clearing debris burning. The emission factors for prescribed burning from the most recent *AP-42* section on Wildfires and Prescribed Burning, Chapter 13, Section 1, the factors for unspecified forest residues in Table 2.5-2 of the *AP-42* Open Burning section (Chapter 2, Section 5), factors developed by Ward, et al. (1989) for logging slash, factors from the EPA CTC study (EPA, 1996) or emission functions from Peterson and Ward (1993) are recommended. Inventory preparers will have to decide which of these factors best suit the activity data that has been collected for the inventory area, and the local fuel types. The *AP-42* section on prescribed burning and Ward, et al. (1989) include factors for two phases of the burn, termed the flame and the smolder. The flame stage is the initial fire, involving the smaller sized and dryer fuels. The smolder phase occurs after the initial flame, and consumes larger sized fuels and fuels that were initially not dry. Using these emission factors would imply a level of detail rarely possible in area source emission estimates. Therefore, other factors provided for “fire” burns that represent the average emission rate for the flame and smolder phases should be used for area source inventory calculations. Assume that the emission factor for non-methane TOC is entirely VOC.

A bench-scale study of emissions from typical land clearing debris materials has been done by the US EPA Control Technology Center (CTC) (EPA, 1996b), which reports emissions of CO, NO, total hydrocarbons (THC), PM_{2.5}, PM₁₀, and some HAPs. Emission factors for CO, CO₂, methane, non-methane hydrocarbons (NMHC), total PM, PM_{2.5}, PM₁₀, and NO from *AP-42*, Ward, et al. (1989) and the CTC report are compiled in Table 16.4-2. Emission factors have been converted to pounds per ton of fuel for this table. Emission factors from *AP-42* are more general and should be used in most cases. However, the Ward et al. (1989) factors and EPA (1996b) factors can be used if the fuel configurations and material burned descriptions match that being burned in the inventory area.

Emission factors and emission functions are also available for some HAPs. Factors from the EPA (1996b) report are presented in Table 16.4-3, and emission functions from Peterson and Ward (1989) are presented in Table 16.4-4. The EPA (1996b) factors are for piled debris burning. The Peterson and Ward (1993) emission functions were developed to estimate emissions for air toxics from prescribed burning emission factors for carbon monoxide (EFCO), methane (EFCH₄), or total particulates (EFPM). In this way, if one of these pollutants' emission factors varies because of different fuel classifications or combustion phases, pollutants estimated using the functions in Table 16.4-4 will also reflect that difference.

TABLE 16.4-2

LAND CLEARING BURNING CRITERIA POLLUTANT EMISSION FACTORS

EF Source	Fuel Configuration	Material Burned	Pollutants, lb/ton							
			CO	CO ₂	Methane	NMHC	Total PM	PM _{2.5}	PM ₁₀	NO
Ward, et al 1989	Piled	Coniferous Slash	153.20	3,271.20	11.40	8.00	20.40	10.80		
	Piled	Woody Debris	185.40	3,143.40	21.72	15.20	36.40	23.40		
AP-42, 13.1	Piled	Logging Slash	74.00		3.60		12.00	8.00	8.00	
AP-42, 13.1	Broadcast	Logging Slash Hardwood	224.00		12.20	12.80	36.00	22.00	24.00	
AP-42, 13.1	Broadcast	Logging Slash Conifer - Short Needle	350.00		11.20	7.00	34.00	24.00	26.00	
AP-42, 13.1	Broadcast	Logging slash Conifer - Long Needle	254.00		11.40	8.40	40.00	26.00	26.00	
AP-42, 2.5	unspecified	Forest Residues	140.00		5.60	18.00	16.00			
Ward, et al 1989	Broadcast	Douglas-Fir Hemlock Slash	312.40	3,082.40	11.00	7.20	29.60	21.80		
	Broadcast	Hardwood Slash	256.20	3,072.20	13.20	10.80	37.40	22.40		
	Broadcast	Long-Needle Pine Slash	178.40	3,201.80	8.20	6.40	39.60	22.00		
	Broadcast underburn	Mixed Conifer Slash	201.40	3,165.40	12.80	9.80	29.00	18.80		
	Broadcast	Juniper	163.00	3,231.00	12.00	10.40	28.30	18.70	20.40	
EPA 1996b	Test burn ^a	Land Clearing Debris (TN)	46.00			32.00		28.26	33.62	0.74
	Test burn ^a	Land Clearing Debris (TN)	32.00			12.00		20.08	20.50	0.10
	Test burn ^a	Land Clearing Debris (FL)	38.00			18.00		3.50	15.50	0.06
	Test burn ^a	Land Clearing Debris (FL)	30.00			8.00		9.12	9.32	0.18

TABLE 16.4-2

(CONTINUED)

EF Source	Fuel Configuration	Material Burned	Pollutants, lb/ton							
			CO	CO ₂	Methane	NMHC	Total PM	PM _{2.5}	PM ₁₀	NO
EPA 1996b	Test burn with blower ^a	Land Clearing Debris (TN)	24.00			14.00		24.14	24.46	
	Test burn with blower ^a	Land Clearing Debris (TN)	22.00			12.00				0.50

Sources: Ward, et al. (1989); EPA (1995a); EPA (1996b)

^a Factors from this source were derived from individual laboratory test burns. Test debris was collected in Tennessee (TN) and Florida (FL). Two reported test burns were undertaken using blowers to simulate air curtain incinerators. These are marked on the table as 'Test burn with blower'. See the reference document for further description of the study.

TABLE 16.4-3

LAND CLEARING BURNING HAP EMISSION FACTORS (EPA, 1996b)

Compound (lb/ton)	Material Source and Fuel Configuration					
	No Blower				With Blower	
	TN	TN	FL	FL	TN	TN
2-butanone(methyl ethyl ketone)	0.084	0.072	0.080	0.032	0.060	0.038
Ethyl benzene	0.074	0.058	0.042	0.018	0.054	0.070
Styrene	0.152	0.140	0.080	0.034	0.118	0.172
Cumene	0.038	0.007	0.004	Nd	Nd	0.036
Phenol	0.075	0.167	0.130	0.088	0.024	0.190
Dibenzofuran	0.010	0.004	0.008	0.005	0.003	0.009

^a Factors from this source were derived from individual laboratory test burns. Test debris was collected in Tennessee (TN) and Florida (FL). Two reported test burns were undertaken using blowers to simulate air curtain incinerators. These are marked on the table as 'with blower'. See the reference document for further description of the study.

^b Nd - not detected.

Fuel Types

Fuel types described here are the same as those that would be burned in prescribed burning, so descriptions of fuel types developed for prescribed burning can be used for land clearing burning as well. Land clearing waste will typically not include live fuels. Fuel types are made up of varying quantities of the following materials (Peterson and Ward, 1993):

- Woody fuels -- include branches, logs, stumps and limbs.
- Duff -- matted layers of partially decomposed organic matter and high organic content soils such as humus or peat.
- Litter -- Fallen leaves and needles, twigs, bark, cones, and small branches that have not decayed to the extent of losing their identity.

TABLE 16.4-4

**HAP EMISSION FUNCTIONS TO BE USED FOR LAND CLEARING BURNING
(PETERSON AND WARD, 1993)**

Pollutant	Emission Factor Function (lb/ton)^a
Formaldehyde (HCHO)	$(0.0137 * \text{EFCO}) - 0.0358$
Acetaldehyde (C ₂ H ₄ O)	$0.315 * \text{EFHCHO}$
Acrolein (C ₃ H ₄ O)	$(0.0029 * \text{EFCO}) + 0.1398$
1,3-Butadiene (C ₄ H ₆)	$0.00213 * \text{EFCO}$
Benzene (C ₆ H ₆)	$0.00592 * \text{EFCO}$
Toluene (C ₆ H ₅ CH ₃)	$0.00588 * \text{EFCO}$
o-Xylenes	$0.00089 * \text{EFCO}$
m,p-Xylene	$0.00161 * \text{EFCO}$
n-Hexane (C ₆ H ₁₄)	$0.00017 * \text{EFCO}$
Polynuclear Organic Material (POM)	$0.000345 * \text{EFPM}$
Methyl Chloride (CH ₃ Cl)	8.8 to 11.4 ^b
Carbonyl sulfide (COS)	0.267

^a EFCO - carbon monoxide emission factor (lb/ton)

EFHCHO - formaldehyde emission factor as calculated with formaldehyde function (lb/ton)

EFPM - particulate matter emission factor (Total PM) (lb/ton)

^b Flaming factor is presented

Example fuel models are listed in Appendix A. In a detailed study of emissions from burning land clearing waste, emissions from varying quantities of each of the materials listed above would be considered as part of the total emissions. However, fuel type groupings that are useable for area source calculations are much more generalized, such as those listed in Table 16.4-2.

Fuel Loading

Fuel loading estimates are necessary in order to use the emission factors, which are based on the weight of the material burned. Specifically, the debris that is burned will be a function of the total biomass on the area, minus any wood or other material logged or harvested, amount of wood that may be collected as fuelwood, and the amount of wood or other material that is landfilled, composted or allowed to decay. For an area source inventory, generalized estimates

can be made for fuel loading, although if specific information is easily available, it is preferred. The most conservative estimate will assume that all material is burned. However, in areas where there is usable timber, where rules restrict burning, or other disposal methods exist, information about logging, landfilling, composting or firewood use should be collected.

The preferred approach for estimating fuel loading for land clearing debris is to use estimates made specifically for the burns that have taken place. If a state forestry service requires a smoke management report for land clearing debris, or has good compliance in a voluntary program, then that data can be collected and used. If tonnages or volumes of land clearing debris are not reported, then alternatives can be local estimates of the species types and debris amounts that would be typical for the area. Regional estimates for fuel loading can also be used. The U.S. Forest Service compiles forest resource data about forest area, volume, removals, residues and timber product outputs, by region/subregion, ownership class, and species group which could be useful in defining fuel loading for land clearing activity.² Forest Service Technical Reports may include enough information to develop a regional estimate of the amount of debris that typically remains after logging or clearing.

State forestry agencies may compile similar data, and may be able to estimate the amount of material cut for lumber or fuelwood and the amount burned. Landfill operators should have records of the amount of land clearing debris that has been brought in to the landfill. In the absence of reliable estimates, assume that all of the debris in an area that is cleared is burned. However, this latter approach will overestimate emissions.

Other potential resources for fuel loading information are state forestry departments in other states. Data collected in a neighboring state for prescribed burning estimates may have enough similarity to the target state's forest types and disposal practices to be useable for an inventory.

Another alternative for estimating fuel loading is to use a procedure drawn from the Intergovernmental Panel of Climate Change (IPCC, 1994). This procedure can be used when the land cleared is logged before clearing and all useable timber on the cleared land is removed before burning the remainder. The amount of timber that is harvested for commercial use may be available through forest service statistics or state economic reports. Estimates of typical timber yields for an area may also be available from state forest service experts or U.S. Forest Service reports. The procedure uses a factor applied to the amount of logged wood to account for the

² An example publication is *Forest Statistics of the United States, 1992, Metric Units*, (USDA, 1994) which has forest area statistics by state, and per hectare estimates of logging residues by subregion and wood type (hardwood or softwood). These publications are produced by regional forest experiment stations, and more recent publications may be available on the regional stations' Web sites through the Internet.

unharvested portion (limbs, small trees, etc.) of the total biomass that was cleared. This factor is called an expansion ratio, since it expands the measured amount of wood that is removed as logs to calculate the amount of material that remains.

The expansion will take two steps. Because commercial timber may be measured by volume, the first step is to convert the volume of harvested wood to weight units, using the values provided in Table 16.4-5. The table gives density conversion factors for hardwoods and softwoods by typical forest type within a region. The generalized factors represent a weighted average density of the three most common (in terms of volume) softwood or hardwood species within the forest type. Forest types are identified by the primary tree species or tree species groups, but will include other tree species that are typically found in that biome. Local or state forestry service personnel should be able to identify a typical forest type for an area. *AP-42* Appendix A also contains more general conversion factors. The more detailed factors in Table 16.4-5 are preferred.

The second step is to expand the amount of commercial timber harvested to represent the amount that was left behind. Default ratios for expanding harvested timber amounts to unharvested biomass are (IPCC, 1994):

- Undisturbed forests 1.75
- Logged forests 1.90
- Unproductive forests 2.00

Undisturbed forests are, or are close to being, in a natural, undisturbed state. These forests would not commonly be cleared. Logged forests are those that have been logged or cleared previously, and are regrowing, but not fully regrown (a forest may take one hundred years or more to return to the state of an undisturbed forest). Unproductive forests have been overused or poorly managed and may have reduced amounts of usable timber. When the forest type is unknown, the more conservative expansion ratio for unproductive forests should be used as a default.

The calculation is:

$$\text{Unharvested biomass} = \frac{\text{Commercially Harvested Timber (ft}^3\text{)}}{\text{Wood Type Density (lb/ft}^3\text{)}} * \text{Expansion Ratio} \quad (16.4-3)$$

This amount can be assumed to be entirely burned, or can be corrected for the amount which is estimated to be disposed of in other ways: landfilled, composted, or used as fuelwood. The remainder is assumed to be open burned.

TABLE 16.4-5

**FACTORS TO CONVERT WOOD VOLUME (CUBIC FEET) TO
WEIGHT (POUNDS) (EPA, 1995)**

Region	Forest Type	Density Conversion Factors	
		Softwood	Hardwood
Southeast and South Central	Pines	31.8	39.9
	Oak-Hickory	33.4	39.9
	Oak-Pine	32.6	39.9
	Bottomland Hardwoods	28.7	36.2
Northeast and Mid Atlantic	Pines	23.6	33.8
	Spruce-Fir	23.0	32.8
	Oak-Hickory	23.3	39.7
	Maple-Beech-Birch	24.0	37.4
	Bottomland Hardwoods	28.7	36.2
North Central and Central	Pines	26.3	33.1
	Spruce-Fir	21.9	30.0
	Oak-Hickory	26.0	39.4
	Maple-Beech	23.2	35.9
	Aspen-Birch	23.1	29.0
	Bottomland Hardwoods	28.7	36.2
Rocky Mountain and Pacific Coast	Douglas Fir	29.5	23.7
	Ponderosa Pine	26.0	23.7
	Fir-Spruce	21.8	23.7
	Hemlock-Sitka Spruce	27.1	27.0
	Lodgepole Pine	26.4	23.7
	Larch	31.7	27.0
	Redwoods	26.0	36.2
	Hardwoods	26.5	24.0

If only the number of acres cleared is known, then Table 16.4-6 provides a default fuel loading value from *AP-42* for forest residues after harvest, from IPCC (1994) for grasslands, and example fuel loading values from Ward et al. (1989). The example values for fuel loading were developed from tests in the Pacific North West for mostly hardwood, mostly long-needle pine, or mixed conifer forest types.

Emissions Calculations

Emissions calculations for emissions from burning land clearing debris use the following general equation:

$$\text{Emissions} = \text{Area Burned (acres)} * \text{Fuel Loading (tons/acre)} * \text{Emission Factor}$$

TABLE 16.4-6

FUEL LOADING FACTORS -- FOR LAND CLEARING DEBRIS

Source	Debris Type	Fuel Loading	
		(ton/acre)	(Mg/hectare)
<i>AP-42</i>	Unspecified forest residues	70	157
Ward, et al., 1989	Hardwood slash	66	149
	Long-needle pine slash	21	46
	Mixed conifer slash	54	121
IPCC, 1994	Grasslands	4.5	10

In some cases, estimates of the tons of material burned will be substituted for the acres burned and fuel loading factors.

4.1.3 YARD WASTES

Yard wastes include grass clippings, leaves, and tree and brush trimmings from residential, institutional, and commercial sources. Planning and data collection for this source subcategory should include research on local and state rules about open burning of these materials, the disposal of yard wastes in landfills, and composting programs that may be in place for the inventory area. Some localities prohibit open burning of yard wastes, and in that case, emissions from this source subcategory may be negligible. On the other hand, localities may

collect yard wastes and dispose of the waste by burning. Estimating emissions in that case would require an estimate of the yard waste collected by the locality, conversion of volume measurements to weight, assumptions about the predominant materials in the waste, and emission factors for the materials.

The preferred approach for this burning type is to collect locality-specific activity information from a local expert. Sanitation and health departments, local recycling and composting programs, and fire and public safety officials may track local generation or incidences of burning and have estimates of the proportions of the yard waste that landfilled, composted and burned.

In most cases, yard waste amounts will be estimated in units of volume, rather than weight. This unit conversion can be problematic, because densities of grass clippings, leaves, or tree and brush clippings can vary from tens of pounds to hundreds of pounds per cubic yard, depending on the material, compaction and moisture content. The preferred approach for converting volumes to weight is to derive a local estimate for yard wastes in the area. Local refuse haulers that collect materials for composting programs may keep track of weights of incoming loads and the volumes of the trucks. For example, if the volume capacity and tare weight (empty weight) of a truck are known, and gross weights (filled weight) of several loads have been recorded, then the weight to volume ratio can be calculated:

$$\text{Ratio} = (\text{Gross-Tare})/\text{Volume} \quad (16.4-5)$$

Where:

Ratio	=	Weight to volume ratio (yd ³ /tons)
Gross	=	Average filled truck weight (tons)
Tare	=	Empty weight of truck (tons)
Volume	=	Volume of truck (yd ³)

There are major uncertainties in this approach, since the types of materials are unknown and it is unknown whether the truck is full or not. However, the material in the truck has most likely been compacted, and the resulting weight estimate can be taken as a conservative upper limit for yard waste density. As a comparison, MSW weighs between 1,100 and 1,400 lb/cu yd when compacted, and 100 and 200 lb/cu yd when uncompacted (NSWMA, 1985).

Emission factors for leaf burning (unspecified), weeds, and forest residues in *AP-42* Tables 2.5-5 and 2.5-6 in Section 2.5 Open Burning, can be used to calculate emission estimates and are shown in Table 16.4-10. The EPA Office of Solid Waste and Emergency Response estimates that as a “ballpark” composition of yard waste, average composition by weight is 50 percent grass, 25 percent brush, and 25 percent leaves (EPA, 1996). These proportions will

vary according to season, region and climate, and it may be that only one type of yard waste is burned, such as leaves in the fall. Alternatively, the conservative assumption of using the higher emission factor between the two sets of factors can be made.

Emissions Calculations

A general emission calculation for yard waste burning is:

$$\text{Emissions} = \left(\begin{array}{c} \text{Yard} \\ \text{Waste} * \\ (\text{tons}) \end{array} \begin{array}{c} \% \\ \text{Grass} \\ \text{Composition} \end{array} \begin{array}{c} \text{Weeds} \\ * \text{Emission} \\ \text{Factor} \end{array} \right) + \left(\begin{array}{c} \text{Yard} \\ \text{Waste} * \\ (\text{tons}) \end{array} \begin{array}{c} \% \\ \text{Brush} \\ \text{Composition} \end{array} \begin{array}{c} \text{Forest} \\ \text{Residue} \\ * \text{Emission} \\ \text{Factor} \end{array} \right) + \left(\begin{array}{c} \text{Yard} \\ \text{Waste} * \\ (\text{tons}) \end{array} \begin{array}{c} \% \\ \text{Leaf} \\ \text{Composition} \end{array} \begin{array}{c} \text{Leaf} \\ * \text{Emission} \\ \text{Factor} \end{array} \right) \quad (16.5-2)$$

Yard waste is the total estimated amount of yard waste burned. If they are available, the proportions of grass, brush or leaves can be used to subdivide that total to be applied to the weed, forest residue or leaf emission factors, respectively. If the waste type proportions are not known, the equation becomes:

$$\text{Emissions} = \begin{array}{c} \text{Yard} \\ \text{Waste} \\ (\text{Tons}) \end{array} * \text{Emission Factor}$$

Where the emission factor used is the highest for the pollutant shown on Table 16.4-7.

TABLE 16.4-7

YARD WASTE BURNING EMISSION FACTORS (EPA, 1995a)^a

Yard Waste Type	Particulate ^b	Carbon Monoxide	TOC ^c	
			Methane	Nonmethane
	lb/ton	lb/ton	lb/ton	lb/ton
Leaf Species Unspecified	38	112	12	28
Forest Residues, Unspecified	17	140	5.7	19
Weeds, Unspecified	15	85	3	9

^a Emission factors in this table have been given a rating of D in AP-42.

^b The majority of particulate is submicrometer in size.

^c Average TOC emissions are reported for leaf burning are 29% methane, 11% other saturates, 33% olefins, 27% other (aromatics, acetylene, oxygenates). For forest residues and weeds, average TOC values are 22% methane, 7.5% other saturates, 17% olefins, 15% acetylene, 38.5% unidentified. Unidentified TOC are expected to include aldehydes, ketones, aromatics, and cycloparaffins.

5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

Alternative methods require less effort and less cost than the preferred methods, but may result in less detail or estimates that are less specific to the area. The choice of a preferred over an alternative method will be determined by the DQOs and budget of the inventory. For this source category in particular, the significance of this source to total area emissions should be considered when choosing methods.

During the planning stage of the inventory, research should be done to identify data sources, rules affecting the source category, or other factors that might influence emissions from the source category. See Section 16.4.1, Planning, for more specific issues.

5.1 MUNICIPAL SOLID WASTE BURNING

5.1.1 FIRST ALTERNATIVE METHOD

The first alternative method for estimating emissions from burning MSW is to collect estimates of total MSW generation in the inventory area from local experts, and subtract the amount of MSW that is disposed of by methods other than open burning. The remaining amount of waste is assumed to be burned. In this case, the waste generation information and the disposal information are specific to the inventory area.

Sources of information for total MSW generation or estimates of the landfilling, incineration or recycling activity in the area would be many of the same information sources listed in Section 4 of this document for MSW open burning: state solid waste agencies, local sanitation agencies, and local health departments. Other sources could be civil engineering departments in universities, local or state planning departments, or environmental public interest groups.

If no estimates of local activity are available, then estimates will need to be generated. The information needed is:

- Estimated total MSW generated in the inventory area;

- Estimated amount of the MSW that is landfilled, either in the inventory area or outside of the area; and
- Estimated amount incinerated, composted, recycled, or otherwise disposed of.

Typical densities of MSW are:

Loose refuse: 100 to 200 lb/cu yd (NSWMA, 1985)

Compacted waste: 1,100 to 1,400 lb/cu yd (EPA, 1995a)

The general equation for estimating the MSW burned is:

$$\text{MSW Open Burned} = \text{Total MSW Generated} - \left(\text{MSW Landfilled} + \text{MSW Disposed of Using Other Methods} \right) \quad (16.5-2)$$

Other methods of disposal for MSW will be any incineration, composting, or recycling that takes place in the area. Some MSW will also be disposed of by open dumping. Activity for open dumping will be difficult to estimate because it is typically illegal, but state solid waste agencies may be able to provide estimates. Local estimates for total MSW generated are preferred, but calculating estimates based on population-based generation rates are suitable for this source category. The recommended population-based waste generation rate is 3.77 lb MSW generated per person per day, or 0.69 tons MSW generated per person per year (EPA, 1996a).

These generation rates are from the Office of Solid Waste's (OSW) annual report on the characterization of MSW in the US and are for 1994.¹ Waste make up, by material type, is listed in Table 16.5-1. Total MSW reported in the OSW annual report is the MSW that enters the waste stream to be landfilled, incinerated, recycled or composted where the composted material is collected then treated. The estimate includes wastes from households, commercial establishments, and other sources. It does not include the portion that may be open burned or disposed of by other means. Thus, it can be assumed that the per capita MSW generation estimate is an underestimate of the total that is generated in the US. However, within a particular area, the national average per capita generation rate could be either an over- or an

¹ The EPA Office of Solid Waste and Emergency Response maintains an Internet home page at: <http://www.epa.gov/epaoswer/osw/>, and can be reached by telephone through the RCRA hotline at 1-800-424-9346 or 1-800-553-7672, or by mail at RCRA Information Center, U.S. EPA, 401 M Street, SW (5305W), Washington, D.C. 20460.

