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IDENTIFICATION AND CHARACTERIZATION OF MISSING OR UNACCOUNTED FOR AREA SOURCE CATEGORIES

FINAL REPORT

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16. ABSTRACT The report identifies and characterizes missing or unaccounted for area source categories. Area source emissions of particulate matter (TSP), sulfur dioxide (SO2), oxides of nitrogen (NOx), reactive volatile organic compounds (VOCs), and carbon monoxide (CO) are estimated annually bu the U. S. EPA. Area sources include all mobile sources and any stationary sources that are too small, difficult, or numerous to be inventoried as point sources. A missing or unaccounted for source category is one that does not explicitly appear on the National Emissions Data System (NEDS) area source category list or the State Implementation Plan (SIP) area source category list in Chapter 4 of Procedures for the Preparation of Emissions Inventory for Precursors of Ozone (EPA-450/4-88-021, December 1988). A partial list of missing or unaccounted for categories identified by this project includes: roofing activities; airport, rail yard, and marine port support activities; charbroiling; automobile fires; paving or traffic paints; road and highway construction; and wineries.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Cookery	Pollution Control	13B	06H
Properties	Automobiles	Stationary Sources	14G	
Analyzing	Fires	Area Source Categories	14B	13L
Roofing	Paints	Railyards	13C	11C
Airports	Paving	Charbroiling	01E	13B
Railroads	Traffic	Automobile Fires	13F	
Marine Terminals	Highways	Traffic Paints	15E	
Charcoal	Construction	Wineries	21D	13M

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ABSTRACT

This report presents the results of work completed under three different work assignments under EPA Contract No. 68-D9-0173. The objectives of this work were to identify and characterize emissions sources not currently accounted for by either the existing NEDS or SIP area source methodologies. Seventy missing sources categories were characterized.

Addressing the area of missing or unaccounted for source categories involved several steps:

- identifying source categories
- data gathering and initial characterization of categories
- priority ranking of characterized categories
- more detailed, in-depth characterization of high ranking categories and emissions estimation methodology development

Information for the characterizations was derived from a number of sources, many of which were identified during the search phase of this project. The principal sources of information were available literature, industry and trade association publications and contacts, and knowledgeable federal and state personnel.

The information presented in these characterizations is intended to provide an initial overview of the process and its emissions, an indication and/or summary of the data available from standard reference materials and primary contacts, alternate methodology development strategies and a basis for ranking these source categories for methodology development.

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LIST OF ACRONYMS

AEERL	U.S. EPA, Air and Energy Engineering Research Laboratory
AGA	American Gas Association
AGST	above-ground storage tank
AIB	American Institute of Baking
AIRS	Aerometric Information Retrieval System
ALAPCO	Association of Local Air Pollution Control Officials
APCA	Air Pollution Control Association (See AWMA)
API	American Petroleum Institute
ARCA	American Race Car Association
AREAL	U.S. EPA, Atmospheric Research and Exposure Assessment Laboratory
AWMA	Air and Waste Management Association (formerly APCA)
AWWA	American Water Works Association
BIA	Barbecue Industry Association
BIS	Bibliographic Information Service
C&EN	Chemical & Engineering News
CAAA	Clean Air Act Amendments of 1990
CARB	California Air Resources Board
CART	Championship Auto Racing Teams
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980 (Superfund)
CFC	chlorofluorocarbon
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CTG	Control Techniques Guidelines
DAF	dissolved air floatation (units)
DEM	Division of Environmental Management
DOE	U.S. Department of Energy
DOT	Department of Transportation
EB	electron beam
EHV	extra high voltage (transmission lines)
EIA	U.S. DOE, Energy Information Administration
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute

LIST OF ACRONYMS (continued)

ERC	U.S. EPA, Environmental Research Center
ESP	electrostatic precipitator
FAA	Federal Aviation Administration
FEDS	Federal Energy Data System
FIP	Federal Implementation Plan
FTP	Federal Test Procedures
HDPE	high density polyethylene
HEM	Human Exposure Model
HSWA	Hazardous and Solid Waste Amendments
HUD	U.S. Department of Housing and Urban Development
IC	internal combustion
IEEE	Institute of Electrical and Electronic Engineers
IWWT	industrial wastewater treatment plant
LDPE	low density polyethylene
LPG	liquefied petroleum gas
LTO	landing/takeoff (cycle)
MSW	municipal solid waste
NAAQS	national ambient air quality standard
NADB	U.S. EPA, OAQPS, National Air Data Branch
NAPAP	National Acid Precipitation Assessment Program
NASA	National Aeronautics and Space Administration
NASCAR	National Association for Stock Car Racing
NCASI	National Council of the Paper Industry for Air and Stream Improvement
NEDS	National Emissions Data System
NESCAUM	Northeast States for Coordinated Air Use Management
NHRA	National Hot Rod Association
NMHC	non-methane hydrocarbon
NO_x	oxides of nitrogen
NPDES	National Pollutant Discharge Elimination System
NRC	National Response Center
NSF	National Science Foundation
NSPS	New Source Performance Standards
NTIS	National Technical Information Service
NYMA	New York Metropolitan Area

LIST OF ACRONYMS (continued)

NYCMA	New York City Metropolitan Area
O_3	ozone
OAQPS	U.S. EPA, Office of Air Quality Planning and Standards
OCS	outer continental shelf
OECD	Organization for Economic Cooperation and Development
OMS	U.S. EPA, Office of Mobile Sources
OSHA	Occupational Safety and Health Administration
OTS	U.S. EPA, Office of Toxic Substances
PAD	Petroleum Administration of Defense (district)
PCB	polychlorinated biphenyl
PET	polyethylene terephthalate
PM_{10}	particulate matter less than 10 μm in diameter
POM	polycyclic organic matter
POTW	publicly owned treatment works
PROC	photochemically reactive organic compound
PSD	Prevention of Significant Deterioration (regulations)
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RITG	radiatively important trace gas
ROD	Superfund Record of Decision
ROG	reactive organic gas
RWC	residential wood combustion
SARA	Superfund Amendments and Reauthorization Act
SCAB	South Coast Air Basin (California)
SCAQMD	South Coast Air Quality Management District (California)
SCC	source classification code
SCCA	Sports Car Club of America
SIC	Standard Industrial Classification (code)
SIMS	Surface Impoundment Modeling System
SIP	State Implementation Plan
SITE	Superfund Innovative Technology Evaluation (Program)
SO_2	sulfur dioxide
SO_x	sulfur oxides
SOC	synthetic organic chemical

LIST OF ACRONYMS (continued)

SRM	solid rocket motor
STAPPA	State and Territorial Air Pollution Program Administrators
THM	trihalomethanes
TLV	threshold limit value
TOG	total organic gas
TPD	tons per day
TPY	tons per year
TSCA	Toxic Substances Control Act
TSDF	hazardous waste treatment, storage, and disposal facility
TSP	total suspended particulate
UCSF	University of California at San Francisco
UV	ultraviolet
VMT	vehicle miles traveled
VOC	volatile organic compound(s)