TABLE 16.5-1

**GENERATION OF MUNICIPAL SOLID WASTE, BY MATERIAL 1994
(EPA, 1996a)**

Materials	lb/person/day
Paper and paperboard	1.71
Glass	0.28
Metals	0.33
Plastics	0.42
Rubber and leather	0.13
Textiles	0.14
Wood	0.31
Other	0.08
Food Trimmings	0.30
Yard trimmings	0.64
Miscellaneous inorganic wastes	0.07
Total MSW Generated	4.41
MSW Generated minus Yard trimmings	3.77

under-estimation. Yard waste should be reported separately, and is discussed in Section 16.5.5 of this chapter.

Estimates of the amount of MSW that is landfilled, and MSW that is disposed of using other methods may have already been collected for the landfill source category emissions estimate described in Chapter 15 of this document. Public health departments, local sanitation departments and individual active landfills may need to be contacted for this information. Activity data for this source category differs from the landfill source category in that landfill activity data includes waste generated before and during the inventory year, and this source category only requires information about the inventory year. Another correction to the landfill

source category activity data may be to remove the estimated amounts of wastes other than MSW. These wastes would be land clearing debris and yard wastes, or industrial wastes, if such wastes are accepted at the landfill.

Emission Factors

The emission factors discussed in Section 4 of this document for municipal waste are recommended. These factors are listed in Table 16.4-4.

5.1.2 SECOND ALTERNATIVE METHOD

The second alternative method for estimating emissions from municipal solid waste burning uses either the activity data collected or the emission estimates that were calculated for another, similar area. The original data should have been collected using the preferred method, but can be data from a different year than that of the current inventory, so long as the similarity between areas is maintained. The data are scaled to the inventory area using a surrogate factor. If activity data are used, the preferred method emission factors are employed to calculate emission estimates.

An alternative to collecting activity from a similar inventory area is to use the per household waste generation factor reported in the EPA report, *Evaluation of Emissions from the Open Burning Of Household Waste in Barrels*, (EPA, 1997). This report is discussed in Section 4.1.2 of this chapter. The waste generation factor used in this report was based on a survey done by the NY State Department of Environmental Conservation's Division of Solid Waste. Table 16.5-2 lists the material types and amounts generated by the surveyed average household of four people. This area is effected by a bottle bill, where beverage containers can be returned for a deposit. This per household waste generation rate is in contrast to the waste generation estimates presented in Table 16.5-1, which is based on the waste total generated by households, commercial establishments and other sources.

The best match between two areas would be for areas that have the same demographic and waste handling situations. During the preparation of emission estimates for the original area, the significant matching factors for activity should have been identified. These factors may include: deposits on glass, plastic and aluminum beverage containers; the presence of a rural, less dense population; lack of refuse haulers; the distance between residences and the landfill; the cost of hauling; and the population's income. If such factors can be identified, they can be used to match inventory areas. Many cities and counties maintain demographic information and information about services that could be useful. The U.S. Census Bureau also reports rural

TABLE 16.5-2**GENERATION OF HOUSEHOLD WASTE, BY MATERIAL (EPA, 1997)**

Materials	lb/household/day
Paper and paperboard	6.7
Glass/Ceramics	1.1
Metals	1.1
Plastics	0.8
Textiles/Leather	0.4
Wood	0.1
Food Waste	0.6
Total Waste Generated	10.8

population numbers for many counties.² The extent of detailed information collected will depend on the DQO of the inventory, the importance of the source category, and resources available.

Rural population is the primary factor for matching inventory areas, and can also be used to scale the emissions or the activity from the original area to the inventory area. Example 16.5-2 shows a typical scaling calculation:

² U.S. Census Bureau data are available on CD-ROMs, paper reports, and can be viewed on the Internet on: <http://venus.census.gov/cdrom/lookup>. Summary files under the Census Summary Tape File 3 (STF3) listing on the Internet site will include population, households, household income, education level and other population and housing statistics by county and by census tract. The Summary Tape File 1A CD-ROM will have the same data, as will the Census printed reports, *Summary Population and Housing Characteristics*, CPH-1 for county-level data, and *Population and Housing Characteristics for Census Tracts and Block Numbering Areas*, CPH-3.

Example 16.5-2

County A has a total population of 38,759, of which 33,951 people are considered rural residents, from U.S. Census data. Using the first alternative method, it has been estimated that 593 tons of MSW is burned in County A. County B has a total population of 181,835, of which 27,078 people are rural residents.

The scaling equation is:

$$\begin{aligned} \text{County B MSW Emissions} &= \frac{\text{County B Rural Population}}{\text{County A Rural Population}} * \text{County A MSW Burned} \\ \text{County B MSW Burned} &= \frac{27,078 \text{ Rural Residents}}{33,951 \text{ Rural Residents}} * \frac{593 \text{ tons MSW Burned}}{1} \\ &= 473 \text{ tons MSW Burned} \end{aligned}$$

Emission Factors

The emission factors discussed in Section 4 of this document for municipal waste are recommended. These factors are listed in Table 16.4-4.

5.2 LAND CLEARING WASTE BURNING

Methods for this burning type all use the emission factors discussed in Section 4, and vary only in the specificity of the activity data and fuel loading factors used to the inventory area. The information sources for activity and fuel loading that are listed in Section 4 for this type of burning can be used for the alternative methods listed below.

5.2.1 FIRST ALTERNATIVE METHOD

The first alternative method is to estimate the amount of debris burned by collecting estimates of debris generated by the land cleared in the inventory area during the inventory time period, and subtracting the amount of debris that is disposed of by other methods.

Activity data is developed for this method in three steps:

- Estimate the amount of land cleared in the inventory area during the inventory time period;
- Estimate the amount of debris generated for a typical acre of cleared land and multiply by the acres of land cleared; and
- Estimate the amount of debris that is not burned -- either landfilled, composted, or if possible estimates of debris that is illegally dumped, and then subtract from the estimated total amount of debris generated.

See the listing of information sources under land clearing activity level data collection in Section 4 of this chapter. Planning departments and DOTs should be contacted for information about the amount of land cleared, and if possible, whether the debris was burned and if the land was logged first, which would reduce the amount of debris. Forest service offices can be contacted for information about the type of plant cover that would be burned in a particular area. State solid waste agencies or environmental agencies may be able to provide estimates of how much land clearing debris is illegally landfilled. State solid waste, landfill operators, and local sanitation agencies should have estimates of the amounts of land clearing debris that were accepted at local landfills during the inventory period. The cost of hauling this type of debris over great distances would be prohibitive. Debris generated far from a landfill is probably not sent to a landfill.

Refer to the land clearing portion of Chapter 4 for more information about information sources and choosing fuel loading and emission factors.

5.2.2 SECOND ALTERNATIVE METHOD

The second alternative method for estimating emissions from burning land clearing waste uses either the activity data collected or the emission estimates that were calculated for another, similar area. Review the discussion of fuel types and fuel loadings for land clearing debris burning in Section 4.2.3. The original data can be collected using either the preferred or the first alternative methods. The data can also be from a different time period than that of the inventory, so long as the similarity between areas is maintained. The data is scaled to the inventory area using a surrogate factor. If activity data is used, the preferred method emission factors are used to calculate emissions.

Areas should be matched by comparing disposal rules, disposal methods, and costs for disposing of land clearing waste, and land cover types. Land covers should share enough common qualities so that the fuel loading is similar. Areas can also be compared by looking at land use

patterns. Clearing that is done for roads and commercial development will clear more per acre of the land than that done for residential development.

Two types of scaling factors can be used for this source subcategory. If most of the land clearing is for residential building, population growth can be used. If land clearing has been done for roads, commercial development and residential building, the acres cleared should be used to scale activity from the original area to the inventory area. Alternatively, the number of residential and commercial building permits may be used to scale activity between the two areas.

Emission estimates are calculated using the same equations and emission factors as the preferred method.

5.3 YARD WASTE BURNING

Alternative methods for this type of burning differ from the preferred approach in that they use less specific activity information and require more assumptions. Please review the discussion of the types of material burned, conversion factors for, and other factors that affect data collection and calculations under the discussion of the preferred method.

5.3.1 FIRST ALTERNATIVE METHOD

The first alternative method uses records of permits and violations of rules prohibiting yard waste burning. If records are maintained of permits and violations, then an estimate of yard waste burning from the permits and reported violations may be possible. Assumptions necessary to transform reports of violations into an estimate of activity are estimates of the typical volume and material for piles of yard waste, and scaling surrogates in order to scale reports of burning from one small portion of the inventory area to the rest of the inventory area.

5.3.2 SECOND ALTERNATIVE METHOD

The second alternative method for estimating emissions from burning yard waste uses either the activity data collected or the emission estimates that were calculated for another, similar area. Review the discussion of yard waste activity and limits on activity in Section 4.2.5. The data is scaled to the inventory area using a surrogate factor. If activity data is used, the preferred method emission factors are employed in the emission estimation calculations.

The area used as a data source should be matched to the inventory area using similarities in rules, waste disposal practices (such as composting programs and yard waste pickup programs) and population density. Activity or emission estimates should be scaled using population.

5.3.3 THIRD ALTERNATIVE METHOD

The third alternative method uses a local per acre waste generation rate, multiplied by residential land use, and corrected with the amounts of yard waste that are estimated to be landfilled or composted for the inventory area. Like the first alternative method discussed above, this method relies on sampling a small portion of activity, and scaling it up for the entire inventory area. The local generation rate is an estimate of what a typical maintained acre produces in grass, trimmings, and leaves during either a year or during the inventory period. Detailed information is unlikely, and gross assumptions will have to be made. Only one contact should be necessary in order to develop a generation rate. Potential contacts are:

- Sanitation or health department personnel in areas where yard wastes are collected separately from other wastes.
- The grounds maintenance crews of a landscaped park, or an institution with grounds that may be similar to residential lots can be contacted for estimates of the waste generated over a typical time period.

Volumes or weight amounts of the wastes collected for a known area can be averaged to a typical acre. See Section 4.2.4 for more information about converting volume measures of yard waste to weight measures. The per acre yard waste generation rate is applied to the amount of the inventory area that is defined as residential, commercial and institutional land use. Local planning departments or tax offices should be able to provide land use information.

The total yard waste generated for the inventory area is corrected by subtracting the amount of waste that is collected and disposed of, or composted in the area. These estimates may be available from health or sanitation departments, landfill operators, waste collection departments, or local recycling and composting programs. It should be assumed that a certain amount of yard waste is composted on-site where it was generated. Local recycling and composting programs may be able to supply estimates of on-site composting. The remaining waste is assumed to be burned.

There are considerable uncertainties in the scaling and correction steps of this approach. The assumption necessary to use the per acre yard waste generation rate to the inventory area will be an assumption of typical lot size.

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6

QUALITY ASSURANCE/QUALITY CONTROL

Data collection and data handling for this source category should be planned and documented in the Quality Assurance Plan. Quality assurance (QA) and quality control (QC) methods may vary based on the data quality objectives for the inventory.

When using survey methods and other detailed methods that require data collection from permits, or reports of violations, then the survey method, sample design, data collection, and data handling steps should be documented in the Quality Assurance Plan. Refer to the discussion of survey planning and survey QA/QC in Chapter 1, *Introduction to Area Source Emission Inventory Development*, of this volume, and Volume VI, *Quality Assurance Procedures*, of the Emission Inventory Improvement Program (EIIP) series. When using other methods, data handling for activity, fuel loading factors, and emission factors should be planned and documented in the Quality Assurance Plan. For all methods, the basis for choosing fuel loading factors, and emission factors should be documented. Methods that use surrogate scaling factors should also include an explanation of why those factors were chosen.

Potential pitfalls when preparing estimates for this source category are the potential overlap and double counting of the open burning subcategories, use of the wrong fuel loading factor, the choice of inappropriate scaling factors, or unit conversion errors.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

The Data Attribute Rating System (DARS) has been developed as a tool to rate emission inventories. A description of the system and the EIIP recommendations for its use can be found in Appendix F of EIIP Volume VI, *Quality Assurance Procedures*. The following discussion uses the DARS rating system as a way to compare the estimation approaches presented in this chapter and analyze their strengths and weaknesses.

There are not large variations in the Data Attribute Rating System (DARS) scores between preferred and alternative methods for most of the open burning source categories discussed in this chapter. Emissions for all of the open burning source categories are estimated using activity, fuel loading, and emission factors, and values for these parameters vary widely for very similar circumstances; this means that for most of these source categories, estimates based on

careful and detailed collection of data for these three parameters may still be far from the actual emissions.

Emission factor scores provided here reflect emission rate variations dependent on differences in the materials burned, burning types (smoldering vs. flaming), and whether the factors are averages of direct measurements or ratios. Activity factor scores reflect variability in the amount of available fuel that actually burned, fuel loading, and spatial and temporal variability introduced when data from one area is scaled or extrapolated to the inventory area.

The effort required in collecting high quality activity information for these open burning source categories and the inherent difficulty in obtaining good quality emission estimates, even when detailed information has been collected, should be considered when planning the inventory and choosing an estimation method.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The DARS scores for emission estimation methods for municipal solid waste burning are shown in Tables 16.6-1 through 16.6-3; for land clearing waste burning, in Tables 16.6-4 through 16.6-6; and for yard waste burning Table 16.6-7 through 16.6-10. A range of scores is given for many of the methods to account for the applicability of the available emission factors to the materials that are actually being burned in the inventory area, the specificity of fuel loading factors used, and different approaches for collection and scaling of activity data for a particular method. DARS scores for these methods and for these source categories can be improved if the uncontrolled variables that affect emissions can be limited.

6.2 SOURCES OF UNCERTAINTY

There are many sources of uncertainty in estimating emissions from open burning source categories. Historically, emissions from this source category have been difficult to estimate because of the lack of cost-efficient data collection methods and the large number of variables that affect emissions. Methods presented here provide some more streamlined approaches, but at a cost of less area-specific estimates. The data quality objectives for a particular inventory and the priority of the open burning source category in the inventory should be used as a guide when choosing inventory methods.

Although the methods presented here generally use only emission factors, fuel loading factors, and activity factors, many other parameters operate when burning actually takes place. Details for these other parameters, which include fuel moisture, type of combustion, and the amount of fuel that is actually burned, are not available at the level required in an area source inventory. The variance that may exist between burning that takes place in the inventory area and the

burning measured to develop emission factors or fuel loadings cannot be defined without a detailed study outside of the usual scope of an area source inventory.

In many cases, methods presented in this chapter recommend that data collected by survey or other detailed methods such as permits or burning violation reports should be done for only a subset of the inventory area or should be collected for another similar area. These data will need

to be scaled to the entire inventory area using a scaling surrogate. In all cases, scaling data from another area will add uncertainty to the estimate of activity. If burning practices are well matched from the data source area to the inventory area, this uncertainty is reduced; but if burning practices are not similar, choosing an appropriate surrogate factor becomes more important. In the case of the yard waste burning methods that use scaling, the inventory preparer is expected to identify an appropriate scaling surrogate. Selecting the best scaling surrogate will depend on the reasons that people burn and the material that they burn. Examples of appropriate scaling surrogates for this subcategory of open burning are the number of rural residences, residential lot size, or household income.

TABLE 16.6-1

MSW BURNING
PREFERRED METHOD: LOCAL ESTIMATE

Attribute	Scores		
	Factor ^a	Activity	Emissions
Measurement	0.4	0.4 - 0.6	0.16 - 0.24
Source specificity	0.6	0.7	0.42
Spatial congruity	0.7	0.7 - 0.9	0.49 - 0.63
Temporal congruity	0.5	0.7	0.35
Composite	0.55	0.63 - 0.73	0.36 - 0.41

^a Emission factors are from AP-42 with a factor rating of D.

TABLE 16.6-2

MSW BURNING
ALTERNATIVE METHOD 1: ESTIMATED TOTAL MINUS LANDFILLED AMOUNT

Attribute	Scores		
	Factor ^a	Activity	Emissions
Measurement	0.4	0.4	0.16
Source specificity	0.6	0.6	0.36
Spatial congruity	0.7	0.7	0.49
Temporal congruity	0.5	0.7	0.35
Composite	0.55	0.6	0.34

^a Emission factors are from AP-42 with a factor rating of D.

TABLE 16.6-3

MSW BURNING
ALTERNATIVE METHOD 2: SCALING OF DATA FROM A SIMILAR AREA

Attribute	Scores		
	Factor ^a	Activity	Emissions
Measurement	0.4	0.4	0.16
Source specificity	0.6	0.5 - 0.6	0.3 - 0.36
Spatial congruity	0.7	0.6	0.42
Temporal congruity	0.5	0.7	0.35 - 0.35
Composite	0.55	0.55 - 0.58	0.31 - 0.32

^a Emission factors are from AP-42 with a factor rating of D.

TABLE 16.6-4

**LAND CLEARING WASTE BURNING
PREFERRED METHOD: LOCAL ACTIVITY AND FUEL LOADING DATA**

Attribute	Scores		
	Factor ^a	Activity	Emissions
Measurement	0.4 - 0.7	0.7	0.28 - 0.49
Source specificity	0.5 - 0.8	0.7 - 0.9	0.35 - 0.72
Spatial congruity	0.7	0.9	0.63
Temporal congruity	0.8	0.6 - 0.8 ^b	0.48 - 0.64
Composite	0.6 - 0.75	0.73 - 0.83	0.44 - 0.62

^a Score depends on the factor used. Refer to source material for emission factors Current AP-42 factors get the lower score.

^b Fuel loading may vary by season, it is unlikely that it will be taken into account for these estimates. The higher score is for data specific to the inventory time period, the lower score is given if data has been collected for a different season, or for an entire year, when seasonal emissions must then be apportioned.

TABLE 16.6-5

**LAND CLEARING WASTE BURNING
ALTERNATIVE METHOD 1: ESTIMATE FROM TOTAL LAND CLEARED AND
AMOUNT OF MATERIAL DISPOSED OF BY OTHER MEANS**

Attribute	Scores		
	Factor ^a	Activity	Emissions
Measurement	0.4 - 0.7	0.30	0.12 - 0.21
Source specificity	0.5 - 0.8	0.60	0.3 - 0.48
Spatial congruity	0.70	0.70	0.49
Temporal congruity	0.80	0.6 - 0.8 ^b	0.48 - 0.64
Composite	0.6 - 0.75	0.55 - 0.6	0.35 - 0.46

^a Score depends on the factor used. Refer to source material for emission factors Current AP-42 factors get the lower score.

^b Fuel loading may vary by season, it is unlikely that it will be taken into account for these estimates. The higher score is for data specific to the inventory time period, the lower score is given if data has been collected for a different season, or for an entire year, when seasonal emissions must then be apportioned.

TABLE 16.6-6

**LAND CLEARING WASTE BURNING
ALTERNATIVE METHOD 2: EXTRAPOLATE DATA FROM A SIMILAR AREA**

Attribute	Scores		
	Factor ^a	Activity	Emissions
Measurement	0.4 - 0.7	0.3 - 0.7 ^b	0.12 - 0.49
Source specificity	0.5 - 0.8	0.6 - 0.9	0.30 - 0.72
Spatial congruity	0.7	0.5 - 0.7	0.35 - 0.49
Temporal congruity	0.8	0.6 - 0.8 ^c	0.48 - 0.64
Composite	0.6 - 0.75	0.5 - 0.78	0.31 - 0.59

^a Score depends on the factor used. Refer to source material for emission factors Current AP-42 factors get the lower score.

^b Activity score depends on the method used to collect data in the similar area (see scoring for preferred and alternative one methods).

^c Fuel loading may vary by season, it is unlikely that it will be taken into account for these estimates. The higher score is for data specific to the inventory time period, the lower score is given if data has been collected for a different season, or for an entire year, when seasonal emissions must then be apportioned.

TABLE 16.6-7

**YARD WASTE BURNING
PREFERRED METHOD: LOCAL DATA**

Attribute	Scores		
	Factor ^a	Activity	Emissions
Measurement	0.4	0.4 - 0.6	0.16 - 0.24
Source specificity	0.6	0.5 - 0.7	0.3 - 0.42
Spatial congruity	0.5	0.7 - 0.9	0.35 - 0.45
Temporal congruity	0.8	0.7	0.56
Composite	0.58	0.58 - 0.73	0.34 - 0.42

^a Emission factors are from AP-42 with a factor rating of D.

TABLE 16.6-8

YARD WASTE BURNING
ALTERNATIVE METHOD 1: SMALL-SCALE SURVEY FROM PERMITS AND VIOLATIONS

Attribute	Scores		
	Factor^a	Activity	Emissions
Measurement	0.4	0.5	0.2
Source specificity	0.6	0.5 - 0.7	0.3 - 0.42
Spatial congruity	0.5	0.5 - 0.7	0.25 - 0.35
Temporal congruity	0.8	0.8	0.64
Composite	0.58	0.58 - 0.68	0.35 - 0.4

^a Emission factors are from AP-42 with a factor rating of D.

TABLE 16.6-9

YARD WASTE BURNING
ALTERNATIVE METHOD 2: EXTRAPOLATE FROM A SIMILAR AREA

Attribute	Scores		
	Factor^a	Activity	Emissions
Measurement	0.4	0.4	0.16
Source specificity	0.6	0.5	0.3
Spatial congruity	0.5	0.5 - 0.6	0.25 - 0.3
Temporal congruity	0.8	0.7	0.56
Composite	0.58	0.53 - 0.55	0.32 - 0.33

^a Emission factors are from AP-42 with a factor rating of D.

TABLE 16.6-10

YARD WASTE BURNING
ALTERNATIVE METHOD 3: ESTIMATED LOCAL YARD WASTE MINUS LANDFILLED OR
COMPOSTED YARD WASTE

Attribute	Scores		
	Factor^a	Activity	Emissions
Measurement	0.4	0.4	0.16
Source specificity	0.6	0.5 - 0.7	0.3 - 0.42
Spatial congruity	0.5	0.5 - 0.7	0.25 - 0.35
Temporal congruity	0.8	0.5	0.4
Composite	0.58	0.48 - 0.58	0.28 - 0.33

^a Emission factors are from AP-42 with a factor rating of D.

7

DATA CODING PROCEDURES

The inventory preparer should check the EPA website (<http://www.epa.gov/ttn/chief/>) for the latest information (codes) available to characterize emission estimates from open burning. A complete list of Source Classification Codes (SCC) can be retrieved at <http://www.epa.gov/ttn/chief/codes/>. Table 16.7-1 lists the applicable SCCs for open burning.

Available codes and process definitions influence and help guide the preparation of emission estimates for this category. Data transfer formats should be taken into account when an inventory preparer plans for data collection, calculation, and inventory presentation. Consistent categorization and coding will result in greater continuity between emission inventories for use in regional and national scale analyses.

7.1 NECESSARY DATA ELEMENTS

If the category emissions data will be transferred to EPA for incorporation into the national criteria and toxics air pollutant inventory, specific data transfer formats are acceptable. The acceptable data transfer format(s) are described and available for download at <http://www.epa.gov/ttn/chief/net/>. The acceptable data transfer formats contain the data elements necessary to complete the data set for use in regional or national air quality and human exposure modeling. The inventory preparer should review the area source portion of the acceptable file format(s) to understand the necessary data elements. The EPA describes its use and processing of the data for purposes of completing the national inventory, in its Data Incorporation Plan, also located at <http://www.epa.gov/ttn/chief/net/>.

TABLE 16.7-1**AREA AND MOBILE SOURCE CATEGORY CODES FOR OPEN BURNING**

Process Description	Source Category Code
Open Burning - All Categories	26-10-000-000
Open Burning - Industrial	26-10-010-000
Open Burning - Commercial/Institutional	26-10-020-000
Open Burning - Residential	26-10-030-000
Open Burning - Other Combustion: Managed Burning -- Slash	28-10-005-000

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APPENDIX A

**PRESCRIBED BURNING
FUEL CATEGORIES
(PETERSON AND WARD, 1993)
TO BE USED FOR
LAND CLEARING WASTE BURNING**

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Emission rates from prescribed burning vary depending on the fuels burned. One system for categorizing the materials burned is the National Fire Danger Rating System, which uses 20 fuel models to organize fuels according to their response to weather and influence on fire behavior. Definitions of fuel components and the 20 fuel models are listed below.

FUEL COMPONENTS

1. Fine fuels less than 1 inch in diameter consisting of grasses, needles, and/or small twigs.
2. Small fuels 1 to 3 inches in diameter consisting of small branches and/or brush stems.
3. Large fuels greater than 3 inches in diameter consisting of large branches and/or logging debris.
4. Live woody fuels from live, brush plants such as chaparral, palmetto-galberry, and juniper.
5. Litter and duff from the organic layers above the mineral soil. The litter retains its original form, in contrast to duff which, by definition, is partially or fully decayed organic residue.

EXAMPLE FUEL MODELS

Brief descriptions of the NFDRS fuel models follow:

- Fuel Model A: Western grasslands vegetated by annual grasses and forbs. Brush or trees may be present, but are very sparse, occupying less than one-third of the area. Examples include cheatgrass and medusahead, open pinyon-juniper, sagebrush-grass, and desert shrub.
- Fuel Model B: Mature, dense field of brush 6 feet or more in height are represented by this fuel model. This model is for California mixed chaparral, generally 30 years or older.
- Fuel Model C: Open pine stands typify Model C fuels. Perennial grasses and forbs are the primary ground fuel, but there is enough needle litter and branchwood present to contribute significantly to the fuel loading. Some brush and shrubs may be present, but they are of little consequence. Examples are open longleaf, slash, ponderosa, Jeffrey, and sugar pine stands.
- Fuel Model D: This fuel model is specifically for the palmetto-galberry understory-pine overstory association of the southeast coastal plains.

- Fuel Model E: This model is for hardwood and mixed hardwood-conifer types after leaf fall. The primary fuel is hardwood leaf litter.
- Fuel Model F: Mature closed chamise and oak brush fields of Arizona, Utah, and Colorado are represented by Fuel Model F. It also applies to young, closed stands and to mature, open stands of California mixed chaparral.
- Fuel Model G: Fuel Model G is used for dense conifer stands where there is a heavy accumulation of litter and downed woody material. Such stands are typically overmature and may also be suffering insect, disease, wind, or ice damage--natural events that create a very heavy buildup of dead material on the forest floor. Types meant to be represented by Fuel Model G are hemlock-Sitka spruce, coast Douglas fir, and windthrown or bug-killed stands of lodgepole pine and spruce.
- Fuel Model H: The short-needed conifers (white pines, spruces, larches, and firs) are represented by Fuel Model H. In contrast to Model G fuels, Fuel Model H describes a healthy stand with sparse undergrowth and a thin layer of ground fuels.
- Fuel Model I: Fuel Model I was designed for clearcut conifer slash where the total loading of materials less than 6 inches in diameter exceeds 25 tons/acre.
- Fuel Model J: This is for clearcuts and heavily thinned conifer stands where the total loading of materials less than 6 inches in diameter is less than 25 tons per acre.
- Fuel Model K: Slash fuels from light thinnings and partial cuts in conifer stands are represented by Fuel Model K. Typically the slash is scattered about under an open overstory. This model applies to hardwood slash and to southern pine clearcuts where the loading of all fuel is less than 15 tons/acre.
- Fuel Model L: This fuel model is meant to represent western grasslands vegetated by perennial grasses. The principal species are coarser and the loadings heavier than those in Model A fuels.
- Fuel Model N: This model was constructed specifically for the sawgrass prairies of south Florida. It may be useful in other marsh situations where the fuel is coarse and reedlike.

- Fuel Model O: Model O applies to dense, brushlike fuels of the southeast. The high pocosins of the Virginia and North and South Carolina coasts are the ideal of Fuel Model O.
- Fuel Model P: Closed, thrifty stands of long needled southern pines are characteristic of P fuels.
- Fuel Model Q: Upland Alaskan black spruce is represented by Fuel Model Q. This fuel model may also be useful for jack pine stands in the Lake States.
- Fuel Model R: This model represents the hardwood areas after the canopies leaf out in the spring.
- Fuel Model S: Alaskan or alpine tundra on relatively well-drained sites is represented by Model S. Grass and low shrubs are often present, but the principal fuel is a deep layer of lichens and moss.
- Fuel Model T: The sagebrush-grass types of the Great Basin and intermountain west are characteristics of T fuels. This model might also be used for immature scrub oak and desert shrub associations in the west, and the scrub oak-wire grass in the southeast.
- Fuel Model U: Closed stands of western long-needled pines are covered by this model. Fuel Model U should be used for ponderosa, Jeffrey, sugar, and red pine stands of the Lake States.

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VOLUME III: CHAPTER 17

ASPHALT PAVING

**Revised Final
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Prepared by:
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Area Sources Committee
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DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

This chapter is one of a series of documents developed to provide cost-effective, reliable and consistent approaches to estimating emissions for area source inventories. Multiple methods are provided in the chapters to accommodate needs of state agencies with different levels of available resources and skills; and different levels of needs for accuracy and reliability of their estimates. More information about the EIIP program can be found in Volume 1 of the EIIP series, *Introduction and Use of EIIP Guidance for Emissions Inventory Development*.

This chapter describes the procedures and recommended approaches for estimating emissions from asphalt paving. Section 2 of this chapter contains a general description of the asphalt paving category, the emission sources, and an overview of available control technologies. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation method for asphalt paving, and Section 5 presents alternative emission estimation techniques. Quality assurance and quality control (QA/QC) procedures are described in Section 6. Coding procedures used for data input and storage are discussed in Section 7, and Section 8 is the reference section.

Throughout this chapter and other EIIP area source methods chapters, we stress that area source categories should be prioritized by the inventory planners so that resources can be spent on the source categories that are the largest emitters, most likely to be subject to regulations or are already subject to regulations, or require special effort because of some policy reason. Prioritization is particularly important for area source inventories, because in some cases, a difficult to characterize source category may contribute very little to overall emissions and attempting a high quality estimate for that source category may not be cost effective.

EIIP chapters are written for the state and local air pollution agencies, with their input and review. EIIP is a response to EPA's understanding that state and local agency personnel have more knowledge about their inventory area's activities, processes, emissions, and availability of information; and require flexible inventory methods to best use their sometimes limited resources. These EIIP area source chapters are written as a set of options presented to inventory professionals capable of using their own experience and judgement to apply the method that best fits their overall needs and constraints.

This source category does not include emissions from asphalt plants, or emissions from other related products such as roofing asphalts and sealers. It also does not include emissions that may occur during the road preparation prior to paving.

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2

SOURCE CATEGORY DESCRIPTION

2.1 PROCESS DESCRIPTION

Asphalt paving is used to pave, seal, and repair surfaces such as roads, parking lots, drives, walkways, and airport runways. Asphalt concrete used in paving is a mixture of asphalt cement, which is a binder, and an aggregate. Asphalt cement is the semi-solid residual material left from petroleum refining after the lighter and more volatile fractions have been distilled out. Hot-mix asphalt is a mixture of heated asphalt cement and aggregate. Asphalt cutbacks are asphalt cements thinned with petroleum distillates (dilutents). Asphalt emulsions are mixtures of asphalt cement with water and emulsifiers. Aggregates used in asphalt cements are typically rock gravel or recycled asphalt pavement, but can also be byproducts from metal ore refining processes. Aggregate may constitute up to 95 percent by weight of the total mixture.¹ Mixture characteristics for asphalt concrete are determined by the amount and grade of asphalt cement used, the addition of solvent- or soap-based liquefying agents, and the relative amount and types of aggregate used.

Recycled asphalt pavement (RAP) is being used more frequently, partly as a means to reduce solid waste. One source estimates that 90 percent of asphalt processed is RAP.¹ To reuse the asphalt, the RAP is typically pulverized; sorted; mixed with recycling agents such as lime or calcium chloride, or additional aggregate; then applied. The five methods of recycling are: cold planing, hot recycling, hot in-place recycling, cold in-place recycling, and full depth reclamation. All except hot recycling occur at the location where paving is to be done, although material removed during cold planing may be processed at an asphalt plant.

2.1.1 ASPHALT CONCRETE

Asphalt concrete is grouped into three general categories: hot-mix, cutback, and emulsified. Each is discussed below. Emissions from the application of hot-mix, cutback and emulsified asphalt are discussed in Section 2.2.

¹ Personal communication between Gary Fore, of the National Asphalt Pavement Association and L. Adams, Eastern Research Group, Inc., February 1997.

Hot-Mix Asphalt

Hot-mix asphalt is the most commonly used paving asphalt for surfaces of 2 to 6 inches thick. Hot-mix asphalt is prepared at a hot-mix asphalt plant by heating asphalt cement before adding the aggregate. To maintain a liquid mixture, these plants must be near to the paving site. In some cases, mobile facilities are used. An estimated 22 million tons of hot-mix asphalt cement concrete were sold in 1994 (Moulthrop, et al. 1997).

Cutback Asphalt

Cutback asphalt is used in tack and seal operations, in priming roadbeds for hot-mix application, and for paving operations for pavements up to several inches thick. In preparing cutback asphalt, asphalt cement is blended or “cut back” with a diluent, typically from 25 to 45 percent by volume of petroleum distillates, depending on the desired viscosity. Cutback asphalt is prepared at an asphalt plant. There are three types of cutback asphalt cement:

- Rapid Cure (RC) which uses gasoline or naphthas as diluents;
- Medium Cure (MC) which uses kerosene as a diluent; and
- Slow Cure (SC) which uses low volatility fuel solvents as diluents.

An estimated 0.75 million tons of cutback asphalt were sold in 1994 (Moulthrop, et al. 1997). This represents about three percent of sales of all asphalt cement types.

A number of states recognize the emission potential from the use of cutback asphalts and have established regulations limiting the amounts used and the time of year when they are used. The inventory preparer should determine whether such regulations are in place for the area to be inventoried before beginning data collection.

Emulsified Asphalt

Emulsified asphalt is used in most of the same applications as cutback asphalts but is a lower-emitting, energy saving, and safer alternative to the cutback asphalts (Moulthrop, et al. 1997). Instead of blending asphalt cement with petroleum distillates, emulsified asphalts use a blend of asphalt cement, water and an emulsifying agent, such as soap. Such blends typically contain one-third water, two-thirds asphalt cement and minor amounts of an emulsifier.² Some

² Telephone conversation between R. Benson of the Asphalt Institute and S. K. Buchanan, Eastern Research Group, Inc., September 1997.

emulsified asphalts may contain up to 12 percent organic solvents by volume (California SCAQMD Rule 1108.1).¹ Emulsification is done at an asphalt plant. Emulsified asphalts cure by two methods: water evaporation and, in the case of cationic and anionic emulsions, ionic bonding. For purposes of this document, the three types of concern are determined by the proportions of the emulsifier and water in the blend:²

- Rapid Set (RS);
- Medium Set (MS); and
- Slow Set (SS).

Approximately 1.76 million tons of emulsified asphalt were used in 1994 (Moulthrop, et al. 1997). This represents about seven percent of overall use of all asphalt types that year.

2.2 EMISSION SOURCES

Emissions from asphalt paving operations occur when asphalt mixtures are applied and as they cure. The pollutants emitted depend on the diluents used and may include volatile organic compounds (VOCs) and hazardous air pollutants (HAPs). Emission estimation methods are available for calculating VOC emissions. To estimate HAP emissions, inventory preparers will need to develop their own HAP content profiles from local data.

2.2.1 ASPHALT MIXTURES

Emissions from the application of the different asphalt mixtures are discussed below.

Hot-Mix Asphalt

For hot-mix asphalt, the organic components have high molecular weights and low vapor pressures. Therefore, hot-mix asphalt use produces minimal emissions of VOCs and HAPs. Estimates for national hot-mix asphalt paving emissions are about one order of magnitude lower than national estimates of cutback asphalt paving. More information about hot-mix asphalt paving emissions can be found in the EPA publication, *Final Report - Evaluation of Emissions*

¹ Telephone conversation between R. Ryan of the U.S. Environmental Protection Agency and L. Adams, Eastern Research Group, Inc., February 1997.

² Additional information on emulsions may be obtained from the Asphalt Emulsion Manufacturers Association, phone: (410) 267-0023

from *Paving Asphalts* (EPA, 1994a). Because emissions from hot-mix asphalt are low, estimation methods will not be included in this chapter.

Cutback Asphalt

For cutback asphalt, emissions are due to the use of diluents that contain VOCs and, in some cases, HAPs. Cutback asphalt has the highest diluent content of the three asphalt categories and, as a result, emits the highest levels of VOCs per ton used. Estimating emissions from the use of cutback asphalt should be given a high priority in this source category. The two major variables affecting both the quantity of VOCs and HAPs emitted and the time over which emissions occur are the type and the quantity of organic solvent used as a diluent. As the rapid cure cutback asphalt has the highest diluent content, use of this type of cutback asphalt produces the highest emissions; evaporative losses are estimated at 95 percent by weight of diluent. Medium cure evaporative losses are estimated at 70 percent by weight of diluent, and slow cure at 25 percent by weight of diluent (EPA, 1996).

Emulsified Asphalt

In general, emulsified asphalts have a lower emission potential than cutback asphalts as they contain less or no diluents. However, some may contain up to 12 percent by volume solvents (California SCAQMD Rule 1108.1).⁵ Therefore, the inventory preparer should consider evaluating the diluent content and composition of emulsified asphalts used in the inventory area, before deciding whether to collect data to estimate emissions. Because cutback asphalt use is regulated by a number of states to reduce VOC emissions, use of emulsified asphalts has gained popularity. Thus, although emulsified asphalt diluent contents are typically lower than the cutback asphalt, the amount used may be twice that of the cutbacks. If the emulsified asphalts in use contain any VOC or HAP diluents, they may be worth including in the inventory.

Recycled Asphalt Pavement

Emissions from the use of recycled asphalt pavement (RAP) are expected to be no higher than from hot-mix use. Heat is used to soften the asphalt coating the aggregate, thus no additional source of VOCs or HAPs is introduced.⁶

⁵ Telephone conversation between R. Ryan of the U.S. Environmental Protection Agency and L. Adams, Eastern Research Group, Inc., February 1997.

⁶ Telephone conversation between R. Benson of the Asphalt Institute and S. K. Buchanan, Eastern Research Group, Inc., September 1997.

2.3 FACTORS INFLUENCING EMISSIONS

2.3.1 PROCESS OPERATING FACTORS

Emissions from asphalt paving depend on the type of asphalt used (hot-mix, cutback, or emulsified). Emissions are also a function of the VOC/HAP content. Because emissions result from diluent evaporation, factors such as temperature will affect the rate of evaporation. Hot-mix asphalt results in the lowest emissions per ton used, followed by emulsified asphalts. Cutback asphalts result in the highest emissions.

2.3.2 CONTROL TECHNIQUES

The primary control option for emissions from asphalt paving is to reduce the amount of any VOC/HAP-containing diluent in the asphalt. However, in some situations, asphalt with a lower diluent content may not meet the performance requirements of the paving job and a higher emitting asphalt must be used. Some reductions are also realized where the slower cure asphalts are used. An estimated 95 percent of the diluent in rapid cure cutback asphalt evaporates, whereas only 25 percent of diluent evaporates from the slow cure cutback asphalts (EPA, 1996). States have also either prohibited the use of diluent-containing asphalts or established seasonal schedules for the higher VOC asphalt cements such that these are not used during the peak ozone formation season.

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3

OVERVIEW OF AVAILABLE METHODS

3.1 ESTIMATION METHODS

Two methods are available for estimating emissions from asphalt paving operations:

- Estimates based on surveys of the state and local Departments of Transportation (DOTs) and paving companies; and
- Estimates using emission factors.

Selection of the appropriate estimation method depends on the relative significance of emissions from this source in the inventory area and the data quality objectives (DQOs) of the inventory plan. Refer to EIIP Volume VI, *Quality Assurance Procedures*, Sections 2.1 and 2.4 for discussions of inventory categories and DQOs.

Before selecting an estimation method, the inventory preparer should research state and local rules for asphalt paving operations in the inventory area. Many state and local air agencies limit or ban the use of cutback asphalts, particularly during the ozone season. If this is the case for the area to be inventoried and the timeframe of interest for the inventory is the ozone season, then the priorities for inventorying asphalt paving operations will change and the estimation method chosen may differ.

3.2 AVAILABLE METHODOLOGIES

Methods for estimating emissions for this source category differ primarily in the amount of data to be collected and the manner in which the data are collected. Surveys are used in the preferred method and the first and second alternative methods. Collecting more locally-specific information will provide more accurate estimates. Surveys are a more intensive data collection effort than gathering activity data to use with emission factors. With surveys, information on the specific HAPs can be requested and the speciated emissions calculated from the outset. Emission factors are only available for VOC estimates; therefore, speciation can be done only after the VOC emissions are estimated using diluent composition information.

3.2.1 VOLATILE ORGANIC COMPOUNDS

VOC emissions depend on the amount of VOCs in the diluent used in asphalt (term used generically to include cutback and emulsified asphalts). For the purposes of the chapter, diluents are assumed to contain 100 percent VOCs. Thus, the amount of each asphalt type and the diluent content must also be determined. Regardless of the estimation method used, assumptions about the amount of VOC that evaporates must be made. Approximations for the amount of diluent that evaporates from cutback asphalt are provided in *AP-42*:

- Rapid cure: 95 percent by weight of the diluent evaporates;
- Medium cure: 70 percent by weight of the diluent evaporates; and
- Slow cure: 25 percent by weight of the diluent evaporates.

Note that evaporation to these levels occurs over a period of about four months. Evaporation curves are provided in *AP-42*. About 75 percent by weight of diluent evaporates in the first day following application of rapid cure cutback asphalts, whereas, it takes about one week for 50 percent by weight of the diluent to evaporate from medium cure cutback asphalts.

Such estimates of evaporation are not available for emulsified asphalts. In the absence of this information, the inventory preparer may elect to apply the estimates for the cutback asphalt evaporation rates or may conservatively assume all the diluent evaporates.

A majority of asphalt paving work is done by the state and local DOTs, either by their own staff or by contractors. Thus information on practices is generally centralized and should be available to the state agency preparing the inventory. In addition, private companies may also pave such surfaces as private roads and parking lots with asphalt materials. They may also pave under contract to other governmental agencies like the military, the Bureau of Land Management, forest service, or entities such as tribal governments. Information on this asphalt use is more difficult to collect. Before undertaking a data gathering effort for these private paving operations, the inventory preparer should assess the potential for these private activities to be a significant emission source. One way would be to determine how much construction and private road maintenance and repair is occurring in the inventory area, perhaps through the cognizant construction permitting agency or a trade association for developers. Another way to assess activity might be to contact a few private paving companies to develop an understanding of how their asphalt uses compare to those by the DOTs. If the activity level is low, the inventory preparer may opt to exclude the private paving operations from the inventory. Because the emissions contribution from private paving operations is often much less than from DOT paving activities, methods to estimate emissions from private paving operations have not been

specifically addressed. These methods would be the same as for paving activities done for or by the state and local DOTs.

For emissions from asphalt paving, the ranking of the estimation methods is as follows:

1. **Preferred Method:** Comprehensive survey of all state and local DOTs for data on asphalts;
2. **Alternative Method 1:** Survey representative state and local DOTs, shorten the survey by making assumptions about asphalt specific gravity, use *AP-42* cutback asphalt emission factors;
3. **Alternative Method 2:** Survey representative state and local DOTs, shorten the survey further by making assumptions about asphalt specific gravity and collecting usage data from other resources (e.g., trade associations), use *AP-42* cutback asphalt emission factors; and
4. **Alternative Method 3:** A per capita or usage emission factor from EPA guidance for preparing carbon monoxide and ozone inventories (EPA, 1991), collect activity data (census data or usage data from trade associations or DOTs).

With the exception of Alternative Method 3, all require assumptions about evaporation of the diluent. As mentioned earlier, *AP-42* is one source for information.

The Preferred Method results in the most accurate estimate because data are collected on actual paving practices. Alternative Method 1 is less accurate as it relies on EPA emission factors rather than actual data. The estimate is improved by the use of activity data that are specific to the inventory area. Alternative Method 2 is less accurate than the Preferred Method and Alternative Method 1 because the usage data are not specific to the inventory area. Published state data needs to be allocated to the local inventory level. Alternative Method 3 is the least accurate, even though local per capita or usage data would be used. The emission factors are based on the assumption that the diluent content is 35 percent solvent (special petroleum naphthas), which is the midpoint of the range of contents according to *AP-42*, and that five percent of diluent remains in the pavement, which is the evaporation rate for rapid cure cutback asphalts. Thus, the resulting emissions may be overestimated.

To date, emission factors have not been developed by industry. However, if these are available at the time the inventory is prepared, the inventory preparer should determine if these would be an improvement over the EPA emission factors before using them. To assess this, the methods used by industry and for *AP-42* for deriving the emission factors need to be compared and a

determination made of which is more accurate, based on a technical evaluation. Also, how well the underlying data represent paving practices in the inventory area should be considered.

3.2.2 HAZARDOUS AIR POLLUTANTS

Surveys can be used to collect HAP data from state and local DOTs. In general, this will involve requesting material safety data sheets (MSDSs) or manufacturer technical data sheets (TDSs) for each of the asphalt types the state and local DOTs apply to identify diluent composition. Resulting estimates are HAP-specific. Emission factors for HAPs are not available; therefore, the inventory preparer must again rely on MSDSs and TDSs. The VOC emission estimates can then be adjusted to determine speciated emissions. Although local data on the HAP content of diluents used in the inventory area are preferred, a secondary source for speciation information may be other state agencies.

3.3 DATA NEEDS

3.3.1 DATA ELEMENTS

The data elements used to calculate emission estimates for this category will depend on the methodology used for data collection. The data elements necessary for an emission calculation that should be requested in a comprehensive survey of state and local DOTs, the preferred method, include:

- types of cutback asphalts (rapid, medium, slow cure);
- types of emulsified asphalts (rapid, medium, slow set);
- amount of each asphalt type used for the inventory year, before aggregate is added;
- diluent content of each type;
- HAP content by weight for each diluent (*for HAP inventories only*); and
- seasonal practices for each asphalt type (*for ozone inventories*).

Also needed for the estimation are the specific gravities (density) of the diluted asphalt and the diluents, where VOC and HAP contents are reported in percents by volume. Default values for the density of cutback asphalt diluents are provided in *AP-42* (0.7kg/L for rapid cure, 0.8kg/L for medium cure, and 0.9kg/L for slow cure). According to the Asphalt Institute, emulsified asphalt

densities are similar to that of water (1.0 kg/L; the *AP-42* default is 1.1 kg/L). Emulsified asphalts with diluents have densities somewhat higher or lower than that of water, depending on the types and amounts of solvents.¹ Solvent densities are available from MSDSs and other standard chemistry references.