CONVERSION FACTORS

To Convert From	To	Multiply By
Acre	Hectare (ha)	2.471
Acre	Square meter (m^2)	4047
Barrel (bbl)	Liter (l)	159
Barrel (bbl) - petroleum*	Gallon (gal)	42
Board foot	Cubic meter (m^3)	0.0024
British thermal unit (Btu)	Gram/calorie (g/cal)	251.98
British thermal unit/hour (Btu/hr)	Watt (W)	0.293
Centigrade	Fahrenheit	(°C+32) 9/5
Cord	Cubic meter (m^3)	3.6224
Cubic foot (ft^3)	Cubic meter (m^3)	0.0283
Cubic foot (ft^3)	Liter (l)	28.316
Cubic foot/minute (ft^3/min)	Cubic centimeter/second (cm^3/sec)	472.0
Cubic yard (yd^3)	Cubic meter (m^3)	0.77
Fahrenheit	Centigrade	(°F-32) 5/9
Foot (ft)	Meter (m)	0.3048
Gallon (gal)	Liter (l)	3.785
Inch (in)	Centimeter (cm)	2.54
Mile (mi)	Kilometer (km)	1.609
Pound steam/hour** (lb/hr)	British thermal unit/hour (Btu/hr)	1400.0
Pound (lb)	Kilogram (kg)	0.45
Pound/ton (lb/ton)	Gram/kilogram (g/kg)	0.496
Pound/square inch (psi)	Kilopascal (kPa)	6.894
Quart (qt)	Liter (l)	0.946
Square foot (ft^2)	Square meter (m^2)	0.0929
Ton	Kilogram (kg)	907.1

*42 gal/bbl is the standard as used in the oil industry. For other industries, different gallons/bbl apply.
**Typical value based on common boiler design parameters. Value will vary depending upon steam temperature and pressure.

SECTION 1
INTRODUCTION

BACKGROUND

Area source emissions of particulate matter (TSP), sulfur dioxide (SO_2), oxides of nitrogen (NO_x), reactive volatile organic compounds (VOC) and carbon monoxide (CO) are estimated annually by the National Air Data Branch (NADB) of the U.S. Environmental Protection Agency (EPA). Area sources include all mobile sources and any stationary sources that are too small, difficult or numerous to be inventoried as point sources. The NADB defines an area source as an anthropogenic mobile or stationary source that emits less than 100 tons per year of TSP, SO_2, NO_x, VOC and CO.[1]

The original National Emissions Data System (NEDS) area source methodologies and algorithms were developed in 1973 and 1974, using 1960 census data, and identified 64 area source categories. The National Acid Precipitation Assessment Program (NAPAP) expanded the NEDS area source category list to 97 categories.

Chapter 4 of *Procedures for the Preparation of Emission Inventories for Precursors of Ozone, Volume I* (EPA-450/4-88-021; NTIS PB89-152409) provides a list of area source categories to be inventoried under a State Implementation Plan (SIP) inventory.[2] The list of area source categories to be inventoried and the emissions estimation methodologies given in the SIP guidance differ noticeably from the NEDS categories and methodology. While emissions sources included in the NEDS and SIP inventories cover a large portion of anthropogenic emissions, many smaller source categories are not accounted for in either inventory. Identification, characterization and inclusion of these categories and their emissions in the inventory program will result in a more thorough and complete emissions inventory.

PURPOSE AND SCOPE

This report presents the results of work completed under three different work assignments under EPA Contract No. 68-D9-0173. The objectives of this work were to identify and characterize emissions sources not currently accounted for by either the existing NEDS or SIP area source methodologies. Missing source categories are characterized, to the extent possible, in the following areas:

---

[1]Readers more familiar with metric units may use the factors at the end of the front matter to convert to that system.

[2]Recently, EPA has issued a revised version of the SIP emissions inventory guidance document, *Procedures for the Preparation of Emissions Inventories for Carbon Dioxide and Precursors of Ozone, Volume I* (EPA-450/4-91-016). This revised document incorporated some results from these previously initiated missing sources projects (Work Assignment Nos. 0/107, 0/113 and 1/101 under Contract No. 68-D9-0173).

- definition/description of the category and activity
- process breakdown (if applicable)
- importance of the category (i.e., reason for considering the category)
- pollutants emitted
- estimate of the pollutant levels
- point/area source cutoff (i.e., does the category have both a point source and an area source component)
- level of detail of available information
- level of detail required by users
- emission factor requirements
- regional, seasonal or temporal characteristics
- urban or rural characteristics
- potential emissions estimation methodology

A *missing* or *unaccounted for* source category is defined as a category that does not explicitly appear on the NEDS area source category list or the SIP area source category list as presented in Chapter 4 of *Procedures for the Preparation of Emissions Inventory for Precursors of Ozone*. Exceptions to this generic definition include, for example, residential liquefied petroleum gas (LPG) consumption, light-duty diesel passenger cars and light-duty diesel trucks. Residential LPG consumption is not explicitly listed as a NEDS area source category, but is accounted for within the methodology for residential natural gas consumption. Light-duty diesel passenger cars and light-duty diesel trucks are also not explicitly accounted for in the NEDS mobile sources methodology, although the diesel vehicle miles traveled (VMT) and diesel fuel consumption are assigned to the heavy duty diesel category. Examples of true missing or unaccounted for source categories include cooling towers, street sweeping, street sanding, restaurant charbroiling[3] operations (wood- or charcoal-fired) and aircraft cruise mode (inflight) operations.

Addressing the area of missing or unaccounted for source categories involves several steps:

- identifying source categories
- data gathering and initial characterization of categories
- priority ranking of characterized categories
- more detailed, in-depth characterization of high-ranking categories and emissions estimation methodology development

[3]*Charbroil* is used as defined in *Webster's New World Dictionary of the American Language*, Second College Edition. Simon & Schuster, Inc. New York, NY. 1986.

This project was designed to identify and characterize the missing or unaccounted for area sources. The complete effort has been divided into phases. Seventy missing or unaccounted for source categories were identified and characterized under Work Assignments 0/107 (Phase I), 0/113 (Phase II) and 1/101 (Phase III) under Contract No. 68-D9-0173.

CONTENTS

Section 2 of this report describes the process of identifying the missing or unaccounted for source categories. The characterization of the source categories is described in Section 3. The 70 characterizations are presented in the Appendix.

SECTION 2

IDENTIFICATION OF MISSING/UNACCOUNTED FOR SOURCE CATEGORIES

INTRODUCTION

Missing or unaccounted for source categories were identified by contacting various individuals and groups, conducting literature searches, reviewing the Clean Air Act Amendments of 1990 (CAAA) and Superfund Amendments and Reauthorization Act (SARA) Title III, investigating changing technologies and reviewing other information sources (e.g., in-house knowledge, telephone book yellow pages, etc.). This chapter discusses the identification procedures and their results.

CONTACTS

Alliance Technologies Corporation (Alliance) contacted individuals and groups, such as EPA personnel, state and local agencies (e.g., Northeast States for Coordinated Air Use Management (NESCAUM), State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials (STAPPA/ALAPCO), etc.), NAPAP participants, Environment Canada, trade and professional associations and environmental groups, to identify and gather information on area source categories not currently inventoried by the NEDS or SIP methodologies. EPA contacts included Regional SIP representatives and other knowledgeable personnel from the Office of Air Quality Planning and Standards (OAQPS), Office of Mobile Sources (OMS), Office of Toxic Substances (OTS), Air and Energy Engineering Research Laboratory (AEERL) and Atmospheric Research and Exposure Assessment Laboratory (AREAL). State personnel were identified from in-house knowledge and experience and from NAPAP contacts. Environmental groups were identified and contacted based in part on in-house knowledge. NAPAP contacts were also identified from in-house knowledge.

A standard series of questions for each contact was developed to ensure consistency and thorough coverage. Table 1 lists the groups and individuals contacted.

A partial list of missing or unaccounted for categories identified by this process include the following: roofing activities; airport, rail yard and marine port support activities; charbroiling; automobile fires; paving or traffic paints; road and highway construction; and wineries. Some contacts provided information useful for characterizing the categories or estimating emissions from the categories. In addition, several contacts registered concerns about the current methodologies. One common concern was that while a detailed emissions estimation methodology may be available for a category, no relevant data necessary for using the methodology exist.

TABLE 1. CONTACTS FOR MISSING SOURCE IDENTIFICATION AND INFORMATION

EPA Personnel - Regional

- Bob Judge, Region I
- Rebecca Taggart, Region III
- Kay Prince, Region IV
- Bill Jones, Region V
- Becky Caldwell, Region VI
- Larry Hacker, Region VII
- Lee Hanley, Region VIII
- Scott Bohning, Region IX
- Mike Lidgard, Region X
- Randy Ramos, Region X

EPA Personnel - Other

- Sue Kimbrough, AEERL
- Bob Hangebrauck, AEERL
- Joan Novak, AREAL
- Arch MacQueen, OAQPS
- Mike Kosusko, AEERL
- Sharon Reinders, OAQPS
- Mark Wolcott, OMS
- Pat Kennedy, OTS
- Kenon Smith, OTS
- Bill Lamason, OAQPS
- Tom Lahre, OAQPS

State Personnel

- Jeff Walker, Alabama
- Willard Hanks, Florida
- Dick Forbes, Illinois
- Richard Dalebout, Michigan
- Wayne Anderson, Mississippi
- Mike Conley, New Mexico
- Rick Leone, New York
- Jim Hambright, Pennsylvania
- Jay Walters, Pennsylvania
- Bill Gill, Texas
- Don Robinson, Utah

Environmental Groups

- Environmental Defense Fund
- Natural Resources Defense Council
- Sierra Club
- World Resources Institute

NAPAP Contacts

- Ron Freeto, Connecticut
- Fred Sellars, ENSR
- Paul Shutt, Michigan
- World Resources Institute

Other Groups/Individuals

- Brian Dunbar, NASA
- Alan Van Arsdale, NESCAUM
- Tony Kosteltz, Environment Canada
- STAPPA/ALAPCO
- Tom Butler, McDonnell-Douglas
- Steve Heisler, ENSR
- Electric Power Research Institute (EPRI)
- Juliette Benedicto, National Paint and Coatings Association

Other

- Radian Study
- Yellow Pages (Durham, Raleigh and Chapel Hill, NC)

LITERATURE SEARCH

Alliance searched the National Technical Information Service (NTIS) database, ChemAbstracts (on Dialog Information Service), EPA holdings and Triangle university collections for reports or papers identifying emissions sources not included in current NEDS or SIP inventories. The NTIS database was searched through the CD-ROM system for the period 1985 through April 1990. General keyword identifiers, such as *area source*, *emission inventory*, etc., were used, as well as specific category keyword identifiers such as *cooling tower* and *pesticide air emissions*. Approximately 135 pages of bibliographic information with abstracts were retrieved and reviewed. Many of the citations referred to documentation from the 1980 and 1985 NAPAP inventories. Ten documents were selected for further review. These NTIS documents were retrieved on fiche from the North Carolina State University public documents collection.

No relevant citations were identified from the EPA holdings search or an on-line title and subject search of the Triangle University Bibliographic Information Service (BIS).

Discussions with Anne Powell (EPA/Environmental Research Center (ERC) Library) led to a search of ChemAbstracts through the Dialogue Information Service. Since searching the potential missing category keywords or identifiers would have been too time consuming and costly, a general identifier search (e.g., *air emissions* and *non-traditional*) was used. An initial search of the database (1967 to the present) produced sixty citations and bibliographic citations. These were received and reviewed. Relevant documents were retrieved from the EPA/ERC Library and Duke University's Engineering Library.

Other information sources reviewed include annual Air Pollution Control Association (APCA) proceedings, APCA specialty session proceedings, EPRI documents, the Third Party NAPAP review documentation and state NAPAP review comments.

Document Summaries

Those documents identified during the literature search and considered useful for this work assignment are summarized briefly in the following pages. A comment has been added after each document summary to characterize the relevant source types and usefulness of information in the document.

Hazardous Waste TSDF (Treatment, Storage, and Disposal Facilities): Fugitive Particulate Matter Air Emissions Guidance Document, C. Cowherd *et al.*, EPA-450/3-89-019 (PB90-103250), May 1989.

The purpose of this document is to provide regulatory and industrial personnel with sufficient information to identify sources of contaminated fugitive particulate matter, estimate the magnitude of emissions, select viable control measures and estimate the effectiveness of those measures in order to ensure that high risks from these facilities do not occur. The following sources are discussed in the document: paved and unpaved roads; open waste piles and staging areas; dry surface impoundments; landfills; land treatment; and waste stabilization.

Comment: No new data on missing or unaccounted for area sources were identified.

Area Sources of VOC (Volatile Organic Compounds) Emissions and Their Contribution to Tropospheric Ozone Concentrations, M. Kosusko and S.L. Nolan, EPA-600/D-89-075 (PB-89-181291), June 1989.

The report quantifies the importance of area sources to total VOC emissions, reviews components of AEERL's nonattainment program, discusses the status of emissions control or prevention for several area sources and reviews some of the regulatory strategies being implemented or considered by state and local pollution control agencies. In 1988, several projects were undertaken by AEERL to develop a greater understanding of the contribution of area sources of VOC to the ozone problem. These include studies related to specific sources of VOC, identification of commercial/consumer product control options and determination of the regional/seasonal variations in emissions. In each study, available sources of information have been used to develop priorities for the sources of emissions contributing to the ozone nonattainment problem. Sources of data include the technical literature, contacts in industry and elsewhere in the EPA and surveys conducted by various trade organizations.

Comment: Good reference section, but no new relevant information.

Screening-level Assessment of Airborne Carcinogen Risks from Uncontrolled Waste Sites, T.F. Wolfinger, JAPCA 39:461-468, April 1989.

This report presents screening-level estimates of the general level of cancer risks arising from uncontrolled waste sites. These risks were determined based on an estimate of the types and amounts of air contaminants at 25 National Priority List sites. Exposures and risks were calculated using the EPA Human Exposure Model (HEM).