Fewer elements are needed if emission factors are to be used. It is still preferable to collect the data from the state and local DOTs, but some may be available from other sources. For example, local paving companies may be able to supply the typical diluent contents and trade associations may be able to provide data on state usage that can be apportioned to the local inventory area. Additionally, an estimate based on surveying representative DOTs may be sufficiently accurate for inventory purposes.

3.3.2 APPLICATION OF CONTROLS

The most effective way to control emissions from asphalt paving is to reduce the VOC and HAP contents in the asphalts. Because the asphalt types have different characteristics and meet specific paving needs, use of the low VOC/HAP asphalts is not always feasible. As the data collected will represent the actual VOC and HAP contents for asphalts in use, no additional adjustment for controls will be needed.

Another control strategy to reduce ozone formation is to prohibit or limit the use of the VOC-containing asphalts during the ozone season, as some states have done. Any adjustments to incorporate state regulatory requirements will need to be made as a part of the temporal allocation of emissions.

3.3.3 SPATIAL ALLOCATION

Spatial allocation is used in two cases in the preparation of an area source inventory: (1) to allocate emissions or activity to the county level, and (2) to allocate county-level emission estimates or activity to a modeling grid cell. For all but one method, the resulting estimate will be at the county level because county level data are used in the estimate. To allocate emissions or activity from the state level to the county level for Alternative Method 2, a number of parameters may be used to determine county level activity. These include highway spending data published by the Federal Highway Administration, population data published by the U.S. Census Bureau, data on miles paved or lane miles from the state DOT, and data on vehicle miles traveled (VMT) from the mobile source emissions group at the agency.

¹ Telephone conversation between R. Benson of the Asphalt Institute and S. K. Buchanan, Eastern Research Group, Inc., September 1997.

Allocation of the emission estimates or activity to a modeling grid can be done using one of four potential spatial surrogates, shown below in order of preference:

1. Detailed information about the miles of highway paved or the vehicle miles traveled (VMT) within each grid cell, or a group of grid cells. This will typically be done by the inventory personnel involved in estimating mobile source emissions.
2. Highway spending data.
3. Lane miles.
4. Population data.

3.3.4 TEMPORAL RESOLUTION

Because asphalt paving activities depend somewhat on the weather, the level of activity over the course of the year will vary from state to state. State and local regulations may also limit activities during the ozone season. For the best information to temporally allocate emissions, the inventory preparer should talk with the state DOT to establish any seasonal patterns. Daily allocation of emissions for asphalt paving operations differ from other source categories in that emissions occur over a period of time after the paving is done (EPA, 1996). Therefore, a seven day week should be used to allocate daily emissions from this source category. However, if the number of days worked per week are being used to estimate the relative amount of asphalt used during a time period, then information about actual work schedules will need to be collected. Application of asphalt paving materials will generally occur 5 days per week during typical business hours; however, some large projects and maintenance operations may involve overtime. Activity is dependant of the weather; more activity will take place during warmer and dryer months. Refer to Chapter 1 of this volume for more information about temporal resolution. Example 17.3-1 shows a typical calculation of daily emissions during the ozone season from annual emissions.

Example 17.3.1

Cutback asphalt use in County A is banned by state regulation. Weather conditions limit the use of emulsified asphalt to the warmer months, from May through September, which is about 21 weeks. Paving work is done 5 days a week during the months of May and September (8 weeks) and 6 days a week from June through August (13 weeks). Asphalt use is expected to be proportionate to the number of days worked. Evaporation of the asphalt diluents are assumed to take place over a period of time after paving. Emissions are expected to occur over 7 days a week.

Because cutback asphalt use is banned, emissions for cutback asphalt are not included in County A's ozone season inventory. Daily emissions from emulsified asphalt paving are calculated from annual emissions by following these steps:

- 1) Calculate the ozone season emissions from the proportion of days worked:

$$\begin{aligned}
 \text{Number of Days} \\
 \text{Asphalt is Applied} &= (8 \text{ weeks} * 5 \text{ days/week}) + (13 \text{ weeks} * 6 \text{ days/week}) \\
 &= 40 + 78 \\
 &= 118 \text{ days asphalt is applied}
 \end{aligned}$$

$$\begin{aligned}
 \text{Activity Percentage} \\
 \text{During Ozone} &= (78 \text{ days}/118 \text{ days}) * 100 \\
 \text{Season} &= 66\%
 \end{aligned}$$

$$\begin{aligned}
 \text{Ozone Season} \\
 \text{Emissions} &= \text{Annual Emissions} * 66\%
 \end{aligned}$$

- 2) Calculate daily emissions from ozone season emissions:

$$\begin{aligned}
 \text{Daily} & \quad \text{Ozone Season} \\
 \text{Emissions} &= \text{Emissions}/(7 \text{ days/week}) (13 \text{ weeks/year})
 \end{aligned}$$

3.3.5 PROJECTING EMISSIONS

A discussion about developing growth factors and projecting emission estimates can be found in Section 4 of Chapter 1 of this volume, Introduction to Area Source Emission Inventory Development. Projecting emissions for this source category will require that two variables be taken into account, the change in paving activity and any change in emission controls. Paving activity may be projected using the same factors used to project changes in local lane miles, VMT, or highway spending.

The EIIP Projections Committee has developed a series of guidance documents containing information on options for forecasting future emissions. You can refer to these documents at <http://www.epa.gov/ttn/chief/eiip/project.htm>.

4

PREFERRED METHOD FOR ESTIMATING EMISSIONS

The preferred method for estimating emissions from asphalt paving is to conduct a comprehensive survey of asphalt use by state and local departments of transportation (DOTs). These highway and road maintenance departments are responsible for much of the total asphalt paving activity. Furthermore, records should be accessible and information should be sufficiently detailed to calculate VOC and HAP emissions. This section provides an outline for preparing and using an asphalt paving survey and calculating emission estimates from the information collected.

Use of the survey method depends on DOTs keeping records of asphalt usage. If DOTs do not keep these records, this method is not practical. Also, a survey of DOTs will not include private asphalt paving activities done by private contractors unless the contractors are also surveyed. However, it is unlikely that a survey of contractors would be as reliable as that of DOTs for a number of reasons. First, the response rate will likely be lower; second, they may not keep as complete or as detailed records; and third, a contractor will do work over county or state boundaries and may not be able to estimate asphalt use for just the inventory area.

Another drawback to this method is that a well-planned, well-implemented survey requires more resources than other methods. Inventory preparers must judge whether the costs of this approach are outweighed by the benefit of having an estimate that is more accurate and specific to the inventory area and time period. Costs and labor efforts are highest the first time that a regional or local survey is performed. Subsequent updates to the survey may be done using fewer surveys at a much lower cost. In the years following the baseline survey, updates on asphalt usage may be all that are needed. Periodically, information on changes in the percentages of different types of asphalt used and the VOC/HAP content will be needed to accurately estimate emissions.

Surveys for area sources are specifically discussed in Volume I of the Emission Inventory Improvement Program (EIIP) series and in Chapter 1 of this volume. A survey of state and county DOTs will consist of: (1) survey planning, (2) survey preparation, (3) survey distribution, (4) survey compilation and scaling, and (5) emission estimation. Discussion of these steps follows.

4.1 SURVEY PLANNING

During the planning phase, the following issues should be addressed:

- Survey data quality objectives (DQOs) should be identified, and procedures for realistically reaching these objectives specified.
- The survey recipients and data needs must be identified.
 - For counties where paving responsibilities are shared to a significant degree by others (e.g., private developers, military installations, state or National Parks), the survey may need to be sent to others besides local DOTs.
 - Where private contractors are used by DOTs, the DOTs may not maintain all the records. Inventory preparers should consider having the DOTs take responsibility for having their contractors complete the survey. However, in the interest of time or due to resource constraints, the inventory preparer may need to survey contractors directly.
 - The use of diluents in emulsified asphalts should be preliminarily assessed. If this is rare or only limited to certain counties or times of the year, then the survey may be able to be shortened.
 - Where the characteristics of the types of asphalts used (i.e., percent diluent and types of solvents) are similar across the state or for a region within the state, a representative profile can be developed and applied to the others. This would greatly reduce the survey effort.
 - The assumptions for diluent evaporation and asphalt densities should be determined.
 - Paving projects may cross county boundaries, thus usage data must be allocated to each county. Alternatively, the inventory area may include only parts of some counties, thus only some of its paving activities need be included. The basis for apportioning these activities is best determined by the cognizant county agencies; however, some surrogates like the ratio of miles paved or population may suffice. A choice of surrogate should be made before the survey design is complete so that the data can be collected.
- Data handling needs specific to this survey must be identified.
- Survey QA/QC methods must be delineated and implemented.

The survey package should include a cover letter explaining the program, the survey form, a list of definitions and a postage-paid return envelope. Both state and local DOTs may need to be surveyed to collect necessary information.

4.2 SURVEY PREPARATION

A survey may be either comprehensive or collect the minimum amount needed to estimate emissions. The more detailed survey necessary for the preferred method would request:

- the types of cutback asphalts used (rapid, medium and slow cure);
- the types of emulsified asphalts used (rapid, medium and slow set);
- the amounts of each type of asphalt used in the inventory year;
- the diluent content of each type of asphalt; and
- seasonal usage patterns (*for an ozone inventory*).

Additional elements to consider requesting include:

- HAP content for each diluent (*for HAP inventories only*);
- specific gravities for each asphalt type (*only if diluent or HAP contents are in percents by volume*); and
- Factors to use for spatial or temporal allocation.

For a HAP inventory, the diluent composition would also be needed (types and percents of each solvent) to determine the HAP content of the diluents. This may be available from material safety data sheets (MSDSs) and manufacturer technical data sheets (TDSs) so the survey respondent should send the relevant MSDSs and TDSs.

Where volume percents are provided, the inventory preparer will also need specific gravities for the diluents or HAPs. These can be determined from standard chemistry references.

Survey preparers should clearly define the time period for which the survey information is being collected. A request for annual data, for instance, should specify the range of months to avoid confusion between fiscal and calendar years. It is preferable to collect data specific to the inventory period, but for periods less than 12 months, usage will probably have to be apportioned by the inventory preparer.

If the survey results need to be adjusted to a different spatial scale for future inventories, factors that may be used to adjust the survey information may also be collected. For example, the miles paved within the county for which the department is responsible could be requested from that

department. Alternatively, VMT as a surrogate may be available from mobile emissions inventory preparers.

The advantages of the more detailed approach are that the inventory developed is specific to the locality, and the information collected can be more readily projected to inventories for subsequent years.

Instructions for using the example survey form are provided on the survey cover page, shown in Figure 17.4-1. Example data request forms are presented in Figures 17.4-2 and 17.4-3. For HAP inventories, MSDSs for each asphalt type should be requested. The HAP weight-percent information on the MSDSs is then used to determine HAP-specific emissions. An alternative survey-based method for a HAP inventory would use a representative sample of the HAP contents for each asphalt type, applied to a more complete VOC inventory of asphalt types and usages.

4.3 SURVEY DISTRIBUTION

The preferred method requires the inventory preparer to contact every DOT in the inventory area. Surveys are best distributed by mail, with an initial call to ensure receipt and to answer any questions, and a follow-up call when the inventory preparer has any questions. Survey distribution issues are discussed in Chapter 1 of this volume.

4.4 SURVEY COMPILATION AND SCALING

Survey compilation and scaling issues are discussed in Volume I of this series. Completed surveys will result in information for many asphalt types and, in the case of HAP inventories, multiple pollutants, so accurate and efficient data compilation will require planning for data transfer and data management.

QC checks should be performed during this phase of the work (see Volume VI for QA/QC methods). Incoming surveys should be checked for errors such as potential unit conversion errors or omissions. Survey information should be checked for reasonableness. Survey recipients may need to be contacted to clarify responses or to correct any errors. Once compiled, survey information should also be subject to similar checks to ensure complete and accurate data entry, prior to analysis. Preliminary sorting of the data by county to compare responses can be used to identify outliers.

Depending on who responds to the survey, results may need to be either scaled up to account for all counties in the inventory area, or scaled down to the inventory area where some counties need only be partially included. In either case, a scaling factor should have been identified in the

Department of Transportation for: _____ county

Street Address: _____

City: _____

Contact Person/Phone Number: _____

The purpose of this survey is to collect information about the amounts and types of asphalts used for paving so that estimates of air pollution from paving operations can be made. Please enter the following information on the attached forms.

1. List the asphalt types used in calendar year _____. Note that Table 17.4-1 is for cutback asphalt; Table 17.4-2 is for emulsified asphalts. Information about hot-mix asphalt is not needed.
2. Provide the cure or set rate for each asphalt type (include units of measure).
- 3.* Provide the amount, in tons, of each asphalt type used.
- 4.* Provide the specific gravity for each asphalt type.
- 5.* Provide the volume percent of diluents in each asphalt type.
6. List the months during the year that each asphalt type is used (*for ozone inventories*).
7. Attach copies of the material safety data sheets and manufacturer technical data sheets for all of the asphalt types listed (*for HAP inventories*).

* For the asphalt mixed with aggregate (less the aggregate) and is not “as applied” during actual paving operations.

FIGURE 17.4-1. SURVEY REQUEST FORM FOR ASPHALT CEMENT USE - INSTRUCTIONS

1	2	3	4	5	6
Identification # or Name	Cure Rate ^a	Amount Used, Tons	Specific Gravity	Diluent Content, Volume %	Amount Used in Each Calendar Month

^a Rapid, medium, slow

FIGURE 17.4-2. CUTBACK ASPHALT DATA REQUEST FORM

1	2	3	4	5	6
Identification # or Name	Set Rate ^a	Amount Used, Tons	Specific Gravity	Diluent Content, Volume %	Amount Used in Each Calendar Month

^a Rapid, medium, slow

FIGURE 17.4-3. EMULSIFIED ASPHALT DATA REQUEST FORM

planning phase, and any necessary requests for information from the survey respondents included on the survey form. Refer to Sections 3.3.3 Spatial Allocation and 3.3.4 Temporal Resolution for more information about allocation and scaling factors for this source category.

4.5 EMISSION ESTIMATION

4.5.1 VOLATILE ORGANIC COMPOUNDS

Emission estimate calculations involve determining emissions of the pollutant(s) of interest, then the application of any necessary spatial or temporal adjustments. Because asphalt paving is defined as an area source, there should be no need to subtract the contribution from point sources from the total. Emission estimate calculations from the information collected by survey require the following steps. The diluent content may be assumed to be 100 percent VOCs.

When the weight of cutback (or emulsified) asphalt used and the volume percent of diluent are provided:

$$\text{Volume of Cutback Used} = \frac{\text{Weight of Cutback Used}}{\text{Density of Cutback}} \quad (17.4-1)$$

$$\text{Volume of Diluent Used} = \text{Volume of Cutback Used} * \text{Volume \% Diluent in the Cutback} \quad (17.4-2)$$

$$\text{Weight of Diluent Used} = \text{Volume of Diluent Used} * \text{Density of Diluent} \quad (17.4-3)$$

$$\text{Mass Emissions} = \text{Weight of Diluent Used} * \text{Weight \% of Diluent Evaporated} \quad (17.4-4)$$

If the weight percent of diluent is provided, Equation 17.4-5 is used instead of Equations 17.4-1, 17.4-2, and 17.4-3 to determine the weight of diluent used. Equation 17.4-4 is still used as the last step to calculate mass emissions.

$$\text{Weight of Diluent Used} = \text{Weight of Cutback Used} * \text{Weight \% of Diluent in the Cutback} \quad (17.4-5)$$

Diluent evaporation rates depend on the type of asphalt used and were discussed earlier. The best information to use is product-specific; however, this kind of information is not expected to be available. In the absence of product-specific data, *AP-42* provides some guidance for cutback asphalts. Note that the diluent densities assumed may differ from those in the inventory area and this will be a source of error.

- Rapid cure cutback asphalts: 95% by weight of diluent evaporates;
- Medium cure cutback asphalts: 75% by weight of diluent evaporates; and
- Slow cure cutback asphalts: 25% by weight of diluent evaporates.

For emulsified asphalts, a conservative estimate can be derived by assuming all the diluent evaporates. Alternatively, values similar to those from *AP-42* for the cutback asphalts might be used.

To convert specific gravity to density for use in Equations 17.4-1 and 17.4-3:

$$\text{Density (lb/gal)} = \text{Specific Gravity} * \frac{8.34 \text{ lb}}{\text{gal}} \quad (17.4-6)$$

or

$$\text{Density (kg/L)} = \text{Specific Gravity} * \frac{1 \text{ kg}}{\text{liter}} \quad (17.4-7)$$

4.5.2 HAZARDOUS AIR POLLUTANTS

To determine HAP emissions, first estimate the VOC emissions from Equations 17.4-1 through 17.4-4, then multiply by the ratio of the HAP of interest to the total VOC emitted (the weight fraction).

$$\text{Mass Emissions for Each HAP} = \text{VOC Mass Emissions} * \text{Weight Fraction of Each HAP} \quad (17.4-8)$$

Where:

$$\text{Weight Fraction of Each HAP} = \frac{\text{Weight of Each HAP}}{\text{Weight of VOC Emitted}} \quad (17.4-9)$$

Example 17.4-1 illustrates how both VOC and HAP emissions are estimated.

Example 17.4-1

Data provided by one county for use in this example are summarized in the table:

Asphalt Type	Amount Used (tons)	Density (lb/gal)	Diluent Content (vol %)
Medium cure cutback asphalt	250	7.8	28
Rapid set emulsified asphalt	190	8.5	7

The MSDSs state the diluent in the medium cure cutback asphalt was naphtha and the diluent in the rapid set emulsified asphalt was xylene. Additional data used in the calculations are:

- density of naphtha = 7.5 lb/gal
- density of xylene = 7.2 lb/gal
- evaporation of diluent from the medium cure cutback asphalt = 75% by weight (from *AP-42*)
- evaporation of diluent from the rapid set emulsified asphalt = 95% by weight (assumed same as for rapid cure cutback asphalt, in *AP-42*)

Example 17.4-1 (Continued)

Combining Equations 17.4-1 through 17.4-4, emissions from the medium cure cutback asphalt use:

$$\begin{aligned}
 &= \frac{\text{Weight of Cutback Used}}{\text{Density of Cutback}} * \frac{\text{Vol \% Diluent in Cutback}}{\text{Density of Diluent}} * \frac{\text{Weight \% Diluent Evaporated}}{\text{Unit Conversion}} \\
 &= \frac{250 \text{ tons}}{7.8 \text{ lbs/gal}} * 0.28 * \frac{7.5 \text{ lbs}}{\text{gal}} * 0.75 * \frac{2,000 \text{ lbs}}{\text{ton}} \\
 &= 100,961 \text{ lbs naphtha}
 \end{aligned}$$

Similarly, emissions from the rapid set emulsified asphalt use:

$$\begin{aligned}
 &= \frac{\text{Weight of Emulsified Used}}{\text{Density of Emulsified}} * \frac{\text{Vol \% Diluent in Emulsified}}{\text{Density of Diluent}} * \frac{\text{Weight \% Diluent Evaporated}}{\text{Unit Conversion}} \\
 &= \frac{190 \text{ tons}}{8.5 \text{ lbs/gal}} * 0.07 * \frac{7.2 \text{ lbs}}{\text{gal}} * 0.95 * \frac{2,000 \text{ lbs}}{\text{ton}} \\
 &= 21,405 \text{ lbs xylene}
 \end{aligned}$$

Total VOC emissions are the sum of the emissions for each type of asphalt used:

$$\begin{aligned}
 &\text{Total VOC} \\
 &\text{Emissions for the One County} = 100,961 \text{ lbs naphtha} + 21,405 \text{ lbs xylene} \\
 &= 122,366 \text{ lbs}
 \end{aligned}$$

Total HAP emissions in this example are the same as total VOC emissions, 122,366 pounds. Speciated HAP emissions are calculated as the sum of each HAP emitted from each type of asphalt used. As each asphalt type contained a single, different HAP, the speciated HAP emissions from each asphalt type are the same as the VOC calculated for each asphalt type, 100,961 lbs naphtha and 21,405 lbs xylene.

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5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

This section provides alternatives to the comprehensive survey approach that is the preferred method. Alternative Methods 1 and 2 require some information collection from state and local DOTs, but some of the information needed is collected from other sources. Alternative Method 3 requires the least amount of data collection, however, the resultant emission estimate is the least accurate.

5.1 VOLATILE ORGANIC COMPOUNDS

5.1.1 ALTERNATIVE METHOD 1: LIMITED SURVEY OF SELECTED DOTs

Alternative Method 1 is a simplified version of the preferred method. Instead of sending surveys to all DOTs, a representative set are selected for surveying. Additionally, assumptions about specific gravities are made by the inventory preparer which reduces the information requested in the survey. The example survey form shown in Figure 17.5-1 differs from Figures 17.4-1 and 17.4-2 only in that specific gravity is no longer requested. For cutback asphalts, densities are assumed to be the same as those used in developing the *AP-42* emission factors in Table 17.5-1, thus *AP-42* emission factors can be used to estimate emissions. For emulsified asphalts, the density is assumed to be the same as that of water.¹

Once the data have been compiled, estimates of use by the rest of the counties must be calculated. To do this, the inventory preparer will apply a ratio of activities for the counties, determined during the survey planning phase. Some possible ratios are miles of highway (state transportation data), VMT (mobile emission inventory preparers), government highway spending (U.S. Office of Highway Information Management), and population (U.S. census data).

¹ Telephone conversation between R. Benson of the Asphalt Institute and S. K. Buchanan, Eastern Research Group, Inc., September 1997.

1 Asphalt Type ^{a,b}	2 Cure or Set Rate ^c	3 Amount Used, Tons	5 Diluent Content, Volume %	6 Months of the Year Used

^a Numbers in each column match the instructions provided in Section 4.4. Item 4, Specific Gravity, is not needed for this alternative.

^b Cutback Asphalt = CA
Emulsified Asphalt = EA

^c Rapid , medium , slow

FIGURE 17.5-1. SIMPLIFIED DATA REQUEST FORM^a

Cutback Asphalt

To estimate emissions from cutback asphalt paving, the data collected on the cure type and diluent content are used to determine the weight percent of cutback asphalt evaporated from Table 17.5-1.

TABLE 17.5-1

**EVAPORATIVE VOC EMISSIONS FROM CUTBACK ASPHALTS
AS A FUNCTION OF DILUENT CONTENT AND CUTBACK ASPHALT TYPE^a**

Type of Cutback ^b	Percent, by Volume, of Diluent In Cutback ^c		
	25%	35%	45%
Rapid cure (RC)	17	24	32
Medium cure (MC)	14	20	26
Slow cure (SC)	5	8	10

^a These numbers represent the percent, by weight, of cutback asphalt evaporated. *AP-42* Emission Factor Rating: C

^b Typical densities assumed for diluents used in RC, MC, and SC cutback asphalts are 0.7, 0.8, and 0.9 kg/liter, respectively.

^c Diluent contents typically range between 25 - 45%, by volume. Emissions may be linearly interpolated for any given type of cutback asphalt between these values.

The weight percent is then multiplied by the weight of cutback asphalt used, also determined from the surveys, to estimate emissions.

$$\text{Mass Emissions} = \frac{\text{Weight of Cutback Used}}{\text{Weight \% of Cutback that Evaporates}} \quad (17.5-1)$$

Emulsified Asphalt

As discussed earlier, data on diluent evaporation are not available for emulsified asphalt. As a conservative estimate, the inventory preparer can choose to assume all the diluent evaporates. Alternatively, some adjustment can be made based on the set rate; data in *AP-42* suggests that the slower the cure, the lower the evaporative emissions. The *AP-42* emission factors in

Table 17.5-1 do not apply, thus emissions must be calculated using Equations 17.4-1 through 17.4-4 in Section 4.5.