Comment: A level of 100 kilograms per year of carcinogenic emissions was assumed based on limited test data. Abandoned waste sites are a missing source, but this document provides no new information on their emissions rates, nor does it address the overall location or characterization of these sites. The reference section may be of some use in identifying the sources of the author's assumptions.

Ethanol Emissions and Control for Wine Fermentation Tanks, California Air Resources Board, ARB/ML-88-027 (PB88-223540), April 1989.

Three emissions control devices (a water scrubber, a carbon adsorption unit and a catalytic incinerator) were tested as part of a pilot program to evaluate technologies to reduce the ethanol content of wine fermentation tank exhaust gases. The devices were evaluated on 1,400 gallon capacity tanks producing red and white wines at the California State University at Fresno. Tank exhaust gases were directed to the control devices through a hood cap collection system. A control tank with no exhaust gas collection system or control device was also tested. Ethanol emissions were monitored using continuous hydrocarbon analyzers at the inlet and outlet of each control device. Each control device was found to be capable of reducing ethanol emissions by at least 90 percent. Continuous monitoring of oxygen and carbon dioxide was performed. Samples were taken to determine moisture content and selected VOC and hydrogen sulfide concentrations. A data logger was used to allow computer data reduction of the continuous monitor results.

Comment: Test data could be used to develop emission factors for wineries.

Assessment of Non-Regulated Sources in the Seattle Area, G.M. Savage and H. Sharpe, Waste Management and Research 5:159-171, 1989.

The results of a quantitative study to assess the extent and degree of non-regulated hazardous waste present in municipal solid waste generated in King County, Washington are reported. The study sampled municipal waste deposited at transfer stations in the county for the purpose of identifying the types and concentrations of non-regulated hazardous waste.

Comment: The document contains a small amount of information on volatile contents of municipal waste based on samples in one county.

PM_{10} Emission Factors for Specialized Open Dust Sources, C. Cowherd and M.A. Grelinger, In Proceedings of the 81st Annual Meeting of APCA, Dallas, TX, June 19-24, 1988 (88-71B.3).

This paper discusses PM_{10} emission factor development for specific open dust sources for which appropriate factors have been unavailable. The source categories include agricultural harvesting and burning, unpaved airport runways, cattle feedlots, construction site preparation, demolition, off-highway vehicle travel, open burning, landfill activities, tailings ponds, transportation tire and break wear, road sanding and unpaved parking lots. Estimation methods employing scientific and engineering procedures and technology transfer techniques were used to fill identified gaps in particulate matter under ten microns in diameter (PM_{10}) emission factors.

Comment: Contains data and estimation methods (for PM_{10}) on fugitive particulate sources, some of which have not been considered previously.

Evaluation of Emissions from Selected Uninventoried Sources in the State of California, Radian Corporation, ARB/R-88-343 (PB88-215215), April 1988.

The California Air Resources Board (CARB) maintains an extensive statewide emissions inventory of criteria pollutants. The document ranks the emissions from 47 emissions source categories that are not currently inventoried by CARB. A primary objective of the study was to evaluate the significant source categories emitting VOC. Sources of ammonia (manure wastes) and particulate matter (wind blown dust) were also considered. The project was conducted in two phases. In the first phase, preliminary emissions calculations for the 47 source categories were prepared. The second phase of the project, presented in this document, focused on eight source categories that were selected from the ranking process. A detailed methodology for calculating statistical confidence intervals for the refined emissions estimates was also developed and applied.

Comment: A useful compilation of information on a number of missing and unaccounted for sources, with some data to relate relative emissions magnitude. Eight categories are given a more thorough treatment with emissions (for California) estimated in some cases.

Sources and Concentration of Chloroform Emissions in the South Coast Air Basin, Science Applications International Corporation, ARB-R-88/344 (PB88-215678), April 1988.

The objectives of this study were to identify and quantify sources of chloroform emissions in the South Coast Air Basin and to relate emissions to ambient concentrations. Phase I consisted of a literature review; written and telephone surveys of users of chloroform precursors (water and wastewater treatment plants, cooling tower users, pulp and paper plants, pharmaceutical manufacturers, laboratories and hospitals); and modeling to relate estimated emissions to historically observed concentrations. A machine-readable annotated bibliography was also developed. Phase II included ambient sampling by carbon molecular sieve at sites throughout the Basin and at two fixed sites; source testing of a swimming pool (using a surface isolation flux chamber) and at two wastewater treatment plants; sampling of marine air and water; and smog chamber modeling of hypothesized atmospheric formation and removal processes. New emissions estimates were developed from field measurement data and the resulting modeled concentrations fit the observed values reasonably well. A conceptual model of cycling of chloroform between the ocean and the atmosphere over the Basin was proposed.

Comment: No new data on missing or unaccounted for area sources were identified.

Updating Nontraditional VOC Source Inventories, R.M. Leone, E.W. Davis and A.D. Jones, In Proceedings of the 80th Annual Meeting of APCA, New York, NY, June 21-26, 1987 (87-58.2).

This paper discusses efforts to develop updated VOC inventories for architectural surface coatings in the New York Metropolitan Area (NYMA) and the State of New Jersey and for consumer/commercial solvent use in the NYMA, the State of New Jersey and the State of California. The discussion includes the preparation of area source emission factors and comparison to *AP-42* factors, problems encountered, sources of information and future year projections.

Comment: The document provides a lengthy list of specific commercial and consumer solvent product types and references to original data sources for product content and distribution data.

Photochemically Reactive Organic Compound Emissions from Consumer and Commercial Products, A. Jones *et al.*, EPA-902/4-86-001 (PB88-216940), November 1986.

The report estimates the emissions of VOC and photochemically reactive organic compounds (PROC) released from the use of consumer products in the States of California and New Jersey and the New York Metropolitan Area. The report describes the data sources and methodologies used to estimate VOC and PROC emissions from consumer products and presents emissions estimates disaggregated by consumer product subcategory and geographic region.

Comment: This document was summarized in the APCA article by Leone, Davis and Jones.

Determination of Air Toxic Emissions from Non-Traditional Sources in the Puget Sound Region, Engineering-Science, EPA-910/9-86-148 (PB87-123550), April 1986.

This report describes the development of emissions estimates for five non-traditional sources in the Puget Sound region, including publicly owned treatment works (POTWs); industrial wastewater treatment plants (IWWTs); Superfund clean-up sites; municipal landfills; and TSDFs. Emissions were estimated for specific facilities from each category. In evaluating emissions, no selected or limited list of toxic materials was used; however, almost all available analyses of wastewaters were prepared to evaluate the presence of EPA's priority pollutant list.

Comment: A relative magnitude assessment of POTW, IWWT, Superfund, municipal landfill and TSDF site air toxic emissions. It may be of use in evaluating emissions magnitudes. It presents average landfill flare gas composition, air toxics and priority pollutant estimates for three landfills.

Air Toxics Technical Assistance for the State of Alaska, R.J. Dickson, S.H. Peoples, and W.R. Oliver, EPA-910/9-87-159 (NTIS PB89-217897), March 1987.

An air toxics emissions inventory was developed for the State of Alaska. The inventory focuses on both point (i.e., specifically identified facilities) and area sources. The area source inventory does not identify facilities, but aggregates emissions totals for a geographic area. Activity data were obtained for the time periods from 1979 through 1986. Included in the report are exact sources of information and the time periods for which they were derived and a summary of point and area source emissions by source type. Also included are tables of data by air toxic compound and a detailed list of the point source emissions by source. Threshold limit values were used to rank the emissions sources and the results are tabulated.

Comment: This document provided no additional information on unidentified area sources. All categories discussed were NEDS or NAPAP area source categories.

Effect of Wind Speed on the Atmospheric Levels of Particles Produced by Traditional and Nontraditional Sources on the Island of Curacao, E. Sanhueza, J. Romero and E. Gijsbertha, Chemosphere 14:91-97, 1985.

TSP, SO_4^{2-} and Pb levels observed downwind from a large refinery and the city of Willemstad are presented. High atmospheric TSP levels are due to refinery emissions and the recirculation of street dust particles produced by traffic.

Comment: No new data on missing or unaccounted area sources were identified.

CAAA AND SARA TITLE III

The CAAA were reviewed for identification of source categories not addressed in NEDS or the SIP inventories, using the House version H.R.3030 (November 9, 1989; renumbered to House of Representatives Bill S.1630) and the Senate version S.1630 (January 23, 1990). Subsequent to passage of the final law in October 1990, the CAAA were reviewed for any material changes to the identification of source categories. Provisions in the SARA Title III legislation were also examined for specific area source categories.

CAAA

Although little mention of specific area sources of emissions was made in the CAAA, several sources were identified, including the following: clean fuels; marine vessels; urban fugitive dust; residential wood combustion; prescribed agricultural burning; prescribed silvicultural burning; rocket

engine and motor firing and cleaning; shipbuilding and repair; aerospace coatings and solvent; oxygenated fuel; outer continental shelf (OCS) oil and gas activities; research facilities; and oil and gas production. Of these sources, residential wood combustion, prescribed agricultural and silvicultural burning and marine vessels are already included in the NEDS or SIP inventories.

Clean Fuels. H.R.3030, Section 182(c)(3), requires that areas classified as nonattainment for ozone submit a SIP revision to include such measures as may be necessary to ensure the effectiveness of the clean fuels vehicle program prescribed under Section 212(b)(2). Although motor vehicles are already included in the NEDS and SIP inventories, a prescribed clean fuels program will change the emissions from these vehicles. Further work to quantify evaporative emissions from gasoline marketing will be required.

Marine Vessels. Section 183(f) requires that EPA "promulgate standards applicable to the emission of any air pollutant from loading and unloading of marine tank vessels which (EPA) finds causes, or contributes to, any pollution that may be reasonably anticipated to endanger public health or welfare." In complying with this section of the CAAA, EPA must examine and quantify emissions from marine tank vessels.

Urban Fugitive Dust, Residential Wood Combustion and Prescribed Agricultural and Silvicultural Burning. Section 190 concerns particulate emissions and requires EPA to issue "technical guidance on reasonably available control measures and best available control measures for urban fugitive dust, and emissions from residential wood combustion and prescribed silvicultural and agricultural burning." EPA should examine its studies on particulate emissions from these sources to determine if more work will be needed to issue the required guidance.

Catastrophic and Accidental Releases. The October 26, 1990 Conference Report indicates that Title III includes a new program under which EPA is to establish reasonable and appropriate regulations to prevent or detect accidental releases to the maximum extent possible. Section 301 of the Amendments amends Section 112(r)(1) of the CAA and states, "It shall be the objective of the regulations and programs authorized under this subsection to prevent the accidental release and to minimize the consequences of any release of any ... hazardous substance."

Rocket Engine and Motor Firing and Cleaning. Section 173(e) states that "the permitting authority of a State or political subdivision shall allow a source to offset by alternative or innovative means emission increases from rocket engine and motor firing, and cleaning related to such firing, at an existing or modified major source that tests rocket engines or motors." EPA should develop appropriate emission

factors to enable the permitting authority to quantify the emissions from the engine testing and cleaning activity.

Aerospace Coatings and Solvents. Section 183(b)(3) requires EPA to publish Control Techniques Guidelines (CTGs) for "all aerospace coating and solvent applications (including military and commercial applications)." EPA should examine its guidance on these emissions sources.

Oxygenated Fuels. Section 187(b)(3) requires areas designated as carbon monoxide nonattainment areas to submit revised SIPs implementing and enforcing a program "with fuels containing such level of oxygen as is necessary." To support this state effort, further work on oxygenated fuels emission factors should be performed.

OCS Oil and Gas Activities. Title VIII, Section 801 requires the Secretary of the Interior to promulgate regulations to reduce the effects of OCS oil and gas marketing activities within 25 miles offshore along the Pacific, Arctic and Atlantic Coasts and part of Florida's Gulf Coast. Other OCS areas will be studied to determine their impacts on adjacent nonattainment areas. Although emissions from petroleum marketing activities are available for on-shore operations, research should be performed to verify that these emission factors are appropriate for use in determining off-shore emissions.

Shipbuilding and Repair. Section 183(b)(4) requires that EPA issue CTGs for "aggregate emissions of (VOC) and PM_{10} into the ambient air from the removal and application of such paints, coatings and solvents used in shipbuilding operations and repair." Research into the formulation of these coatings, operations and control and research into emissions from sandblasting activities need to be undertaken for this sector.

Research Facilities. Section 112(c)(7) requires EPA to establish a separate category for research and laboratory facilities and hazardous air emissions. These facilities do not produce commercial products. No separate inventory category now exists and research is required to determine how to effectively inventory research facilities as point or area sources.

Oil and Gas Production Wells. Section 112(n)(4) permits EPA to create an area source category for hazardous emissions from oil and gas production wells. Implementation of this provision would require research into the pollutant species emitted and development of emission factors and activity data.

SARA Title III

Title III of SARA (also known as the Emergency Planning and Community Right-To-Know Act of 1986) was reviewed for any mention of area sources not included in NEDS or SIP inventories; however, no sources were mentioned.

CHANGING TECHNOLOGIES

Using in-house knowledge and experience, Alliance identified several area source categories where changing technologies may result in emissions from source categories not currently included in NEDS or SIP inventories. Some categories identified through this process include the following:

- ultraviolet (UV) and electron beam (EB) curable coatings
- clean fuels/alternate fuels
- chlorofluorocarbon (CFC) substitutes
- artificial wetlands designed to treat domestic sewage
- compressed natural gas
- pulp bleaching by ozone
- recycling activities
- drinking water ozonation
- coronal discharge
- innovative hazardous waste destruction and remediation techniques

OTHER SEARCH ACTIVITIES

In addition to the activities described earlier in this section, the telephone book yellow pages were searched. These searches not only helped to directly identify sources not currently in the area source inventories, but also provided insight to the identification process. Sources identified through this process include small bakeries; fermentation processes found in breweries, distilleries and wineries; adhesives and glues application; commercial pesticide use; photocopiers and laser printers; and commercial charbroiling and deep fat frying.