Combining these equations, emissions from emulsified asphalts are calculated as:

$$\text{Mass Emissions} = \frac{\text{Weight of Emulsified Asphalt Used}}{\text{Density of Emulsified Asphalt}} * \frac{\text{Volume \% of Diluent in the Emulsified Asphalt}}{\text{Density of Diluent}} * \text{Weight \% of Diluent Evaporated} \quad (17.5-2)$$

The equation is further simplified by assuming that emulsified asphalt is the same density as water, regardless of the diluent content.² The density parameters cancel and emissions are calculated as:

$$\text{Mass Emissions} = \frac{\text{Weight of Emulsified Asphalt Used}}{\text{Volume \% of Diluent in the Emulsified Asphalt}} * \text{Weight \% of Diluent Evaporated} \quad (17.5-3)$$

When all the diluent is assumed to evaporate, the value in Equation 17.5-3 for percent diluent that evaporates is 100. When less than complete evaporation is assumed, the value of the percent diluent represents the adjustment.

An example is provided to illustrate use of Alternative Method 1.

Example 17.5-1:

Data provided by one county for use in this example are summarized in the table:

Asphalt Type	Amount Used (tons)	Diluent Content (vol%)
Medium cure cutback asphalt	250	28
Rapid set emulsified asphalt	50	7

² Telephone conversation between R. Benson of the Asphalt Institute and S. K. Buchanan, Eastern Research Group, Inc., September 1997.

Example 17.5-1 (Continued)

Interpolating from Table 17.5-2, about 16 percent of the weight of the cutback asphalt would evaporate from a medium cure cutback asphalt with 28 percent by volume of diluent.

$$\begin{aligned}\text{Mass Emissions,} \\ \text{Cutback Asphalt} &= 250 \text{ tons} * \frac{2,000 \text{ lbs}}{\text{ton}} * 0.16 \\ &= 80,000 \text{ lbs}\end{aligned}$$

To determine emissions from the use of emulsified asphalt, densities for the diluent and the emulsified asphalt are needed. Assuming the density for emulsified asphalt including diluent is the same as for water, 8.34 lbs/gal, and assuming 100% of the diluent evaporates:

$$\begin{aligned}\text{Mass Emissions,} \\ \text{Emulsified Asphalt} &= 50 \text{ tons} * \frac{2,000 \text{ lbs}}{\text{tons}} * 7\% * 100\% \\ &= 7,000 \text{ lbs}\end{aligned}$$

Total VOC emissions are the sum of the emissions for each type of asphalt used:

$$\begin{aligned}\text{Total VOC Emissions} \\ \text{for the One County} &= 80,000 \text{ lbs} + 7,000 \text{ lbs} \\ &= 87,000 \text{ lbs}\end{aligned}$$

5.1.2 ALTERNATIVE METHOD 2: STATE USAGE DATA, MINIMUM DATA COLLECTION FROM DOTs

Alternative Method 2 involves the use of state asphalt usage data from other sources like the Asphalt Institute, rather than requesting this from DOTs, as is done with the preferred method

and Alternative Method 1.³ First the state level data must be apportioned to the county level. As discussed earlier, the basis for this should be determined in the planning phase. Like extrapolating representative county data to counties for which data have not been collected as done in Alternative Method 1, some options to use as a basis for this allocation include miles of highway, VMT, government highway spending budgets, and population.

State usage data from the Asphalt Institute may not distinguish between the cutback and emulsified asphalt types. The information needed to proportion the total into emulsified and cutback categories can be collected from state and local DOTs. As with Alternative Method 1, a representative group of DOTs should be identified, then information on practices and usage can be collected by telephone. The goal is to (1) determine the percents of each asphalt type that are used, (2) their typical diluent contents, and (3) when the types are used (for ozone inventories). An example telephone survey is shown in Figure 17.5-2.

Once the usage by county has been assigned and the data on asphalt types are available, the equations under Alternative Method 1 can be used to estimate emissions (Equations 17.5-1 and 17.5-3).

5.1.3 ALTERNATIVE METHOD 3: VOLUME USAGE EMISSION FACTORS

The least preferred alternative, Alternative Method 3, is to use volume-based emission factors applied to total asphalt usage data (Table 17.5-2).

These emission factors were prepared for EPA's 1991 guidance for preparing CO and ozone inventories (EPA, 1991) and are discussed in that document. Data on asphalt use must be requested from county DOTs, or state usage data from sources like the Asphalt Institute can be apportioned to the county level as described for Alternative Method 2.

Per capita factors based on national average asphalt use are **not** recommended for this source category, because population is not a reliable indicator of local activity when scaling down from a national level, and usage can vary from year to year, making a factor developed from one year's data inappropriate for another year. A per capita factor developed from state specific data may be an inexpensive way to estimate emissions when the source category is not a high priority.

³ The Asphalt Institute can be contacted by telephone: (606) 288-4960, or through their internet web page: <http://www.asphaltinstitute.org>.

Asphalt Type	Cure/Set Rate	Estimated % of Total Usage	Approximate Diluent Content	Months of the Year Used ^a
Cutback Asphalt	rapid			
	rapid			
	medium			
	medium			
	slow			
	slow			
Emulsified Asphalt	rapid			
	rapid			
	medium			
	medium			
	slow			
	slow			

^a Only needed for ozone inventories.

FIGURE 17.5-2. EXAMPLE TELEPHONE SURVEY FORM

TABLE 17.5-2
ASPHALT PAVING EMISSION FACTORS

Asphalt Type	Volume-based ^a (lb VOC/Barrel Asphalt)
Cutback asphalt	88
Emulsified asphalt	9.2

^a Assuming that the density of asphalt is similar to that of water, 8.34 lbs/gal, one barrel (42 gal) of asphalt weighs 350 lbs.

Asphalt Paving

The EIIP Asphalt Paving chapter was compared to the NTI source category, Asphalt Paving: Cutback Asphalt. The EIIP chapter states that no generic emission factors for HAPs were available. We can supplement the EIIP asphalt paving chapter by using the speciation profiles used in the NTI for cutback asphalt. The speciation profile used in the NTI is shown in Table 17.5-3.

TABLE 17.5-3

HAP SPECIATION PROFILES FOR ASPHALT PAVING: CUTBACK ASPHALT

HAP	Percent Weight of VOC
Ethylbenzene	2.3
Toluene	6.4
Xylene (mixed isomers)	12.2

Once the data have been collected, emissions are estimated as follows:

$$\text{Mass Emissions} = \frac{\text{Volume Usage}}{\text{Emission Factor}} * \frac{\text{Volume Used}}{(\text{Barrels of Asphalt})} \quad (17.5-4)$$

5.2 HAZARDOUS AIR POLLUTANTS

The simplest way to collect the necessary composition information to determine HAP emissions, is for the inventory preparer to request material safety data sheets (MSDSs) or manufacturer technical data sheets (TDSs) from the DOTs receiving the survey. The weight percent of each HAP is taken from the MSDS or TDS, then is multiplied by the weight of VOC emissions estimated by any of the alternative methods to determine the speciated emissions (see Equations 17.4-8 and 17.4-9). Alternatively, the inventory preparer may solicit HAP information from local vendors or a few representative DOTs to establish typical compositions for the asphalt types used in the inventory area. Again, this information is applied to the VOC estimate to determine the speciated HAP emissions.

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6

QUALITY ASSURANCE/QUALITY CONTROL

Data collection and data handling for all estimation methods for this source category should be planned and documented in the Quality Assurance Plan. Quality assurance (QA) and quality control (QC) methods may vary based on the data quality objectives for the inventory.

When using survey based estimation methods, the QA Plan should address the survey method and sample design, in addition to data collection, and data handling steps. Refer to the discussion of survey planning and survey QA/QC in Chapter 1, *Introduction to Area Source Emission Inventory Development*, of this volume, and Volume VI, *Quality Assurance Procedures*, of the Emission Inventory Improvement Program (EIIP) series. When using other methods, data collection, data handling, apportioning of activity data to the inventory area and by asphalt type (for the second alternative method) should be laid out in the QA Plan.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

The highest quality results will come from collecting the most detailed, locality- and time-specific data possible. The preferred approach, if there is good survey coverage, should yield such high quality data. When there are too many asphalt users in the inventory area to survey completely, or when not all of the survey forms are returned, the first alternative method can still provide information about asphalt types, diluent contents, and usage that can be used to develop a high quality area source emission estimate. However, the work involved in collecting the required information through surveys is significantly higher than the work required for the second and third alternative methods. The greater amount of work involved in the preferred and first alternative methods is rewarded in estimates that are more specific to the inventory area and time period. Because asphalt types used and amounts of asphalt used can vary substantially by locale and time period, this more detailed information could be useful, especially where rules have been put in place since the previous inventory period, or new rules are being considered.

The Data Attribute Rating System (DARS) has been developed as a tool to rate emission inventories. A description of the system and the EIIP recommendations for its use can be found in Appendix F of EIIP Volume VI, *Quality Assurance Procedures*. The following discussion uses the DARS rating system as a way to compare the estimation approaches presented in this chapter and analyze their strengths and weaknesses.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The DARS scores for asphalt paving emission estimate methods are shown in Tables 17.6-1 through 17.6-4. The preferred method should provide very good results, so long as most of the asphalt use is included in the survey. The first alternative method, a simplified survey, will also provide good results, but will be less specific because of the scaling of the sample data and the use of average emission factors in some of the equations. Both of these two methods reflect use of specific types of asphalt during the inventory period. Scoring for these two methods scores the asphalt type and diluent content information collection under the emission factor attribute, and scores the usage of each type of asphalt as the activity factor.

The second and third alternative methods, in contrast, are less representative of the inventory area and time period. The second alternative method provides results that reflect state asphalt type usage, but not necessarily local asphalt type usage. The proportions of the asphalt types and the diluent type and content are used to determine the emission factor. Scores for the emission factor attributes are lower than those for the survey methods since this method uses a less specific approach for identifying asphalt types. The third alternative method uses emission factors that were developed through a 1989 top-down, material balance approach. The emission factor attribute scores for this method reflect the overestimation that is introduced by taking this more general approach.

6.2 SOURCES OF UNCERTAINTY

Actual emissions from this source category are affected by variables such as diluent contents of asphalts, climate, road types, and repair frequencies. Emission estimates are affected by the collection of information about the types and amounts of asphalt, diluent contents, scaling factors and the use of average or default diluent contents and densities. Because of these variables, local, inventory time specific data is the best way to reduce uncertainty in emission estimates.

It is important, however, to look at the uncertainty of estimates for asphalt paving in the context of emissions from all area sources. For example, in an area where cutback asphalt use is banned during the inventory season, emissions from emulsified asphalt may be so low that a high degree of uncertainty in the estimate may not significantly impact the overall quality of the inventory.

TABLE 17.6-1

**DARS SCORES FOR ASPHALT PAVING
PREFERRED METHOD: COMPREHENSIVE SURVEY**

Attribute	Factor	Activity	Emissions
Measurement	0.8	0.9	0.72
Source specificity	0.9	0.9	0.81
Spatial congruity	0.9	0.9	0.81
Temporal congruity	1	0.9	0.90
Composite	0.90	0.90	0.81

TABLE 17.6-2

**DARS SCORES FOR ASPHALT PAVING
ALTERNATIVE METHOD 1: SIMPLIFIED SURVEY**

Attribute	Factor	Activity	Emissions
Measurement	0.7	0.8	0.56
Source specificity	0.8	0.9	0.72
Spatial congruity	0.8	0.8	0.64
Temporal congruity	1	0.9	0.90
Composite	0.83	0.85	0.71

TABLE 17.6-3

**DARS SCORES FOR ASPHALT PAVING
ALTERNATIVE METHOD 2: STATE-LEVEL USAGE DATA**

Attribute	Factor	Activity	Emissions
Measurement	0.4	0.7	0.28
Source specificity	0.6 - 0.7	0.8	0.48 - 0.56
Spatial congruity	0.6	0.7	0.42
Temporal congruity	0.8	0.8	0.64
Composite	0.60 - 0.63	0.75	0.46 - 0.48

TABLE 17.6-4**DARS SCORES FOR ASPHALT PAVING
ALTERNATIVE METHOD 3: EMISSION FACTORS**

Attribute	Factor	Activity	Emissions
Measurement	0.3	1	0.30
Source specificity	0.5	0.5	0.25
Spatial congruity	0.5	1	0.50
Temporal congruity	0.5	1	0.50
Composite	0.45	0.88	0.39

7

DATA CODING PROCEDURES

The inventory preparer should check the EPA website (<http://www.epa.gov/ttn/chief/>) for the latest information (codes) available to characterize emission estimates from asphalt paving. A complete list of Source Classification Codes (SCC) can be retrieved at <http://www.epa.gov/ttn/chief/codes/>. Table 17.7-1 lists the applicable SCCs for asphalt paving.

Available codes and process definitions influence and help guide the preparation of emission estimates for this category. Data transfer formats should be taken into account when an inventory preparer plans for data collection, calculation, and inventory presentation. Consistent categorization and coding will result in greater continuity between emission inventories for use in regional and national scale analyses.

7.1 NECESSARY DATA ELEMENTS

If the category emissions data will be transferred to EPA for incorporation into the national criteria and toxics air pollutant inventory, specific data transfer formats are acceptable. The acceptable data transfer format(s) are described and available for download at <http://www.epa.gov/ttn/chief/net/>. The acceptable data transfer formats contain the data elements necessary to complete the data set for use in regional or national air quality and human exposure modeling. The inventory preparer should review the area source portion of the acceptable file format(s) to understand the necessary data elements. The EPA describes its use and processing of the data for purposes of completing the national inventory, in its Data Incorporation Plan, also located at <http://www.epa.gov/ttn/chief/net/>.

TABLE 17.7-1

AREA AND MOBILE SOURCE CATEGORY CODES FOR ASPHALT PAVING

Process Description	Source Category Code
Cutback Asphalt - Total: All Solvent Types	24-61-021-000
Cutback Asphalt - Special Naphthas	24-61-021-370
Cutback Asphalt - Solvents: NEC ^a	24-61-021-999
Emulsified Asphalt - Total: All Solvent Types	24-61-022-000
Emulsified Asphalt - Special Naphthas	24-61-022-370
Emulsified Asphalt - Solvents: NEC	24-61-022-999

^a NEC = Not elsewhere classified.

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VOLUME III: CHAPTER 18

STRUCTURE FIRES

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Prepared by:
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Prepared for:
Area Sources Committee
Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

This chapter is one of a series of documents developed to provide cost-effective, reliable and consistent approaches to estimating emissions for area source inventories. Multiple methods are provided in the chapters to accommodate needs of state agencies with different levels of available resources and skills; and different levels of needs for accuracy and reliability of their estimates. More information about the EIIP program can be found in Volume 1 of the EIIP series, *Introduction and Use of EIIP Guidance for Emissions Inventory Development*.

Throughout this chapter and other EIIP area source methods chapters, we stress that area source categories should be prioritized by the inventory planners so that resources can be spent on the source categories that are the largest emitters, most likely to be subject to regulations or are already subject to regulations, or require special effort because of some policy reason. Prioritization is particularly important for area source inventories, because in some cases, a difficult to characterize source category may contribute very little to overall emissions and attempting a high quality estimate for that source category may not be cost effective.

EIIP chapters are written for the state and local air pollution agencies, with their input and review. EIIP is a response to EPA's understanding that state and local agency personnel have more knowledge about their inventory area's activities, processes, emissions, and availability of information; and require flexible inventory methods to best use their sometimes limited resources. These EIIP area source chapters are written as a set of options presented to inventory professionals capable of using their own experience and judgement to apply the method that best fits their overall needs and constraints.

This chapter describes the procedures and recommended approaches for estimating emissions from structure fires. Section 2 of this chapter contains a description of this category. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation methods for structure fires, and Section 5 presents alternative emission estimation techniques. Quality assurance and quality control procedures are described in Section 6. Data coding procedures are discussed in Section 7, and Section 8 lists all references cited in this chapter.

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2

SOURCE CATEGORY DESCRIPTION

Accidental structure fires result from unintentional actions, arson, or natural events. Structure fires covered in this chapter are accidental fires that occur in residential and commercial structures. Accidental industrial fires are not included in this chapter because detailed emission estimates are required that depend on the materials burned in each fire. Discussions about this source can be found in two EPA documents (EPA, 1991 and EPA, 1993). A method for estimating emissions from firefighters' practice fires is not defined in this chapter, but if it is necessary to estimate fires from this source, the emission factors and the approach used in this chapter to determining fuel loading may be useful.

Prescribed fires, agricultural fires, and other forms of open burning are discussed in Chapters 16, 19, and 20 of this volume. Fires covered in these chapters are those that occur because of intentional actions (excluding arson) and are used to reduce or remove waste materials.

2.1 PROCESS DESCRIPTION

Structure fires covered in this chapter are only those affecting residential or commercial structures. Accidental fires in yards, of vehicles and telephone poles are not included in this chapter. Emissions from these types of fires are assumed to be very small.

Structural materials such as insulation and wood, and the contents of structures such as furniture, carpets, clothing, paper and plastics, can burn in a structure fire. Not all of the contents and structural materials burn in a fire, rather, the fire burns a portion of the contents and structural material in the rooms where the fire originates and spreads. The average total material burned (fuel loading) in a residential fire is estimated to be 1.15 tons (CARB, 1994). The emission estimation methods discussed here are not valid for industrial fires where chemicals or industrial materials are burned. Emission estimates for industrial fires should be based on the type of industrial chemicals burned in each fire.

2.2 FACTORS INFLUENCING EMISSIONS

Emissions from structure fires depend on the structure type, physical properties of combustible materials, and amount of material combusted. Residential and commercial structures will tend to have differences in mixtures and quantities of combustible materials that will cause

differences in structural fire emissions. The portion of the structure and contents that are burned is a function of the extent of the fire as well as the available fuel loading.

Process control mechanisms do not exist for accidental structure fires. Programs that improve public awareness may reduce the number of accidental structure fires. However, the correlation between such programs and reductions in structure fires is difficult to determine. Fire codes also serve to reduce emissions from structure fires by requiring reductions in available fuel, installation of sprinkler systems, and warning systems that improve emergency response time.

3

OVERVIEW OF AVAILABLE METHODS

Calculations for estimating emissions for structure fires use an equation based on emission factors, fuel loading, and activity data. Area source methods can not address all of the complexity involved in this source category. This section provides an overview of inventory planning issues for the structure fire source category, outlines the preferred and alternative methods, and discusses temporal adjustments and emission projection issues.

One of the particular difficulties in estimating emissions from the structure fire source category is the lack of activity data, in terms of the number of incidents and the quantity of material burned. When parameters have poorly defined or unavailable information, inventory preparers will need to make well-educated assumptions.

Preferred and alternative methods in this chapter differ mainly in the level of detail and area-specificity of the collected fuel loading and activity data. Each method has advantages and disadvantages in terms of the expense and labor required for the method and the resulting quality of the emission estimate. The inventory preparer must select a method based on the desired accuracy of the emissions inventory, the resources available to develop the inventory, and the potential for the source to contribute to the emissions inventory.

3.1 PLANNING

The first step in planning for structure fire estimation is to determine if enough fires took place in the inventory area during the inventory time period to warrant including this source category in the inventory. Refer to the second alternative method for ways to estimate the scale of potential emissions from this source.

If it is determined that this source category should be included in the inventory, then the next step is to choose an emission estimation method. This choice is based on the inventory data quality objectives (DQOs), the estimated scale of the emissions relative to other area sources, and availability of the information needed to make the calculations. The available information and the amount of time and resources needed to collect it should be balanced with the priorities and DQOs of the inventory to select the appropriate method for the inventory. Refer to EIIP Volume VI, Quality Assurance Procedures, Sections 2.1 and 2.4 for discussions of inventory categories and DQOs. Detailed information about this source category should be available from local fire marshals and public safety departments, or state agencies that oversee public safety.

National summary statistics on structure fires are available from the United States Fire Administration and the National Fire Protection Agency (NFPA).^{1,2}

3.2 AVAILABLE METHODS AND DATA REQUIREMENTS

The preferred and alternative methods for estimating emissions from structure fires are summarized in Table 8.3-1. Emission factors are available to estimate particulate matter (PM), total organics (TOG), methane (CH₄), sulfur oxides (SO_x), carbon monoxide (CO), hydrogen cyanide, formaldehyde, acrolein, and nitrogen oxides (NO_x) (Butler, 1972; EPA, 1995). To use these emission factors, the total tons of material burned must be obtained from the activity and the fuel loading. Calculation parameters to determine the quantity of material burned are provided with the description of each estimation method.

TABLE 18.3-1

SUMMARY OF AVAILABLE METHODS FOR STRUCTURAL FIRES

Method Description	Activity Data
PREFERRED Collect data for the number of residential and non-residential structural fires. Use the fuel loading and emission factors provided. Calculation: Number of fires * Fuel Loading Factor * Emission Factor	- Number of fires occurring within inventory area
ALTERNATIVE 1 Collect data on the number of fires for a representative portion of the inventory area and scale to the entire inventory area based on population. Use the fuel loading and emission factors provided.	- Number of fires for superset or subset area - Inventory area and subset area population
ALTERNATIVE 2 Use the fires per capita factor provided with the method, fuel loading and emission factors provided.	- Inventory area population

¹ The United States Fire Administration can be contacted at: 16825 South Seton Ave., Emmitsburg, MD 21727, phone: (301) 447-1000, or on the Internet: <http://www.usfa.fema.gov/>

² The National Fire Protection Agency can be contacted at: 1 Batterymarch Park, Quincy, MA, 02269, phone: (617) 770-3000, or on the Internet: <http://www.nfpa.org/>

The preferred method uses activity data collected for the entire inventory area. The first alternative method uses activity data for either a subarea or a similar area that is scaled or apportioned to the entire inventory area. A similar area is one that has the same population density and housing characteristics. The second alternative is based on default per capita activity.

3.3 ADJUSTMENTS

3.3.1 APPLICATION OF CONTROLS

No controls are available for this sources. The number of structure fires may be reduced as a result of public awareness programs. The activity may reflect the impact of such programs.

3.3.2 SPATIAL ALLOCATION

Spatial allocation of the activity data is necessary for the alternative estimation methods. In those cases, the data must be extrapolated or scaled to the inventory area using a spatial surrogate. In addition to scaling or extrapolating emissions or activity from one area to another, emissions or activity may need to be allocated within the inventory area. The recommended spatial allocation surrogate for structure fires is population.

3.3.3 TEMPORAL RESOLUTION

Seasonal Resolution

Structure fires vary seasonally. Structural fires may increase during cold weather for some inventory areas due to careless open burning, Christmas lights, or space heater or fireplace use. For this reason, it is emphasized that the inventory preparer should investigate the time of occurrence for these fires relative to the time period of the inventory during the inventory planning stage.

The preferred method for apportioning structural emissions by season is to use local season-specific activity data. The preferred emission estimation method is detailed enough to collect season-specific data. In this case, information is collected on an incident-by-incident basis, and emissions are either calculated for each incident or can be apportioned according to locally specific activity levels.