DEVELOPMENT OF LISTS AND DEFINITIONS

Categories identified through the search phase were combined into a master list of missing/unaccounted for sources. This list contains all the identified categories, regardless of their

emissions potential. The master list was reviewed by knowledgeable Alliance personnel and a preliminary working list was developed containing those categories considered most important to characterize. The working list was submitted to EPA for review and was revised based on the comments received. Identified categories were aggregated into major headings and then disaggregated into specific category listings. Definitions were developed for each source category. Tables 2 and 3 contain the master list and the final working list, respectively. Information discovered while researching certain categories for characterization sometimes resulted in redefining the category and changing the category title from the master list to the final working list. The list of "changing technologies" source categories was developed and maintained separately from the previously mentioned lists.

Alliance recognizes the uncertainty inherent in the development of the working list. For example, process upset releases of emissions may be great. This category, however, was not included in the working list. EPA may want to review the master and working lists for additional important categories for future characterization.

TABLE 2. MASTER LIST OF MISSING/UNACCOUNTED FOR SOURCE CATEGORIES

Bioprocess Emissions Sources
- Biogenics
- Bioprocess
  - Alcoholic beverage use
  - Bakeries (small, grocery stores)
  - Dairies
  - Fermentation processes
    - Breweries
    - Distilleries
    - Wineries
  - Silage storage

Catastrophic/Accidental Releases
- Catastrophic releases
  - Rail car accidents
  - Plane crashes
  - Oil/gas well ruptures and fires
  - Tank farm failures and fires
- Process upsets at stationary sources

Evaporative Emissions Sources
- Agriculture
  - Aerial application/agricultural spraying/crop dusting
  - Fertilizers and fertilizer application operations
  - Lawn maintenance
- Aircraft Support Emissions
  - Airplane cleaning and deicing
  - Airport support activity - fuel combustion
  - Airport support activity - refueling
- Automotive
  - Automobile lubricants
  - Automobile wrecking
  - Automobile washing/waxing establishments
  - Automotive cleaners/waxes/polishes
  - Automotive fluids and fluid leaks
  - Automotive rustproofing/undercoating
  - Service station/vehicle activities
    - Diesel fuel emissions
    - Lubricating
    - Repair
    - Tire repairing
  - Windshield deicers
- Biocides
  - Cooling towers
  - Pest control (exterminating/fumigating)
  - Sterilizing operations
  - Swimming pool (chlorination)
  - Water treatment (chlorination)

(continued)

TABLE 2. MASTER LIST OF MISSING/UNACCOUNTED FOR SOURCE CATEGORIES (continued)

Commercial Solvents
- Acoustical tile finishing (ceilings)
- Adhesives and sealants application
- Beauty salons/schools
- Blueprint machines/blueprinting
- Candle making
- Carpet/rug/upholstery cleaning and deodorizing
- Caulking and sealing compounds
- Copying machines/mimeograph
- Foam packaging
- Foam-spray packaging materials
- Furniture making/manufacturing
- Glass tinting and coating
- Industrial and commercial cleaning/building cleaning
- Insulation (sprayed/blown)
- Laminating (application)
- Laundry products
- Lubricants and silicones
- Metal cleaners and polishes
- Mimeographing
- Mortuaries
- Plastics - fabricating/finishing/decorating
- Plywood and veneer
- Printed and etched circuits/microchips
- Roofing activities and repair
- Rubber coating
- Screen printing
- Service activity at airports, rail yards, ports
- Taxidermy
- Tobacco processing
- Traffic painting
- Waterproofing
- Wood floor and furniture finishing/stripping/refinishing

Consumer Solvents
- Adhesives and sealants application
- Ball point and porous tip pens
- Carpet/rug/upholstery cleaning and deodorizing
- Caulking and sealing compounds
- Copy machines
- Household cleaners and polishes
- Insect repellents and sprays
- Laundry products
- Lubricants and silicones
- Metal cleaners and polishes
- Mothproofing
- Personal products
- Plumbing chemicals
- Recreational boat cleaners/polishes/waxes

(continued)

TABLE 2. MASTER LIST OF MISSING/UNACCOUNTED FOR SOURCE CATEGORIES (continued)

- Consumer Solvents (continued)
  - Shoe polishes/waxes/dyes
  - Taxidermy
  - Waterproofing
  - Wood floor and furniture finishing/stripping/refinishing
- Laboratory Chemicals/Solvents
  - Animal hospitals
  - Medical clinics and doctors' offices
  - Research and testing laboratories
- Oil and Gas Production and Evaporative Losses
  - Oil and gas production - drilling
  - Oil and gas production - field activity
  - Oil tanks (home, above ground)
  - Petroleum spills
- Refrigerants (servicing, disposal and accidental releases)
  - Air conditioners (home and car)
  - Refrigeration and air conditioning equipment (commercial/industrial)
  - Refrigerated trucks
  - Refrigerants (leaking coolant)

Mobile Sources

- Air
  - Helicopters
  - Inflight aircraft emissions
- Land
  - Compressed natural gas vehicles
  - Mobile sources - evaporation and running losses
  - Motor vehicle racing
  - Off-highway four wheel drive vehicles
- Marine
  - Petroleum vessel loading and unloading losses

Fugitive Dust Sources

- Agricultural
  - Aerial application/crop dusting
  - Agricultural harvesting/farming operations
  - Feed preparation
  - Grain grinding
  - Grain elevators
  - Soil preparation
- Construction Trades
  - Construction site preparation
  - Demolition activities
  - Dynamiting/explosives
  - Road construction/earth moving
  - Sandblasting

(continued)

TABLE 2. MASTER LIST OF MISSING/UNACCOUNTED FOR SOURCE CATEGORIES (continued)

- Mining
  - Coal mines and coal waste
  - Mining, sand and gravel fugitives
  - Tailings ponds (dry)
- Military
  - Target ranges
  - Training exercises
    - Tanks
    - Troops
- Municipal and Residential Activities
  - Chimney sweeping and cleaning
  - Landfill activities
  - Road salting
  - Street sanding/sweeping/cleaning
- Other
  - Landfilling
  - Tire and brake wear
  - Unpaved airport runways
  - Unpaved parking lots

Ozone Sources

- Photocopiers and laser printers (ozone)
- Electric arc welding
- Extra high voltage transmission lines
- Pulp bleaching with ozone
- Tanning booths (ozone)
- UV and EB curable coatings
- UV sterilization
- Water treatment (ozonation)

Small-Scale Combustion Sources

- Fuel Combustion
  - Butane gas equipment (compressors)
  - Exempt internal combustion (IC) engines
  - Fireplaces
  - Gas dryers (methanol)
  - Kerosene space heaters
  - Rocket launches and test firings
  - Small electric utility boilers
  - Wood combustion - nonresidential
  - Wood stoves - residential
- Other Combustion
  - Automobile fires
  - Cigarette smoke
  - Crematories

(continued)

TABLE 2. MASTER LIST OF MISSING/UNACCOUNTED FOR SOURCE CATEGORIES (continued)

Food Preparation
- Charbroiling
- Deep fat frying
- Grills (gas and charcoal)
- Residential kitchens
- Restaurants