Alternative apportioning methods for structure fires are, in order of preference:

- Collect data from another area, either a subset, superset, a similar area, or from a year other than that of the inventory for the inventory area. Using this approach should include an effort to match the surrogate area or year to the inventory area and year in terms of the factors that influence the frequency and severity of accidental fires;
- Use estimates of activity from a local expert, such as the fire marshal or public safety office; or
- Use the seasonal distribution reported in the National Fire Data Center's report, *Fire in the United States*.³ An example for 1994 of the monthly distribution of residential and nonresidential structure fires is provided in Table 18.3-2. Please note that this distribution represents national averages, and the distribution of occurrences within a particular inventory area may differ. Non-residential fires for this report are classified as industrial and commercial properties, institutions, educational establishments, mobile properties, and properties that are vacant or under construction.

Daily Resolution

Structure fires can be expected to take place seven days a week. Structure fire occurrences are consistent through the week.³ The preferred and alternate methods discussed above for attaining seasonal resolution apply for daily resolution as well.

3.3.4 OTHER FACTORS INFLUENCING EMISSION ESTIMATES

Natural disasters may affect structure fire activity and the resulting emissions. Natural disasters such as hurricanes, tornadoes, ice storms or floods may cause electricity outages which increases the use of fire in residences and increase the risk of structure fires. If the per capita activity factor is used to develop the inventory, expert opinion may be required to estimate the impact of natural disasters on structural fire activity.

³ Fire in the United States 1985 - 1994, Ninth Edition, FA - 173/July 1997, or a similar and more recent publication can be ordered from: United States Fire Administration, Federal Emergency Management Agency, Publications Center, Room N310, 16825 South Seton Avenue, Emmitsburg, MD 21727, or ordered through the Web site: <http://www.usfa.fema.gov/>

TABLE 18.3-2**OCCURRENCE OF RESIDENTIAL AND NON-RESIDENTIAL STRUCTURE FIRES IN 1994,
BY MONTH^a**

Month	Residential Structure Fires %	Non-Residential Structure Fires %
January	12.6	9.0
February	9.8	7.8
March	9.1	9.0
April	8.2	9.3
May	7.4	8.6
June	7.5	8.9
July	7.4	8.5
August	6.9	7.8
September	6.6	7.4
October	7.5	8.1
November	8.0	7.8
December	9.0	7.7
Total	100	99.9

^a Source: FEMA, 1997.

3.3.5 PROJECTING EMISSIONS

A discussion about developing growth factors and projecting emission estimates can be found in Section 4 of Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development*.

Projecting emissions for structure fires usually will take into account only changes in activity levels. Sources of variation in structural fires include:

- Changes in population, either in total population or population shift in residential housing types; and

- Changes in fire codes, building codes, or inspection policies that reduce the risk of fires.

4

PREFERRED METHOD FOR ESTIMATING EMISSIONS

Emissions from structure fires are determined by the incidence of fires and the amount and the type of material burned. The preferred method presented here is a set of guidelines for identifying the parameters that need to be collected, where the information can be located, and the assumptions that can be used in order to develop reasonable estimates. There is no universal data source that can be used for every inventory to estimate emissions for this source category. When lists of potential data sources are given as part of a method, one or more of these data sources may need to be contacted.

As with all area source inventory categories, documentation should be maintained for data collected, assumptions, information contacts, and calculations. Because preparation of an inventory for this source category requires making assumptions in order to develop activity levels, the basis for all assumptions must be well documented.

For structure fires, costs and labor efforts are highest the first time that the preferred method is used. Subsequent updates to the inventory can be done using a local activity adjustment factor, if a suitable scaling surrogate can be identified. Subsequent inventories should take advantage of the data handling and quality assurance/quality control (QA/QC) routines put into place the first time the method was used. See discussions of surveys for area sources in Volume 1 of the EIIP series and in Chapter 1 of this volume for more information.

4.1 STRUCTURE FIRES

The preferred method for estimating emissions from structure fires should be used if more detailed emission estimates are needed for planning, or the source category is a high priority. If the information needed for this method can be easily compiled, then it may be worthwhile to develop locality-specific activity surrogate factors and fuel loadings.

4.1.1 ACTIVITY LEVEL DATA COLLECTION

The preferred method for structural fires uses the statistics for the total number of fires in an inventory area. Structure fire statistics by month are preferred for seasonal inventories such as

ozone or CO inventories. If the default fuel loading factor is being used, then data on the structure types that are involved in the fires need not be collected.

Potential information sources for locality-specific structure fires activity data are local or state fire marshals or local or state fire and public safety departments. Reporting and availability of information about structure fires will vary by locality. These contacts may also be able to provide estimates of material loss for the inventory area, either as a portion of the structure or as tons burned per fire.

When collecting information about occurrences of structure fires, be certain that the definition of a structure fire counted by the fire marshal is actual fires and not the number of emergency calls. Also, clarify the size of the fires if possible. Structure fires can be very small, such as electrical wiring or cooking fires, or they can be large, consuming the entire structure. Most reported fires will be small. Additionally, if fires that take place on residential property, such as garage fires, are classified separately from other residential fires, then statistics for garage fires should be obtained and included in the activity used to estimate emissions. Descriptions of the statistics will also assist in determining if the majority of fires within the inventory area are accounted for by the fire marshal.

4.1.2 FUEL LOADING

Fuel loading estimates are necessary to convert the activity (number of fires) to units compatible with the emission factors, which are based on the weight of material burned. The material burned will be a function of the total material available and the duration of the fire. The total combustible material depends on the intended use of the structure. Structures can be broadly classified as residential and non-residential, which includes commercial and institutional structures. Residential structures can be further classified as single family and multi-family dwellings. The state or local fire marshal may be able to provide estimates of material loss for the inventory area, either as a portion of the structure or tons burned per fire. However, losses are usually reported in terms of the dollar value lost.

The most conservative fuel loading estimate will assume that all the combustible material is burned. However, this is not likely for most structural fires. Locality-specific fuel loading factors for different structure types would improve the emission estimate, but a fuel loading factor of 1.15 tons per fire using a method developed by California Air Resources Board

(CARB) is an acceptable default value for all types of structures.⁴ The CARB approach to developing a local fuel loading factor could be used for other inventory areas.

The fuel loading factor is based on an estimate of combustible structural content for a typical residence, and an estimate of the average loss per fire. Combustible structural content is the sum of the combustible structural materials and the building contents. Fuel loading is a percentage of the total combustible structural content. Fuel loading is calculated:

$$\text{Combustible Structural Materials} = (\text{Structural Mass} + \text{Contents}) * \text{Loss Percentage} \quad (18.4-1)$$

Combustible structural mass is calculated by multiplying an estimate of combustible material per square foot in the building structure by the average residence's square footage:

$$\text{Combustible Structural Materials (tons)} = \left(\frac{\text{Combustible Structural Mass}}{\text{lb/sq ft}} * \frac{\text{Square Footage per Residence}}{\text{sq ft}} \right) \div 2000 \text{ lb/ton} \quad (18.4-2)$$

CARB's estimate for combustible structural mass is 16.3 pounds per square foot. Assuming an average residence size is 1350 square feet, combustible structural materials would be:

$$\begin{aligned} \text{Combustible Structural Materials} &= (16.3 \text{ lb/sq ft} * 1350 \text{ sq ft}) \div 2000 \text{ lb/ton} \\ &= 11 \text{ tons} \end{aligned} \quad (18.4-3)$$

Average residence size can vary from region to region. Inventory preparers are encouraged to identify a local average residence size. The U.S. Census Bureau⁵ reports that the national median residence size in 1995 was 1732 square feet.

Combustible building contents are calculated by multiplying an estimate of contents per square foot in the building structure by the average residence's interior floor space:

⁴ This method is derived from the CARB *Emission Inventory Procedural Manual, Vol. III: Methods for Assessing Area Source Emissions*, developed by the California Environmental Protection Agency: Air Resources Board. The latest version of the manual is available on the internet at: <http://www.arb.ca.gov/emisinv/areasrc/areameth.htm>

⁵ The U.S. Census Bureau maintains an Internet Web site at: <http://www.census.gov/>

$$\text{Combustible Building Contents (tons)} = \left(\frac{\text{Combustible Building Contents}}{\text{lb/sq ft}} * \frac{\text{Floor Space}}{\text{per Residence sq ft}} \right) \div 2000 \text{ lb/ton} \quad (18.4-4)$$

CARB's estimate for combustible building contents is 7.91 pounds per square foot. Assuming an average floor space per residence is 1200 square feet, combustible building contents would be:

$$\begin{aligned} \text{Combustible Building Contents} &= (7.91 \text{ lb/sq ft} * 1200 \text{ sq ft}) \div 2000 \text{ lb/ton} \\ &= 4.7 \text{ tons} \end{aligned} \quad (18.4-5)$$

CARB estimates that the average loss per fire is 7.3 percent of the combustible structural content. The average loss is based on monetary losses reported by FEMA and the average value of residences reported by the California Association of Realtors. The loss rate is applied to the estimated total combustible structural content to obtain a fuel loading per fire:

$$\begin{aligned} \text{Fuel Loading} &= \left(\frac{\text{Combustible Structural Materials}}{\text{tons}} + \frac{\text{Combustible Building Contents}}{\text{tons}} \right) * \frac{\text{Loss Rate}}{\%} \\ &= (11 \text{ tons} + 4.7 \text{ tons}) * 0.073 \\ &= 1.15 \text{ tons/fire} \end{aligned} \quad (18.4-6)$$

The percent loss was estimated based on monetary losses. Fire marshalls typically report losses as dollar loss statistics. There are, however, several weaknesses in using the dollar loss to estimate the percentage of material combusted. First, material may be damaged by smoke or sprinkler systems and counted as loss even though it is not combusted. Second, the value of contents or structures is not directly proportional to the mass. Finally, the percent monetary loss is the average loss divided by the average dollar value of structures. Since these two values do not come from the same data source, there can be discrepancies in how they are determined. Despite these weaknesses in representing material combusted, percent dollar losses may be the most practical way to represent the percentage of material burned in a fire.

Emission Factors

Emission factors for structural fires are presented in Table 18.4-1. The emission factors given are assumed to apply to all structure types.

TABLE 18.4-1

EMISSION FACTORS FOR STRUCTURE FIRES

Pollutant	Factor (lb/ton burned)	Reference
PM	10.8	CARB, 1994 ^a
TOG	13.9	CARB, 1994 ^a
Hydrogen cyanide	35.49	EPA, 2000
Formaldehyde	1.02	EPA, 2000
Acrolein	4.41	EPA, 2000
Hydrochloric acid	15.11	EPA, 2000
VOC	11	EPA, 1991
NO _x	1.4	EPA, 1991
CO	60	EPA, 1991

^a See footnote 4 in the text for more information about this document.

Emission Calculations

Emissions from structure fires are determined by multiplying the number of reported structure fires by the fuel loading per fire and the emission factors from Table 18.4-1:

$$\text{Emissions} = \text{Emission factor} * \text{Activity} * \text{Fuel loading} \quad (18.4-7)$$

where:

Emissions	=	Emissions for a given pollutant (lb emitted)
Emission factor	=	Emission factor for a certain pollutant (lb emitted/ton burned)
Activity	=	Number of fires within the inventory area (fires)
Fuel loading	=	Fuel loading per fire (ton burned/fire)

If emissions are being calculated for an inventory season, and local season-specific activity is not available, emissions can be apportioned using any of the three alternative apportioning approaches from Section 3.3.3 of this chapter. Example 18.4-1 shows a typical calculation for one county in an inventory area.

Example 18.4-1:

County A has had 115 structure fires reported for the inventory year. Information about the structure types and the extent of the material burned in each fire was not collected, so the default fuel loading of 1.15 tons per fire was used. The PM emissions for structure fires in County A are:

$$\begin{aligned}\text{Emissions} &= 10.8 \text{ lb/ton} * 115 \text{ fires/year} * 1.15 \text{ tons/fire} \\ &= 1,428 \text{ lbs/year} \\ &= 0.71 \text{ tons/year}\end{aligned}$$

5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

Alternative methods require less effort and less cost, but may result in estimates that are less detailed and/or less locality-specific. The choice of a preferred over an alternative method will be determined by the DQOs and budget for the inventory. For this source category in particular, the significance of sources to the total area emissions should be considered when choosing methods.

During the planning stage of the inventory, research should be done to identify data sources and other factors that might influence emissions from the source category. See Section 3.1 of this chapter for specific issues.

5.1 FIRST ALTERNATIVE METHOD

The first alternative method for estimating emissions from structural fires uses the same emission factors and same default fuel loading described in the preferred method for this category. The first alternative method relies on activity data from a larger inventory area that is apportioned to the inventory area, or on activity data from a subarea that is scaled to the inventory area. Activity information may be available from state or local fire marshals and public safety departments, neighboring inventory areas, or from a subset of the inventory area.

When activity data is available for the whole state, or an area larger than the inventory area, then the number of fires for the state will need to be apportioned to the county level. Population can be used to apportion the number of fires. The equation to apportion the number of fires is:

$$\text{Fires in county} = \text{Fires in state} * \text{county population/state population} \quad (18.5-1)$$

If activity data is scaled from a subarea or similar area, population is also used for scaling. When information is collected for a small area and scaled to the inventory area, the number of fires that occurred in that subarea can be collected from the few fire departments that serve that subarea. The area that is used as a source of activity data should be similar to the entire inventory area. According to statistics in the report, *Fire in the United States: 1985 - 1994* (FEMA, 1997), cooking and heating are the leading causes of residential structure fires. As a

result, heating types may have some influence on fire incidences, and structure fire activity from an area that has distinctly different residential heating types than the inventory area may not be a good match. The U.S. Bureau of Census can provide data on population and heating types.⁶ The scaling equation for structure fire activity from a subarea to a county in the inventory area is:

$$\text{Fires in county} = \text{Fires in subarea} * \text{county population/subarea population} \quad (18.5-2)$$

After activity data is scaled or apportioned to the inventory area, the default fuel loading factor, emission factors, and emission calculations are the same as those described for the preferred method.

Use any of the three alternative seasonal apportioning methods listed in Section 3.3.3 of this chapter.

5.2 SECOND ALTERNATIVE METHOD

The second alternative method for estimating emissions from structural fires uses the same emission factors and the same fuel loading that is described in the preferred method. However, for this method, the activity is obtained by multiplying a national average factor of fires per capita by the inventory area population. The number of fires per capita is based on an estimated 602,500 total fires reported for 1994 (FEMA, 1997) and a U.S. population of 260.4 million (1994 U.S. population)⁷, averaging 2.3 fires per 1,000 people. If more recent data on total fires becomes available, then those data can be used to calculate a more recent per capita activity factor. Inventory area population is multiplied by the per capita factor to get the estimated number of structure fires in the area.

After the inventory area activity level is determined, emission calculations are the same as those described for the prescribed method, using the default fuel loading of 1.15 tons per fire and the emission factors in Table 18.4-1. Example 18.5-1 shows typical calculations.

⁶ Census data is available through the U.S. Bureau of Census, Commerce Department, Washington, DC, or through the Web site: <http://www.census.gov>.

⁷ U.S. Bureau of Census Web site: <http://www.census.gov>.

Example 18.5-1:

County B's population is 0.5 million people. The structure fire activity is determined to be:

$$\begin{aligned}\text{Activity} &= \text{population} * \text{fires/population} \\ &= 0.5 \text{ million people} * 2.3 \text{ fires/ 1,000 persons} \\ &= 1,150 \text{ fires}\end{aligned}$$

PM emissions can then be calculated as:

$$\begin{aligned}\text{Emissions} &= \text{emission factor} * \text{activity} * \text{fuel loading} \\ &= 10.8 \text{ lb/ton} * 1,150 \text{ fires/year} * 1.15 \text{ tons/fire} \\ &= 14,283 \text{ lbs/year}\end{aligned}$$

Use any of the three alternative seasonal apportioning methods listed in Section 3.3.3 of this chapter.

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6

QUALITY ASSURANCE/QUALITY CONTROL

Data collection and handling for the structure fire source category should be planned and documented in the Quality Assurance Plan. Assumptions used and decisions made concerning data sources should be documented. Refer to the Quality Assurance Quality Control (QA/QC) section of Chapter 1, *Introduction to Area Source Emission Inventory Development*, of this volume, and the QA volume (VI) of the Emission Inventory Improvement Program (EIIP) series. Potential pitfalls when developing emissions estimates:

- Incomplete or inaccurate reports of the number of fires;
- Reporting that covers a geographic area that is either larger or smaller than that for the inventory; and
- Inaccurate estimates of the material burned for each fire.

Potential errors common to many area source methods are calculation errors, including unit conversion errors and data transfer errors.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

In this chapter, three estimation methods are presented. The preferred method uses local data on fire incidences collected for the entire inventory area, fuel loading factors developed from local data or default factors from CARB, and a set of emission factors compiled from multiple sources (see Table 18.4-1). The first alternative method uses local data on fire incidences collected for a subset of the inventory area, the CARB default fuel loading factors, and the same set of emission factors as the preferred method. The second alternative method uses the national average factor of fires per capita to develop the activity, the CARB default fuel loading factor, and the emission factors used for the preferred and first alternative methods. Using the most accurate activity data, in the form of fire incidences and fuel loading, is the way to develop the best emission estimates. However, inventory planners should consider the costs of data collection versus the benefit of a more accurate estimate for a very small emissions source.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The Data Attribute Rating System (DARS) has been developed as a tool to rate emission inventories. A description of the system and the EIIP recommendations for its use can be found in Appendix F of EIIP Volume VI, Quality Assurance Procedures. The following discussion uses the DARS rating system as a way to compare the estimation approaches presented in this chapter and analyze their strengths and weaknesses.

The DARS scores for the three estimation methods are summarized in Tables 18.6-1 through 18.6-3. Variation between scores depends on the activity data used. All scores assume that good QA/QC measures were performed and that no significant deviations from the prescribed methods were made.

TABLE 18.6-1
STRUCTURE FIRES
PREFERRED METHOD: LOCAL DATA

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5	0.6	0.3
Source specificity	0.7	0.4	0.28
Spatial congruity	0.7	0.7	0.49
Temporal congruity	0.7	0.9	0.63
Composite	0.65	0.65	0.43

TABLE 18.6-2

STRUCTURE FIRES
ALTERNATIVE METHOD 1: SCALED LOCAL ACTIVITY

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5	0.5	0.25
Source specificity	0.7	0.4	0.28
Spatial congruity	0.7	0.6	0.42
Temporal congruity	0.7	0.9	0.63
Composite	0.65	0.6	0.4

TABLE 18.6-3

STRUCTURE FIRES
ALTERNATIVE METHOD 2: PER CAPITA ACTIVITY

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5	0.4	0.2
Source specificity	0.7	0.3	0.21
Spatial congruity	0.7	0.5	0.35
Temporal congruity	0.7	0.8	0.56
Composite	0.65	0.5	0.33

6.1.2 SOURCES OF UNCERTAINTY

Another way to assess the emission methods is to examine the associated uncertainty. For the preferred and first alternative methods, activity data is derived from local data, and can be treated as survey data. Uncertainty for survey data can be quantified (see Chapter 4 of Volume VI of the EIIP series). The uncertainty for the second alternative method, using fires per 1,000 people, can be calculated by referring to the supporting documentation for the national fire estimates (FEMA, 1997). This uncertainty will only pertain to the national estimate.

Additional uncertainty will be introduced by scaling the activity estimate to an inventory area, where average conditions of fire incidence may not exist.

A source of uncertainty for all of the methods is the fuel loading factor. No two fires will burn the same amount of material, and material types and structure sizes vary from region to region in the United States, as well as within a single county. The default fuel loading factor provided here is an average of a highly variable factor, and should be understood to represent a practical way to estimate area-wide emissions.

Emission factors also contribute to overall uncertainty. Emission rates of any pollutant for this source category will be highly variable, given that the process is uncontrolled combustion of mixed materials, and is not well constrained. This uncertainty cannot be quantified.

DATA CODING PROCEDURES

The inventory preparer should check the EPA website (<http://www.epa.gov/ttn/chief/>) for the latest information (codes) available to characterize emission estimates from structure fires. A complete list of Source Classification Codes (SCC) can be retrieved at <http://www.epa.gov/ttn/chief/codes/>. Table 18.7-1 lists the applicable SCCs for structure fires.

Available codes and process definitions influence and help guide the preparation of emission estimates for this category. Data transfer formats should be taken into account when an inventory preparer plans for data collection, calculation, and inventory presentation. Consistent categorization and coding will result in greater continuity between emission inventories for use in regional and national scale analyses.

7.1 NECESSARY DATA ELEMENTS

If the category emissions data will be transferred to EPA for incorporation into the national criteria and toxics air pollutant inventory, specific data transfer formats are acceptable. The acceptable data transfer format(s) are described and available for download at <http://www.epa.gov/ttn/chief/net/>. The acceptable data transfer formats contain the data elements necessary to complete the data set for use in regional or national air quality and human exposure modeling. The inventory preparer should review the area source portion of the acceptable file format(s) to understand the necessary data elements. The EPA describes its use and processing of the data for purposes of completing the national inventory, in its Data Incorporation Plan, also located at <http://www.epa.gov/ttn/chief/net/>.

TABLE 18.7-1

AREA AND MOBILE SOURCE CATEGORY CODES FOR STRUCTURE FIRES

Process Description	Source Category Code
Structure Fires - total	28-10-030-000

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VOLUME III: CHAPTER 24

CONDUCTING SURVEYS FOR AREA SOURCE INVENTORIES

Final Report

December 2000



Prepared by:
Eastern Research Group

Prepared for:
Area Sources Committee
Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

1.1 WHAT IS A SURVEY?

A survey is a method of gathering information from a number of individuals (a “sample”) in order to learn something about the larger population from which the sample has been drawn. Surveys can be conducted using different tools and may have variety of purposes, but all surveys have two characteristics in common:

- Information is collected from only a sample of the population; and
- Information is collected by means of standardized questions so that every individual surveyed responds to exactly the same question(s).

The steps involved in the survey process are presented in Figure 24.1-1. Inventory preparers often use survey questionnaires to gather point source emissions inventory data. Emission inventories for area sources are usually not compiled using the same methods as emission inventories for point sources. The level of effort required to collect data and estimate emissions from the large number of individual facilities or activities would be very high, especially with respect to the relatively low levels of pollutants emitted by each. To estimate emissions from area sources, the individual facilities or activities are grouped with like facilities or activities into broad source categories so that emissions can be collectively estimated using one methodology. A survey approach can be used to gather information needed to calculate area source emission estimates or used to develop region-specific emission factors for the development of emission estimates.

1.2 HOW CAN THIS CHAPTER HELP ME?

This chapter is intended to help state and local air pollution control agency personnel determine if a survey is needed as part of their area source emissions inventory development effort, and if so, will assist them in planning and implementing each of the steps in the survey process.

1.3 HOW IS THIS CHAPTER ORGANIZED?

This chapter consists of 10 sections and presents information you can use to:

- Determine if you need to conduct a survey (see Section 2);

Steps in the Surveying Process

1. Define the purpose. Be specific!
2. Determine if a survey is needed.
3. Define the population.
4. Develop the survey plan.
5. Develop survey questions.
6. Develop introduction and instructions.
7. Pretest instrument.
8. Edit and revise questionnaire.
9. Obtain approvals as required.
10. Distribute the survey.
11. Follow-up as required.
12. Quality control/data reduction.
13. Analyze the data.
14. Compile the results.

Figure 24.1-1. Steps in the Surveying Process

- Prepare a written plan for your survey effort (see Section 3);
- Choose the appropriate type of survey for your project (see Section 4);
- Select an appropriate sample for your survey (see Section 5);
- Identify the appropriate contacts (see Section 5);
- Design an effective survey document (see Section 6 and 7);
- Distribute and track the survey (see Section 8);
- Compile the data; and
- Conduct quality control/quality assurance (QA\QC) throughout the survey process.

1.4 WHERE CAN I GO FOR ADDITIONAL INFORMATION?

While this document attempts to compile the information necessary to plan and conduct a survey, you may wish to refer to more in-depth references for additional information on some aspect the of the survey process. Section 10 of this chapter presents complete citations for all of the references used to prepare this document. In addition, you can find valuable information in:

Babbie, E. (1990). *Survey Research Methods*. Belmont, CA: Wadsworth, Inc.

Braverman, M.T. & Slater, J.K. (Eds) (1996). *Advances In Survey Research. New Directions for Evaluation*, 70. San Francisco, CA: Jossey-Bass.

Dillman, D. (2000). *Mail and Internet Surveys: The Tailored Design Method*. New York: John Wiley & Sons.

Fink, A. (1998). *How to Design Surveys*. The Survey Kit No. 5. Thousand Oak, CA: Sage.

Fink, A. & Kosecoff, J. (1998). *How to Conduct Surveys: A Step-by-Step Guide*. Thousand Oaks, CA: Sage.

Fowler, F.J. (1993). *Survey Research Methods. Sage Applied Social Research Methods Series Volume 1*. Thousand Oaks, CA: Sage.

Kalton, G. (1983). *Introduction to Survey Sampling. Sage Series on Quantitative Applications in the Social Sciences*, Volume 35. Thousand Oaks, CA: Sage.

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- Rea, L.M. & Parker, R.A. (1997). *Designing and Conducting Survey Research: A Comprehensive Guide*. San Francisco, CA: Jossey-Bass.
- Smith, M.L. & Glass, G.V. (1987). *Research and Evaluation in Education and the Social Sciences*. Englewood Cliffs, NJ: Prentice-Hall.
- Sudman, S. & Bradburn, N.M. (1982). *Asking Questions: A Practical Guide to Questionnaire Design*. San Francisco, CA: Jossey-Bass.

2

HOW DO I DETERMINE IF A SURVEY IS NECESSARY?

In general, you should remember that any survey requires an extensive level of effort. The decision to undertake a survey should be made only after you have considered all other possibilities.

Surveys can be useful tools for collecting information from a large population—they can provide data to make calculations or information on which to base decisions. Although surveys can be expensive, difficult, or time-consuming, there are times when a survey is the most appropriate tool to use to gather data. To determine if a survey is required as part of the data collection effort for an area source emissions inventory for a specific category, you should:

- Assess your data needs;
- Evaluate the relative importance of the category to total emissions inventory;
- Evaluate your data quality objectives;
- Assess data availability;
- Evaluate resource availability;
- Consider the administrative clearances needed under federal or state rules to conduct a survey of the private sector; and
- Consider if it is possible to coordinate the information collection activity with other inventory efforts.

Each of these criteria is discussed in the following sections.

2.1 ASSESS YOUR DATA NEEDS

In order to determine if you must conduct a survey to collect the data needed for your area source emission inventory effort, you must first develop a specific definition of what data are required. The more specific you can make your definitions, the easier it will be to collect the

appropriate data. The objectives of a survey can usually be phrased in the form of a question, such as:

- Which control devices do autobody refinishers use?
- How much solvent do dry cleaning facilities purchase on an annual basis?
- How much wood do households burn per week in the winter?

Surveys may be used to collect qualitative information for the source category, but should be designed to produce quantitative results—that is, results that can be expressed numerically and can be used in rigorous data analysis.

For area source inventory purposes, keep in mind that the data collected from the sample will be scaled up for the entire inventory region. Even if not specifically stated in the inventory preparation plan, you will need to identify and collect reasonable surrogate data.

2.2 EVALUATE THE RELATIVE IMPORTANCE OF THE CATEGORY TO YOUR TOTAL EMISSIONS INVENTORY PROGRAM

You should use existing inventory data and your knowledge of federal, state, and local regulations to determine the importance of an individual emissions inventory project within the scheme of the overall responsibilities of your agency.

Questions to ask include:

- Does the source category emit a large percentage of the pollutant(s) of interest? Is the category a significant source of volatile organic compounds, hazardous air pollutants (HAPs) nitrogen oxides, sulfur dioxide, carbon monoxide, particulate matter, or ammonia?
- Is an accurate inventory of the pollutants of interest of particular importance to your agency (e.g., PM-2.5, ozone precursors, specific HAPs)?
- What is the end use of the inventory? An inventory with significant regulatory implications such as a residual risk study for HAP sources may require a survey component for data collection, while an inventory for source characterization may not.

Inventory efforts identified as high priority should be afforded sufficient resources to ensure that complete and accurate data are compiled. For many area sources, this data collection effort may require a survey.

2.3 EVALUATE THE DATA QUALITY OBJECTIVES FOR THE INVENTORY

The first step in planning any inventory is to define the purpose and intended end use of the inventory. This information is used to determine the data quality objectives (DQOs) and the quality control/quality assurance (QA/QC) requirements for the inventory. DQOs are qualitative and quantitative statements of the uncertainty that a decision maker is willing to accept in the estimates and/or decisions made with inventory data. For a more complete discussion of DQOs, refer to EIIP Volume VI, Chapter 2 (Documentation).

Preparation of a written DQO statement should be part of the initial planning stages of the inventory process. The DQO statement should address:

- Accuracy (or uncertainty) of emission estimates;
- Completeness;
- Representativeness; and
- Comparability,

For inventory efforts with strict DQOs, it may be necessary to conduct a survey in order to ensure that appropriate data are collected.

You can use the Data Attribute Rating System (DARS) to evaluate the merits of one emission estimation method relative to another. DARS defines certain classifying attributes that are believed to influence the accuracy, appropriateness, and reliability of an emission factor or activity, and assigns a numerical score to each of these components that are combined to arrive at an overall confidence rating—an uncertainty estimate—for the inventory. You can develop DARS scores for several potential estimation methods and use this information when planning your inventory. For example, the DARS scores for two alternative methods to estimate emissions from the architectural surface coatings area source category are shown in Table 24.2-2. One method is based on a survey of paint distributors, the second uses a national per capita factor. The more resource-intensive survey method results in a much higher overall DARS score. You can use this information when considering questions such as:

- How much better can an inventory get if a survey is used compared to other methods?

TABLE 24.2-1

**DARS SCORES (UNITLESS) FOR ARCHITECTURAL SURFACE COATING
EMISSIONS ESTIMATED BY TWO DIFFERENT METHODS**

Attribute	Factor	Activity	Emissions
Local Survey			
Measurement/Method	0.7	0.9	0.63
Source Specificity	1.0	1.0	1.00
Spatial	1.0	1.0	1.00
Temporal	1.0	1.0	1.00
Composite	0.925	0.975	0.908
National Per Capita Factor			
Measurement/Method	0.3	0.4	0.12
Source Specificity	1.0	0.3	0.30
Spatial	0.3	0.3	0.09
Temporal	0.7	1.0	0.70
Composite	0.575	0.500	0.30

- Does this amount of improvement justify the additional cost?

You will need to balance the inventory quality objectives and the available resources in order to formulate a workable strategy for your inventory. Refer to EIIP Volume VI (Chapter 4 and Appendix F) for detailed discussions of DARS.

2.4 ASSESS DATA AVAILABILITY

Before taking on any data collection effort, survey or non-survey, you should always check to see if the data have already been compiled. Each of the chapters in this volume suggest references of information for the respective area source categories. In general, you should also check for relevant data in:

- Permit files or compliance files;
- Case studies and site visit reports;
- U.S. Department of Commerce publications including *County Business Patterns*, *Census of Population*, *Census of Manufacturers*, *Census of Agriculture*, *County and City Data Book*, *Current Industrial Reports*, *Annual Housing Survey*, and *Census of Retail Trade*;
- U.S. Department of Energy publications such as *State Energy Data Reports*, *Natural Gas Annual*, and *Petroleum Marketing Annual*;
- State Departments of Transportation and State Energy Offices (for information on gasoline consumption and paving activities);
- State Departments of Labor (for employment data by SIC [Standard Industrial Classification] code);
- Local industrial directories (these are often organized by SIC code and provide employment data);
- Trade and professional association publications;
- Regional planning commission publications;
- Agency-sponsored surveys;
- National and state directories of manufacturers; and
- Data compiled by private research and development companies such as the *Directory of Chemical Producers* compiled by SRI International.

2.5 EVALUATE RESOURCE AVAILABILITY

As with any task, the resources required to conduct a survey will be determined by the scope of the project. You will need to evaluate your agency's ability to commit the appropriate resources—both personnel and money—to ensure that the survey is designed and conducted properly. Taking shortcuts can invalidate the results. The cost of a survey is a function of the completeness and specificity of the questionnaire, the size of the target audience, and the thoroughness of the QA/QC follow-up activities (Radian, 1996).

The survey process consists of a series of steps including planning, sample design, sample selection, contact identification, questionnaire preparation, pre-testing, mail-out, response tracking, follow-up activities, data collection, data reduction, data processing, data extrapolation, and QA/QC at each step. Each of these steps may require experience not readily available in an emissions inventory agency. You may need to factor in the cost of additional personnel or “learning curve” inefficiencies. Examples of resources required to conduct a survey include (Ferber, et al., 1994):

- Managerial staff time for planning the study and supervision through the various stages;
- Labor and material costs for design and pretest of the questionnaires;
- Computer hardware and software for data management;
- Telephone charges;
- Postage (surveys are often sent via registered mail);
- Reproduction and printing costs;
- Labor and materials cost for mail-out including compilation of up-to-date mailing lists, production of labels and cover letters, stuffing envelopes;
- Labor cost for programming e-mail or Internet surveys; and
- Labor costs for tracking responses, including data logging and follow-up with non-respondents.

You should recognize that allowing ample resources for quality checks at each step of the survey process is critical to a well-designed and well-conducted survey project. Be sure to include the cost of a rigorous QA/QC program when developing a project budget.

You must also consider the amount of time available to prepare the inventory. It may take several months to conduct a survey and analyze the data. If an emissions estimate must be prepared in 3 months and the survey process requires 6 months, you will need to use a non-survey method, even if a survey would result in a more accurate estimate of emissions.

2.6 CONSIDER THE ADMINISTRATIVE CLEARANCES

Before deciding to conduct a survey, you must identify any regulations that relate to the conduct a survey of the private sector. Specifically:

- Federal - Under the Paperwork Reduction Act, any Federal Government entity must obtain an approval from the Office of Management and Budget (OMB) to collect substantially similar information from ten or more respondents in any 12 month period. If EPA decides to collect information, it must prepare an Information Collection Request and submit it for OMB approval.
- Typically, the Director of the air quality regulatory agency has the authority to request information. However, you should identify the procedures that apply to your agency prior to planning and mailing the survey.

2.7 CONSIDER IF IT IS POSSIBLE TO COORDINATE THE INFORMATION COLLECTION ACTIVITY WITH OTHER INVENTORY EFFORTS

Because survey efforts are time-consuming and expensive, you should consider the possibility of coordinating your data collection efforts with other activities being conducted by your agency. Surveys are frequently conducted by permitting groups. If another survey is being planned that will include an appropriate population to collect the information that you require for your emissions inventory estimate, it may be most efficient to work cooperatively to collect the required information.

Two points must be carefully considered when making the decision to combine data collection efforts:

- You must make certain that the surveyed population represents a sample that is appropriate for all of the data collection efforts. Both the sample size and sample representativeness must be evaluated for each the data collection efforts.
- You must design the survey with extreme care. Unless response to the survey is mandatory, you will need to carefully balance the effort to collect information for more than one project with the need to keep the survey short and simple. If the questionnaire becomes too long or too confusing, recipients may not be willing to complete and return the form.

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3

WHAT IS THE MOST IMPORTANT ASPECT OF CONDUCTING A SURVEY?

Simply put, *the key to a successful survey effort is good planning.*

Careful and thorough planning of survey procedures will greatly facilitate the process and can prevent the need for costly revisions to the survey while in progress or emissions estimates that are generated from the survey data. Before the inventory process begins, your agency should prepare an inventory preparation plan to identify the required staffing levels and resource allocations. The inventory preparation plan will also specify the methods and procedures to be used by each member of the inventory team to collect, handle, review, and report emissions data. Refer to the *Handbook for Criteria Pollutant Inventory Development: A Beginner's Guide for Point and Area Sources* (EPA, 1999b) for additional information on inventory preparation plans.

While careful planning and survey design take time and may add front-end costs to the inventory effort, you should keep in mind that good planning actually reduces overall costs by preventing:

- Time wasted by the repeated need to make short-term decisions on what to do next;
- Duplication of data collection efforts;
- Time wasted collecting and analyzing irrelevant data; and
- Unplanned data analysis in the hope of finding relevant information in an incomplete data set (GAO, 1991).

As part of the inventory preparation plan, as a stand-alone document, or as a series of documents, you should **prepare a written plan that covers every phase of the survey process**. The written plan should clearly identify the goals, methods, and resources required for each step in the survey process. The written plan should:

- Define the data quality objectives;

- Define the data to be collected;
- Determine appropriate sample size;
- Identify the sample selection technique;
- Identify the survey technique;
- Outline techniques for design, pilot test, and revision of the survey;
- Identify the mail out and tracking techniques;
- Identify the data entry procedures;
- Identify the statistical methods to be used in the data analysis; and
- Identify the QA/QC procedures to be conducted during all phases of the survey process.

These survey procedures are discussed in the following sections.

4

WHAT SURVEY TECHNIQUES ARE AVAILABLE?

There are a variety of methods that can be used to collect survey data:

- Mail surveys;
- Electronic (E-mail or website) questionnaires;
- In-person interviews; and
- Telephone interviews.

The advantages and disadvantages of each method are described in the following sections. The information below was summarized from several documents (Fink and Kosecoff, 1998; Creative Research Systems, 2000; and Parker, 1999).

4.1 MAIL SURVEYS

Mail surveys, also referred to as “paper questionnaires”, are documents mailed to the sample population that include a cover letter, instructions, and a form for the recipient to complete and return.

Advantages of the mail survey include:

- Mail surveys are one of the least expensive survey techniques. Unlike interview techniques, you will not need a team of trained interviewers;
- Mail survey forms can contain graphics. Use of diagrams, photographs, and tables is not possible with telephone interviews and may be limited with e-mail survey forms;
- Unlike interview techniques, mail surveys allow the survey recipients to respond when it is convenient for them. Mail surveys are considered less intrusive than telephone or personal interviews;

- This method gives survey recipients time to consider and research responses increasing the accuracy and completeness of the responses; and
- There is no possibility for interviewer bias to influence the respondents.

Disadvantages of the mail survey include:

- Mail surveys require more time than other survey techniques. You may need to wait for several weeks after mailing the questionnaires before you can assess your response rate. It may take several more weeks to follow-up with non-respondents;
- It may be difficult to obtain up-to-date and accurate mailing lists;
- Respondents may misinterpret or omit questions; and
- Mail surveys require motivated or interested respondents. Without legal requirements or incentives, respondents may choose to ignore a survey form.

4.2 E-MAIL SURVEYS

E-mail surveys are documents electronically distributed to the sample population. These messages include an introduction (similar to the cover letter of a paper survey), instructions, and a form for the recipient to complete and return via e-mail. More people have e-mail than have full Internet access, making e-mail a better choice than web page surveys for some populations.

Advantages of the e-mail survey include:

- E-mail surveys are one of the least expensive survey techniques. Because there are not fees for mailing or costs for interviewers time, it does not cost more to collect large samples;
- E-mail surveys can be fast. You can send the survey and receive responses in a period of days;
- The novelty element and convenience of an e-mail survey might stimulate higher levels of response than an ordinary paper survey;
- With many systems, you can attach picture and sound files; and

- Like paper surveys, e-mail surveys allow recipients to respond at their convenience and to carefully consider their responses.

Disadvantages of the e-mail survey include:

- It may be difficult or expensive to obtain up-to-date and accurate e-mail address lists;
- The sample population is limited to those with e-mail access. You will need to either acknowledge this when you identify the sample or be willing to distribute paper surveys to those who do not have e-mail access;
- It can be difficult to track e-mail responses. It is not unusual for recipients to forward the survey to multiple associates—or to respond more than once. It is important that the size and the representativeness of the sample that the responses be carefully monitored;
- Many people dislike unsolicited e-mail even more than unsolicited regular mail; and
- Respondents may misinterpret or omit questions.

4.3 WEB PAGE SURVEYS

Surveys can be posted on Internet web pages. The web pages include an introduction (similar to the cover letter of a paper survey), instructions, and a form for the recipient to complete and submit.

Advantages of web page surveys include:

- Web page surveys can be extremely fast and reach a large population;
- Like e-mail surveys, it does not cost more to collect large samples;
- These surveys can be designed to be interactive. The programs can be designed to provide respondents with explanations of terms or complex questions. Web page questionnaires can use complex question skipping logic and randomizations;
- The forms can be designed so that only “legal” answers are accepted, reducing the resources required for QA/QC and follow-up;

- Data in the submitted responses can be automatically entered into programs for analysis; and
- Web page questionnaires can use colors, fonts, and formatting options not available with an e-mail surveys.

Disadvantages of web page surveys include:

- The sample population is limited to those with Internet access. You will need to either acknowledge this when you identify the sample or be willing to distribute paper surveys to those who do not have Internet access;
- Depending on your software, you may have no control over who replies. This issue can be addressed by posting the survey on a page that can only be accessed directly (there are no links to it) or by restricting access by requiring a password; and
- Constructing an Internet web page may require a software engineer or programmer.

4.4 IN-PERSON AND TELEPHONE INTERVIEWS

In-person and telephone interviews are conducted by trained individuals who collect information from individuals using a written script and prepared data forms.

Advantages of in-person and telephone interviews include:

- The interviewer can explore answers given by respondents or provide additional information to ensure that the respondent understands each of the questions;
- The interviewer can prompt the respondent to prevent incomplete or inappropriate responses;

Disadvantages of in-person and telephone interviews include:

- Conducting interviews is resource intensive. You will need to find up-to-date phone numbers, schedule the interviews, ensure that all of the interviewers are well trained, and supervise dispersed personnel performing a complex task; and

- This type of survey has the greatest possibility that the interviewer can influence (bias) the results.

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5

HOW DO I DETERMINE HOW MANY SURVEYS TO SEND - AND TO WHOM?

5.1 WHAT ARE THE ADVANTAGES OF SAMPLING FROM THE ENTIRE POPULATION?

A complete enumeration (or census) of the entire population may not be practical and is almost never economical. Collecting data from a properly identified sample of the population requires fewer resources than a census. You can use inferential statistics to determine a population's characteristics by directly observing only a portion (or sample) of the population.

Additionally, a sample may be more accurate than a census. A poorly designed and/or poorly conducted census can provide less reliable information than a carefully obtained sample.

Keep in mind that two things are absolutely necessary, however, to ensure a high level of confidence that the sample represents the population:

- A sufficiently large sample; and
- An unbiased sample.

5.2 HOW DO I IDENTIFY THE POPULATION?

As a starting point, you need to be familiar with the following terms (Fridah, 1998):

- Population - a group of individual persons, objects, or items from which samples are taken for measurement. For example, a “population” from an area source inventory might be all dry cleaners.
- Sample - a finite part of a statistical population whose properties are studied to gain information about the whole. For example, a “sample” for an area source inventory might be 10 percent of the dry cleaners in the non-attainment counties within a given state.

- Sampling - the act, process, or technique of selecting a suitable sample, or a representative part of a population for the purpose of determining parameters or characteristics of the whole population

The first step in the survey process is to define the relevant population (Ferber et al., 1994). This is particularly important for area source inventory efforts. Unlike surveys conducted for point source inventories, the best recipient may not be at the point of emissions. For example, an area source survey on solvent use could be sent to manufacturers, distributors, retailers, users—or a combination of these groups. You will need to identify the appropriate facilities/subcategories or point in production/use within the surveyed source category to serve as the population.

To identify the appropriate population, you should carefully evaluate:

- The data requirements for the survey effort; and
- The practical considerations of surveys of the different potential populations. In the solvent use example, it might be most practical to survey the manufacturers or the distributors.

In order to identify the relevant population, you will need to compile a list of the names, address, and general process category of each facility in the inventory area that could be included in the survey. This list could be based on information resources including:

- **Existing Inventories.** A recent or recently updated, well-documented, existing air emissions inventory is a good starting point. However, many existing inventories may focus on pollutants other than those needed in the inventory being prepared. Thus, certain sources that emit only one type of pollutant may not be well represented.
- **Other Inventories.** In addition to emissions inventories, other environmental inventories may be useful in identifying plants in various Standard Industrial Classification (SIC) Codes. Information in the Toxic Release Inventory System (TRIS), gathered annually under the “Community Right-to-Know” Law of the Superfund Amendments and Reauthorization Act (SARA Title III), and facility inventories developed under Title V may be useful. The TRIS database gives plant locations and SIC Codes, as well as quantitative information on emissions of specific toxic chemicals including many solvents. Title V permits may provide specific information about area source processes taking place at a facility.

In addition, listings of water pollution sources and hazardous waste generators are maintained by state water pollution and hazardous waste agencies. These may be used to identify potential sources in various SIC codes.

- **Air Pollution Control Agency Files.** Compliance, enforcement, permit application, or other air pollution control agency files may provide valuable information on the location and types of sources in the area of concern. These files can also be used later to cross-check certain information supplied on questionnaires.
- **Other Government Agency Files.** Files maintained by labor departments and tax departments frequently aid in the preparation of the mailing list. Such files will include various state industrial directories in which companies are listed alphabetically by SIC code and county. The information available in these files will vary from state to state. Thus, it is advisable to contact the appropriate personnel with these agencies to become familiar with which listings are available.
- **Other Local Information Sources.** The following local information sources can be consulted, where available:
 - Local industrial directories—A local industrial development authority may provide a current list of the sources that operate in the inventory area. These are often organized by SIC code and provide employment data.
 - *Yellow Pages*—The local telephone directory will have names, addresses, and telephone numbers of many industrial/commercial facilities that may be emissions sources. However, telephone directory areas often do not correspond to county or community boundaries.
 - Manufacturers and suppliers—Firms that make or supply equipment and materials such as solvents, storage tanks, gasoline pumps, incinerators, or emissions control equipment maybe used to identify industries emitting VOCs, HAPs, CO, and nitrogen oxides.
- **National Publications.** The national publications listed below can be used when available. However, the information in them may be older and less accurate than local primary references.
 - Dun & Bradstreet, *Million Dollar Directory and Middle Market Directory* compile lists of companies by SIC code and county (refer to <http://www.dnb.com>);

- Dun & Bradstreet, *Industrial Directory*;
- National Business Lists—Companies are listed by SIC Code and county with information on financial strength and number of employees; and
- Trade and professional society publications—Names and addresses of members are listed along with their type of business.

5.3 HOW DO I DETERMINE THE SAMPLE SIZE?

The sample size is dependent on:

- The data quality objectives established for the accuracy of the results of the survey project;
- Available resources;
- The nature of the analyses to be performed; and
- The degree of heterogeneity of the population.

Ideally, the sample size chosen for a survey should be based on how reliable the final estimates must be. In practice, a trade-off is usually made between the ideal sample size and the expected cost of the survey. You can get a general idea of the sample size needed for your survey project from the checklist in Table 24.5-1.

Risk, as it relates to sample size determination, is specified by two interrelated factors:

- The confidence level; and
- The precision (or reliability) range.

To minimize risk, you should have a high confidence (say 95 percent) that the true value you seek (the actual value in the population) lies somewhere within a small interval (say + or - 5 percent) around your sample value (your precision). The desired degree of precision and confidence level are established as part of the data quality objectives.