Waste Treatment and Disposal Sources
- Abandoned waste sites
- Barge, tank, tank truck, rail car and drum cleaning
- Composting
- Landfill methane
- Package plants - wastewater treatment
- Recycle/recovery/reclamation processes and facilities
- Refinery sludge dewatering
- Remediation activities/Superfund sites
- Septic tanks and system cleaning
- Waste oil disposal

Miscellaneous Sources
- Acetylene/acetylene welding and other welding types[1]
- Anodizing/planting/electroplating[1]
- Building ventilation systems
- Chemical and portable toilets
- Coffee and other beverages
- Diaper services
- Distribution center activity
- Fire suppression chemicals
- Galvanizing[1]
- Machine shops
- Masonry (mixing)
- Meat curing/packing
- Metal heat treating[1]
- Metallizing[1]
- Mirrors - resilvering
- Newspaper printing
- Photographic processes (film developing)
- Rendering companies (bones, fat, grease, tallow, scraps)
- Sewer cleaning
- Synthetic organic chemical storage tanks, especially exotic petrochemicals

[1]light industrial source

TABLE 3. WORKING LIST OF MISSING/UNACCOUNTED FOR AREA SOURCE CATEGORIES

BIOPROCESS	
Bakeries (small)	Bakeries emit VOC, primarily ethanol, formed by yeast action during the baking process. Commercial bakeries are covered in the existing point source methods and in the NAPAP area source categories, but small operations such as in-store bakeries remain uninventoried.
Breweries	Although large commercial breweries are covered in point source inventories, small-scale (e.g., "micro") and home brewing are not included among point or area sources. Fugitive alcohol emissions from the fermentation process are likely, but small in magnitude. Grain drying also releases VOC, primarily methanol.
Distilleries	Fugitive alcohols are released from the aging process.
Silage Storage	Particulate matter, CO_2 and NO_x are emitted from degradation processes during storage. Significant emissions are likely to occur at cooperative storage centers, but individual silos would have some contribution to the total.
Wineries	Wineries contribute fugitive ethanol emissions from the fermentation and aging processes.
CATASTROPHIC/ACCIDENTAL RELEASES	
Catastrophic/Accidental Releases - Rail Car, Tank Truck and Industrial Accidents	These accidents are usually chemical spills, with or without combustion, occurring randomly but with some frequency. Emissions depend on the chemical spilled, opportunity for combustion, remediation efforts and weather conditions. Releases may involve spillage of materials being transported or handled, fuel and materials combustion.
Natural Gas Well Blowouts	Natural gas well ruptures and fires occur in onshore and offshore exploration and have significant potential for both direct release and combustion emissions.
Oil Spills	Spills and petroleum well ruptures affect Outer Continental Shelf waters and coastlines, contributing evaporative VOC emissions and the potential for combustion products, depending on the cargo, remediation and weather conditions. Spills may also occur in inland waterways and on highways.

(continued)

TABLE 3. WORKING LIST OF MISSING/UNACCOUNTED FOR AREA SOURCE CATEGORIES (continued)

EVAPORATIVE	
Agriculture	
Lawn Care Products	Home and commercial lawn maintenance includes VOC emissions from the carrier solutions in the spraying of pesticides and fertilizers, and potential volatile and/or toxic releases of the active ingredients. This category also covers roadside herbicide spraying.
Pesticide Application	Crop dusting and municipal and commercial spray application of agricultural pesticides contribute VOC and particulate matter through the active and carrier ingredients. Herbicide and fertilizer application is another potential emissions source. This category includes commercial and consumer extermination and fumigation products that are applied inside and under residences and buildings.
Aircraft Support Emissions	
Aircraft Deicing	Exterior deicing of planes takes place during cold weather operations. The composition of deicing compounds should be investigated for the potential for evaporative emissions.
Airport Support Vehicles	Activities such as airport vehicle and equipment fuel combustion contribute to airport emissions.
Aircraft Refueling	Plane refueling contributes evaporative VOC emissions.
Automotive	
Automotive Cleaners/ Waxes/Polishes	VOC are emitted from many commercial and consumer car care products, including aerosol propellants, aerosol solvents and nonaerosol solvents.
Automobile Fluids and Fluid Leaks	Fluids include leaking brake fluid, transmission fluid, antifreeze (ethylene glycol), windshield washer fluid (alcohol), and lubricants and oils. Emissions occur due to leaks at commercial establishments, residences and on the roadway, or draining fluids at residences. (See Vehicle Repair under Service Station/Vehicle Activities.)
Automotive Rustproofing/ Undercoating	Application of rustproofing and undercoating products in the aftermarket releases VOC from solvent-based coatings.

(continued)

TABLE 3. WORKING LIST OF MISSING/UNACCOUNTED FOR AREA SOURCE CATEGORIES (continued)

EVAPORATIVE (continued)	
Service Station/Vehicle Activities	
Diesel Fuel Evaporation - Service Stations	VOC emissions occur due to the loading and unloading of diesel fuel at service stations, including underground tank losses, vehicle refueling and spillage.
Vehicle Lubrication	"Lube" and oil change emissions from waste oil evaporation release VOC prior to disposal.
Vehicle Repair	Auto repair includes drained fluids (including gasoline), cleaning solvents (e.g., carburetor cleaners), touch-up paints, etc.
Biocides	
Cooling Towers	Chlorination of cooling towers creates volatile trihalomethane species which are released to the atmosphere. Other emissions include process contaminants, water conditioning additives and suspended and entrained particulate matter, including chromium. Sources include power generation, industrial process and "comfort" cooling towers.
Commercial Solvents	
Adhesives and Sealants (Commercial)	VOC are emitted from commercial application of adhesives and glues for wood, plastics and other materials, primarily in the service and construction sectors.
Laminating	Application of laminates for packaging and other purposes has the potential to emit VOC.
Laundry Products (Commercial and Consumer)	Commercial and consumer laundry products can contain petroleum distillates. These components are emitted as the product is used and vented to the atmosphere. Dry cleaning is a current area source and is excluded from this category.
Traffic Painting	Oil-based road and parking lot paints emit VOC during application, especially in the summer peak painting season.

(continued)

TABLE 3. WORKING LIST OF MISSING/UNACCOUNTED FOR AREA SOURCE CATEGORIES (continued)

EVAPORATIVE (continued)	
Consumer Solvents	
Adhesives and Sealants (Consumer)	VOC are emitted from consumer application of adhesives, sealants and glues for wood, plastics and other materials (e.g., wood glues and caulks).
Household Cleaners and Polishes	Cleaners and polishes contain solvents both as active ingredients and propellants (aerosols). Examples include furniture polishes, metal cleaners and polishes, basin/tub/tile cleaners, all-purpose cleaners, window cleaners, etc.
Personal Products	This category includes personal products such as hair sprays, aftershaves, colognes, etc.
Laboratory Chemicals	
Research and Testing Laboratories	Laboratories associated with universities and hospitals routinely vent solvent emissions (e.g., toluene) through hoods to the outside atmosphere. Small commercial labs probably fall beneath point source criteria and are likely not included in inventories.
Oil and Gas Production	
Well Drilling	Drilling includes release of methane, degassing of drilling fluids and evaporation of fugitive oil. Emissions from numerous small wells operating on a more-or-less continuous basis are not tracked.
Field Activity	Emissions include sulfur species from the sour gas H_2S and well head sweetening. Field sources include offgas from the sweetening process, flanges, valves, venting, etc.
Refrigerants	
Refrigerants - Leaking Coolant	Leaking coolant refers to upset leaks from all types of refrigeration equipment.
Refrigeration/Air Conditioning Equipment	These emissions are coolant fugitives from the normal operation of stationary refrigeration equipment.
Refrigerated Trucks	Refrigerated trucks may lose coolant in transit.