TABLE 24.5-1

FACTORS IMPACTING SAMPLE SIZE

	Large sample	Small Sample
The calculations or decisions to be made based on the survey data have important or costly consequences	✓	
The data quality objectives for level of confidence are high	✓	
The data quality objectives for level of confidence are low - only a rough estimate is required		✓
The population to be sampled is relatively heterogeneous (high level of variance)	✓	
The population to be sampled is relatively homogeneous (little variance)		✓
Project costs increase dramatically with sample size		✓
Project costs and time required vary only slightly with increases in sample size	✓	
Financial and staffing resources are limited		✓
Time allowed for project completion is limited		✓

Basic statistics books present the formulas that you can use to determine sample size.

On-line calculators are available to determine sample size, for example:

- <http://www.au.af.mil/au/hq/selc/samplsiz.htm>
- <http://www.surveysystem.com/sscalc.htm>

Also, you should adjust the computed sample size (n) by dividing by the expected response rate. For instance, if you determined that the appropriate sample size for your survey effort was 125 and you expect a 75 percent response rate, you should make your sample size equal $125/0.75$ or 166.

If more sources are identified on the mailing list than can be realistically handled with available resources, your agency should review the mailing list to reduce the number of facilities to be sent questionnaires.

One way to reduce the size of the mailout is to develop an initial estimate of emissions by facility. If the number of employees in a company is known, then an estimate of the emissions potential can be made using available per-employee emission factors. This will provide a rough estimate of the emissions potential of each facility, which can then be used to select a sample of facilities that represent a range of emissions to receive the questionnaire. Any bias that this selection process introduces to the returned surveys should be considered when scaling up the survey results. Another way to reduce the size of the mailout is to contact the intended recipients of the survey by telephone before mailing the survey. These brief contacts with plant managers or other appropriate employees will indicate whether the pollutant-emitting process takes place at the facility (or if the facility is even operating), and reduce the number of surveys that are sent out unnecessarily.

5.4 HOW DO I SELECT THE SAMPLE?

Just as important as the size of the sample is the determination of the appropriate sampling method. Random sampling always produces the smallest possible sampling error—the size of the sampling error in a random sample is affected only by random chance. Because a random sample contains the least amount of sampling error, it is referred to as an unbiased sample. Note that this does not mean that the sample contains no error, but rather the minimum possible amount of error.

Sampling techniques range from simple random selection of the population units to highly complex samples involving multiple stages or levels of selection with stratification and/or clustering of the units into various groupings. Whether simple or complex, a properly designed sample always has two distinguishing characteristics:

- All the units in the target population have a known, nonzero chance of being included in the sample; and
- The sample design is described in sufficient detail to permit reasonably accurate calculation of sampling errors.

These features make it scientifically valid to draw inferences from the sample results about the entire population which the sample represents (Ferber et al., 1994).

The sampling method will be determined by the objectives of the survey effort. Table 24.5-2 lists some of the common sample selection techniques. The two most useful random sampling techniques are simple random and stratified random sampling methods.

Stratified random sampling is often conducted for area source survey projects (Radian, 1996). For example, most urban areas with a diversified economy contain numerous, small manufacturing facilities that may use solvents in coating, degreasing, or wipe cleaning operations. These facilities could include wood products manufacture and coating, plastics coating, miscellaneous metal parts manufacture and coating. The large number of operations and the differences in raw materials and production characteristics require that you develop a survey approach to accurately collect information that can be statistically extrapolated to the entire population of non-point source facilities. You could use a stratified random survey to solve this problem:

- The first stratum might be to use source category codes such as the Area and Mobile Source (AMS) Codes and the Source Classification Codes (SCC) to group facilities manufacturing similar materials.
- A second stratum might be to use number of employees to distinguish between larger and smaller facilities to account for different rates of material usage.

Stratified random sampling requires a detailed knowledge of the distribution of attributes or characteristics of interest within the population to determine the homogeneous groups that compose the population. A stratified random sample is superior to a simple random sample because the population is divided into smaller homogeneous groups before sampling, resulting in less variation the samples. This enables you to reach the desired degree of accuracy with a smaller sample size. But, if you cannot accurately identify the homogeneous groups, you are better off using the simple random sample because improper stratification can lead to serious error.

TABLE 24.5-2

TYPES OF SURVEY SAMPLING METHODS

Method	Description	Conditions When the Sampling Design is Useful
Haphazard sampling	“Any sampling location will do” Take samples at convenient locations or times. Can lead to biased estimates.	A very homogeneous population over time and space is essential if unbiased estimates of population parameters are needed. This method of selection is <i>not</i> recommended due to difficulty in verifying this assumption.
Judgement sampling	Subjective selection by an individual. Select samples that appear to be “representative” of average conditions. Can lead to biased estimates. Accuracy is difficult to measure.	The target population should be clearly defined, homogeneous, and completely assessable so that sample selection bias is not a problem. Conversely, specific samples are selected for their unique value and interest rather than for making inferences to a wider population.
Simple random sampling	Each population unit has an equal chance of being selected for measurement. Selection of one unit does not influence selection of other units. The best way to choose a simple random sample is to use a random number table or a computer-generated series of random numbers. As the first step, you assign each member of the population a unique number. The members of the population chosen for the sample will be those whose numbers are identical to the ones on the random number list in succession until the desired sample size is reached.	The simplest random sampling design. Other designs below will frequently give more accurate estimates if the population contains trends or patterns of emission rates.
Stratified random sampling	Divide target population into non-overlapping parts. If one group is proportionally larger than another, its sample size should also be proportionally larger. As appropriate, different sampling techniques can be used in each of the different groups.	Useful when a heterogeneous population can be broken down into parts that are internally homogeneous. For example, solvent usage might be stratified according to the end product produced.

TABLE 24.5-2

(CONTINUED)

Method	Description	Conditions When the Sampling Design is Useful
Multi-stage sampling	Divide target population into primary units. Select a set of primary units using simple random sampling. Randomly subsample each of the selected primary units. Example: collect soil samples (primary units) at random, then select one or more aliquots at random from each subsample.	Needed when measurements are made on subsamples of the field sample. This technique has limited applicability to emissions inventory development.
Cluster sampling	Clusters of individual units chosen at random. All units in chosen clusters are measured.	Useful when population units cluster together (schools of fish, clumps of plants, etc.) and every unit in each randomly selected cluster can be measured. This technique has limited applicability to emission inventory development.
Systematic sampling	Samples are selected at intervals, locations, or times according to a predetermined spatial or temporal pattern. For example, assign each member of the population a unique number, choose a random number as a starting point and then survey every n^{th} member. This is a non-random sampling method! Regardless of how much you mix the population before selecting a starting point, the fact remains that once that point is chosen, further selection of members for the sample is non-random (no independence).	Usually the method of choice when estimating trends or patterns of emissions over space. Also useful for estimating the mean when trends and patterns are not present or they are known a priori or when strictly random methods are impractical.
Double sampling	If data using one measurement technique has a strong linear relationship to data obtained with less expense or effort using another measurement technique, more samples can be taken using the less expensive method. The linear relationship between the two techniques is then applied to estimate the mean for the more expensive method.	Useful when there is a strong linear relationship between the variable of interest and a less expensive or more easily measured variable.

TABLE 24.5-2

(CONTINUED)

Method	Description	Conditions When the Sampling Design is Useful
Search sampling	Used to geographically locate pollution sources or to find “hot spots” of elevated contamination.	Useful when historical information, site knowledge, or prior samples indicate where the object of the search may be found. This technique has limited applicability to emissions inventory development. This approach, however, could be used to develop information that would describe the spatial characteristics of emissions in relationship to a specific parameter (for example, lawn and garden equipment use versus household income).

Source: Gilbert, 1987

6

WHAT SHOULD I CONSIDER WHEN PREPARING THE QUESTIONNAIRE FORM?

You will need to develop a questionnaire specifically tailored for each source category you survey. While this may require significant resources, it will allow you to use industry-specific terminology and ask only relevant questions thus reducing confusion and increasing accuracy.

6.1 WHAT ARE THE MOST IMPORTANT ASPECTS OF PREPARING THE QUESTIONNAIRE FORM?

Many factors are critical to designing a survey form that will result in a high response rate and usable data. The most important points to keep in mind are:

- **Make certain that you ask the right questions;**
- **Design the questionnaire for the person who will be asked to fill it out; and**
- **Be as brief as possible.**

The goal is to design a survey that will provide you with accurate information that meets your data needs. Chapters 2, 3, 4, 13, 14, and 17 of this volume all contain example survey forms.

6.2 WHERE DO I START?

As the first step in designing a survey, you must set the survey boundaries so that you can write the correct questions. You need to have a specific definition of all of the information that the survey is being developed to collect. This should be included in the inventory preparation plan.

Construct a list of potential questions and use the following criteria to determine which questions should be included in the final survey:

- Does the question pertain to a stated survey goal? If a question is not necessary, do not include it.

- Place your questions into three groups: need to know, useful to know, and nice to know. Discard the last group.

For area source inventory purposes, keep in mind that the data collected from the sample will be scaled up for the entire inventory region. Even if not specifically stated in the inventory preparation plan, you will need to identify and collect reasonable surrogate data.

6.3 WHAT SHOULD I CONSIDER FOR THE SURVEY FORMAT?

6.3.1 KEEP THE SURVEY BRIEF

Keep the survey as **short and simple** as possible—this is very important to both the response rate and the accuracy of the responses. You should invest the resources to make the survey as understandable, simple, and quick as possible for the recipient. Remember, they are doing you a favor and you want to maintain a good agency-industry working relationship.

Carefully consider the physical size and format of the document. Again, keep the form as short as possible. If you need only a few specific data items, consider a pre-printed, postage-paid postcard.

While brevity is important, you should not design a survey that looks crowded or confusing. Techniques for wise use of space on a page include:

- Using columns in the page layout;
- Using different fonts and bold text for emphasis;
- Defining sections and emphasizing key items using lines, boxes, or shading; and
- Printing double-sided pages.

6.3.2 DESIGN THE QUESTIONNAIRE TO FIT THE MEDIUM

You need to design the questionnaire to fit the medium. Each survey type (paper, e-mail, web site, or interview) has advantages and limitations. For example, only some survey formats allow you to incorporate graphics. Review the descriptions of each survey type presented in Section 4 of this chapter. Use the survey medium to its fullest potential.

6.3.3 CONSIDER ALL OF THE SURVEY “USERS”

You want to make the survey attractive and easy for the recipient to complete. However, there are other people who will be working with the survey, and if you keep them in mind while

designing the forms, you can save time and money. Once the survey is completed and returned, it will go through several processes:

- Log-in;
- QA/QC to check for completeness and reasonableness of responses; and
- Data entry.

Design the survey so that each of these processes can be conducted quickly and accurately (Creative Research Systems, 2000):

- For questions requiring text answers, you should allow sufficient space for handwritten answers. Lines should be about one half inch apart.
- Try to keep the answers in a straight line, either horizontal or vertical. Studies show that the best place for answers is the right hand edge of the page.

6.3.4 MISCELLANEOUS TIPS

Other techniques that can improve response rate or the accuracy of the responses for your survey include:

- Leave a space at the end of the questionnaire entitled “Other Comments”. A respondent might include a remark about an issue you had not even considered.
- Include the return address on each page of the survey. It is not unusual for return envelopes and forms to get separated.

6.4 WHAT IS MOST IMPORTANT FOR THE QUESTIONS?

You need to make sure that all of the questions are simple and well-worded. Keep in mind that the way you phrase a question can change the answers you get.

6.4.1 OPEN-END AND CLOSED-END QUESTIONS

An open-end question is one that the recipients answer in their own words. In many area source inventory surveys, you will be requesting that the recipient provide “fill in the blank” information. When you write open-end questions:

- Be specific;

- Clearly indicate the relevant time period for the requested data; and
- Clearly indicate the units of measure for the response.

A closed-end question lists the possible answers from which the respondents choose the response appropriate for their facilities. When you write closed-end questions:

- Provide references or lists so that recipients use appropriate chemical trade names, synonyms, Chemical Abstract Service (CAS) numbers, etc.;
- Make certain that you include all of the possible responses;
- Include a blank space for “Other” responses (just in case!); and
- Clearly indicate the relevant time period for the requested data.

6.4.2 “DON'T KNOW” OR “NOT APPLICABLE”

Include instructions for items that recipients do not want to, or cannot, answer. Allow a “Don't Know” or “Not Applicable” response to all questions, except to those in which you are certain that all respondents will have a clear answer.

While this may seem like an invitation for incomplete survey forms, it actually makes the QA/QC review of the returned surveys much simpler. Without “Don't Know” or “Not Applicable” as response choices, the respondent may simply skip the question. This requires either follow-up by the inventory staff or a decision by the QA/QC and data analysis groups on how to enter and analyze the data.

6.4.3 MISCELLANEOUS TIPS

Other techniques that can improve response rate or the accuracy of the responses for your survey include:

- Use industry-appropriate terminology.
- Define all acronyms the first time you use them.
- Each question should be self-explanatory or accompanied by clear directions.
- Make certain that each question addresses only one issue. Ask separate questions rather than try to collect multiple data points with one question.
- Clearly identify the time period (months, year) you need data for.

- Consider asking for the raw data. That way you'll know how values were calculated and will be able to perform QA/QC checks.

6.5 INSTRUCTIONS

Prepare a set of procedures and instructions to accompany the survey. The instructions should clearly and completely (yet briefly):

- Explain, in general terms, how to fill out the questionnaire;
- Provide specific directions for how to complete each type of question;
- Tell the recipient the date the survey should be returned to the agency; and
- Provide names and contact information for agency personnel who can provide technical assistance with survey issues.

6.6 PILOT TESTING

The purpose of pilot testing is to see how well your cover letter motivates your respondents and how clear your instructions, questions, and answers are. You should always have the survey reviewed by peer reviewers within your agency (experts) **and** a focus group from the appropriate industry. Pilot testing takes time and may be expensive, but it is best to identify areas for improvement before the survey is distributed. Once the survey has been sent out, changing the directions, questions, or potential responses is no longer an option.

After explaining the purpose of the pilot test, let the peer reviewers read and answer the questions without interruption. When they are through, ask them to critique the cover letter, instructions, and each of the questions and answers. Rigorous pilot testing:

- Reveals whether people understand the directions;
- Reveals whether people can answer each of the questions;
- Helps you confirm that you are using the appropriate industry-specific terminology;
- Tells you how long it takes to complete the survey;

Use the reviewers' recommendations and comments to finalize your survey document.

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7

WHAT SHOULD I CONSIDER WHEN PREPARING THE COVER LETTER?

The cover letter is key to a successful survey effort. If the cover letter does not command attention, the attached questionnaire might not be considered a priority and it may be filed away or discarded.

Start with an introduction or welcome message. In the case of mail questionnaires, this message can be in a cover letter or on the questionnaire form itself. If you are sending e-mails that ask people to take a web page survey, put your main introduction or welcome message in the e-mail. State who you are and why you want the information in the survey. A good introduction or welcome message will encourage people to complete your questionnaire.

7.1 WHO SHOULD SEND THE LETTER?

Whenever possible, survey forms should be sent by the state or local air pollution control agency. Most of the surveys conducted to collect information required to compile an area source inventory are voluntary—recipients are not legally required to respond. Recipients are more likely to respond to a survey from a state agency than to a request from a contractor.

If you send the survey cover letters on state or local air pollution control agency letterhead and have them signed by a government official, you may have a positive influence on the response rate.

7.2 WHO SHOULD RECEIVE THE LETTER?

There are two possible strategies for the distribution of survey forms: approaching the facilities directly, or dealing with trade associations and requesting that they collect the information from their members.

If you choose to send surveys directly to facilities, your effort will be more successful if you have specific contact names. If it is not feasible or economical to compile contact information, determine an appropriate job title and clearly mark the outer envelope (e.g., “Attention: Plant Manager”) to direct the survey to the proper supervisory personnel.

A trade association that supports the inventory effort can be a valuable ally in a data collection effort. These groups are used to working with government agencies and may have access to contact information that is not publicly available. Facilities may be more comfortable sharing information with a trade group than sending it to a government agency. However, keep in mind that if you adopt this strategy, you may lose control over the techniques used to choose the sample from the population. If the size and composition of the sample are critical to the survey study design, this strategy may not be appropriate.

7.3 WHAT SHOULD BE INCLUDED IN THE LETTER?

The cover letter should be as short and direct as possible. A strong statement about any existing and applicable regulations which require the recipient to respond is your most powerful tool for maximizing return rate. If response to your survey is not a legal requirement, you should include a statement explaining the potential benefit of the survey effort to individual facilities and the industry as a whole. Explain why the survey is important to your agency and your state.

Another important item to include in the cover letter is the response due date. To improve the return rate, you should present the final due date in the cover letter so that it will not be overlooked by the recipients who do not read the instructions. Provide a reasonable amount of time for recipients to complete the survey—but not so much that they set it aside to do it later and then forget it.

You should clearly state that all Confidential Business Information (CBI) will be handled appropriately. In addition, you should provide names and contact information for agency personnel who can provide technical assistance with survey issues.

8

WHAT IS REALLY INVOLVED IN THE MAIL OUT AND TRACKING STEPS?

The process of mailing and tracking the survey includes:

- Preparing the mailing list;
- Pre-screening;
- Assembling survey packets;
- Mailing the survey packets;
- Tracking responses; and
- Following-up with non-respondents and incomplete responses.

8.1 PREPARATION OF THE MAILING LIST

The first step in the survey distribution process is to compile a mailing list that tabulates the name and address of each facility to be surveyed. Assign each facility a unique identification code. Whenever possible, identify a specific individual at each facility. You should have collected most of this information while conducting research to identify the relevant population. Refer to Section 5.2 of this chapter for a list of potential data sources.

Invest the time and effort to ensure that the appropriate facility and contact information has been identified. Check and double check addresses—it will save you lots of time in the long run if you don't have to deal with lots of returned survey packages.

You can greatly increase the efficiency and accuracy of the survey process if you use a database or spreadsheet program to construct your mailing list. A well-designed database can be used to generate mailing forms, create identification labels for each form, track survey returns, and format data for analysis and reporting. This type of tool will enable you to enter facility-specific information only once, rather than repeating data entry at several steps of the survey process.

8.2 PRESCREENING

You can improve the response rate by contacting the survey recipients before you send out the survey forms. Prescreening can be used to:

- Collect information (does the process of interest occur at the facility?) to help limit the number of surveys that are sent to inappropriate facilities;
- Confirm mailing addresses and ensure that appropriate contacts have been identified; and
- Inform the recipients about the upcoming survey project and foster support for the effort.

8.3 PREPARATION AND MAILING

The survey package will include the envelope; cover letter; survey form; and a pre-addressed, postage-paid return envelope.

To expedite tracking and data processing procedures, print duplicate mailing labels and place one on the outer envelope and the second one on the survey form. This will ensure that the proper identification code is on the returned survey. Mailing labels should contain the following information:

- SIC code (if applicable);
- Unique identification number;
- Contact name (or appropriate job title if a specific contact has not been identified);
- Contact title;
- Facility name;
- Street address;
- City;
- County;
- State; and

- Zip code.

If you were not able to identify specific contact information for a facility, determine an appropriate job title and clearly mark the outer envelope (e.g., “Attention: Plant Manager”) to direct the survey to the proper supervisory personnel.

Your agency will need to carefully consider whether to send the surveys via first class or registered mail. With registered mail, the sending agency is informed when a questionnaire is received. Registered mail is more expensive and labor-intensive, but it does positively impact the response rate—simply because the recipient knows that the agency knows that the survey was delivered. Whether to spend money on registered mail depends on the importance of high response rate of success of the survey project. As an alternative, you might consider using registered mail for the largest or “most important” sources.

8.4 TRACKING AND FOLLOW-UP

Responses can begin arriving within a few days after mailing. The majority of the early returns will be from companies that are not sources of the emissions being studied and questionnaires returned by the postal service as undeliverable.

The following records must be kept for every survey form that you send:

- Facility information—all of the information included on the mailing label;
- Date mailed;
- Date returned;
- Whether follow-up is required; and
- Status of follow-up effort.

Follow-up will be required if the survey is returned by the postal service; the facility receives the survey but does not respond; or if the response is inadequate.

For all surveys “Returned to Sender”, you will need to conduct research to find up-to-date information and re-send as appropriate. Log in corrected addresses, contact information, date mailed, and date returned for all surveys re-sent.

Approximately 2 weeks before the survey response deadline, you should begin to contact the facilities that have not responded. If the number of non-respondents is small, you can collect the information through telephone contacts or plant visits. If a facility refuses to complete the

survey, your agency might take legal action (if appropriate) to force a response; or you will need to follow the data handling procedures for non-responses outlined in the QA/QC plan.

Returned surveys will be checked by the QA/QC staff to ensure that the information on each form is complete and reasonable. If the data are determined to be inadequate, your agency will need to re-contact the surveyed facility. Telephone calls or plant visits are the most efficient means to collect the complete or revised information. Direct contact will provide your agency with the opportunity to clarify any misunderstood questions and assist the facilities to complete the survey form.

9

I GOT RESPONSES - NOW, WHAT DO I DO WITH ALL OF THAT DATA?

As survey responses are received, they are logged in and put through an initial data check to determine if responses are complete and the data are reasonable. The QA/QC procedures and criteria for this check should be presented in the inventory preparation plan. As described in Section 4 of this chapter, you will need to follow-up with facilities that do not respond or that submitted inadequate data.

Following the initial QA/QC check and any required follow-up, your data entry team can input the information into the appropriate data files. Consider designing look-up tables or pull-down menus in the data entry programs to define and fill in permissible entries—this is particularly helpful when the data entry involves lots of chemical names.

Your QA/QC staff will then review the entered data as required by the QA/QC procedures and criteria to verify the accuracy of the data entry. You can also use automated computerized checks to:

- Ensure against entering inappropriate data in a field—for example characters where numbers are expected;
- Conduct range checks to confirm that values are within a specified minimum and maximum for a specific variable; and
- Highlight outliers or suspect data.

Refer to Volume VI of the EIIP series, *Quality Assurance Procedures*, for additional information on QA/QC of data entry and analysis.

You will need to address any outliers identified in the data set by using apply programming solutions, statistical techniques, or your knowledge of the sources and processes. These procedures should be defined in the inventory preparation plan.

A properly designed area source survey will collect the necessary data and include a mechanism for “scaling up” the survey results. By the nature of area sources, it may not be possible to survey the entire population of a source category. The method extrapolating from a sample to

the population will depend on the type of source that is covered by the survey effort. Refer to the source-specific chapters in this volume for additional information.

A suggested method on how to scale up your survey results can best be illustrated using an industrial source category example. You conduct a survey of facilities reporting under SIC code 2711, Newspapers. In the county of interest, a publicly available business database shows 150 facilities in this SCC code. You randomly select 25 facilities and mail surveys:

- 5 do not respond; and
- 20 respond.
 - 2 are listed under wrong SIC codes;
 - 14 are listed under correct SIC codes, and complete the survey; and
 - 4 are listed under correct SIC code, but do not complete the survey adequately.

So, out of the 150 facilities in this SCC code:

- You know nothing about 20% (the non-respondent facilities);
- You know something about the respondent 80%:
 - 8% report under the wrong SIC code;
 - 56% you can develop emission estimates for; and
 - 16% you can NOT develop emission estimates for.

Thus, your sample data can be extrapolated to 72% (108 facilities) of the total population reporting under that SIC code. Emission estimates can also be extrapolated to the unknown 20% by assuming that 8% of these facilities report under the wrong SIC code, and 92% (27 additional facilities) report under the correct SIC code.

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