(continued)

TABLE 3. WORKING LIST OF MISSING/UNACCOUNTED FOR AREA SOURCE CATEGORIES (continued)

EVAPORATIVE (Continued)	
Other	
Synthetic Organic Chemical Storage Tanks	Although some storage sources are in the point source inventory, many SCCs are either unavailable or unused for organic material storage, at the point of manufacture, distribution or use.
FUGITIVE DUST	
Earth Moving	
Farming Operations	Dust from farming includes tilling, cultivating, disking and harvesting operations. These emissions are seasonal and vary by soil type, crop, etc.
Landfill Activities	Activities at landfills include cell construction, filling, temporary/permanent covering and dust from vehicle travel.
Road Construction	Fugitive dust is produced during bed cutting, filling and construction, depending on soil types and local conditions. VOC are contributed from paving and chemical dust suppressants.
Other	
Grain Grinding and Feed Preparation	Small-scale private or cooperative milling of grains for animal feed produces fugitive dust from milling, mixing and handling.
Road Salting and Sanding	Winter road deicing generates particulate emissions from vehicular grinding and entrainment of applied salt and sand.
Sandblasting	Sandblasting incorporates commercial architectural activity, but excludes industrial process activities.
Street Sweeping and Cleaning	Municipal street maintenance activities generate airborne dust depending on local conditions and equipment.
MOBILE	
Air-based	
Inflight Aircraft	Inflight emissions as defined occur below the inversion layer. Emissions center around airports and result from private, commercial and military craft. Military training flights merit consideration due to sustained, low-level exercises.

(continued)

TABLE 3. WORKING LIST OF MISSING/UNACCOUNTED FOR AREA SOURCE CATEGORIES (continued)

MOBILE (Continued)	
Land-based	
Compressed Natural Gas Vehicles	The use of compressed natural gas, especially in the transportation sector, is currently under development.
Mobile Source Evaporative and Running Losses	Evaporative and running losses considered by the MOBILE4[1] model can now be incorporated into inventories.
Motor Vehicle Racing	Fuel combustion and evaporative emissions and particulate matter from dirt tracks result from motorcycle and automobile racing, including track, road, off-road, drag and other racing.
Marine	
Petroleum Vessel Loading and Unloading Losses	This category addresses primarily petroleum product fugitives emitted during filling, transfer and unloading at ports.
OZONE (Direct Emissions)	
Drinking Water Treatment with Ozone	Ozone is gaining acceptance in this country as an alternative disinfectant for potable water. Fugitive losses from ozone generators and contactors are potential emissions sources.
Extra High-Voltage (EHV) Transmission Lines	Ozone emissions occur due to coronal discharges along EHV electrical transmission lines at points of high local voltage gradients.
Photocopiers and Laser Printers	Ozone emitted from copiers and printers is generally considered an indoor problem, but high volume equipment may be vented to the atmosphere. The category includes commercial establishments and business, government and personal use.
Pulp Bleaching with Ozone	This technology is not yet beyond the pilot plant stage; however, ozone releases from onsite production and use may be significant as this technology penetrates the industry.
UV and Electron Beam Curable Coating	Coatings cured with UV light and electron beams are a substitute for thermally-cured, solvent-based coatings. UV radiation is a direct ozone source. Emissions are vented directly to the atmosphere to avoid corrosion. VOC and toxic compounds from the coating may also be released.
Welding	Ozone is directly produced and emitted during arc welding. Other emissions include combustion products and toxics from flux materials. Emissions are associated with welding shops, automotive repair, maintenance and construction activities.

(continued)

TABLE 3. WORKING LIST OF MISSING/UNACCOUNTED FOR AREA SOURCE CATEGORIES (continued)

SMALL-SCALE COMBUSTION	
Fuel Combustion	
Fireplaces	Fireplaces represent incomplete combustion sources at lodges, residences, etc. that emit particulate matter, NO_x, CO and VOC. Fireplaces differ from wood stoves because they are usually not primary heat sources, not continuously used, and are less efficient combustors.
Kerosene Space Heaters	Residential or commercial kerosene space heaters may be vented directly to the atmosphere and may be an indoor air concern. Sources include portable and fixed units.
Rocket Launches and Test Firings	Particulate matter, VOC and other combustion products are emitted during civilian and military rocket tests and launches. Most emissions are limited to a few areas of the country.
Small Electric Utility Boilers	Electric utilities releasing less than 100 tons per year (TPY) of priority pollutants are not individually covered in national and many state point source inventories. Assignment of emissions to point or area source categories merits consideration.
Wood Stoves	Residential wood stoves produce VOC, CO, NO_x and particulate matter, depending on stove type and fuel characteristics.
Food Preparation	
Backyard Charcoal Grills	VOC and particulate matter arise from combustion of the primary fuel, food and/or any fire-starter, principally from gas or charcoal (flame) cooking.
Commercial Charbroiling	VOC and particulate matter arise from meat cooking at fast food and full service restaurants, including flame-fired broilers and direct-flame cooking.
Commercial Deep Fat Frying (Restaurants)	Hot oils and greases used in frying potatoes, dough, chicken and fish emit VOC and entrained particulate matter, which may be released directly or vented to the ambient air.
Residential Deep Fat Frying	Hot oils and greases used in frying potatoes, dough, chicken and fish emit VOC and entrained particulate matter, which may be released directly or vented to the ambient air.

(continued)

TABLE 3. WORKING LIST OF MISSING/UNACCOUNTED FOR AREA SOURCE CATEGORIES (continued)

SMALL-SCALE COMBUSTION (continued)	
Other Combustion	
Cigarette Smoke	Cigarette smoke is a source of VOC, CO, NO_x, particulate matter and air toxics and is a ubiquitous indoor and outdoor source.
WASTE TREATMENT AND DISPOSAL	
Barge, Tank, Tank Truck, Rail Car and Drum Cleaning	VOC from residual contents and cleaning agents may be released to the atmosphere during cleaning operations.
Innovative Waste Treatment Technologies	New technologies for hazardous and solid waste incineration and destruction, waste reduction and remediation may create new categories of emissions sources. These sources, their potential emissions and the sources they replace should be identified as the technologies are developed.
Landfill Methane	Methane is released from anaerobic decomposition of landfilled wastes.
Package Plants (Wastewater Treatment)	Package plants are small, automated (usually) domestic waste treatment plants not requiring full-time supervision (e.g., at subdivisions and golf courses). VOC are emitted from incoming wastestreams during treatment.
Recycling Processes	Paper, plastic, glass and solvent recycling is a growing business. Particulate matter, sulfur oxides (SO_x), NO_x, CO and VOC originate from the recycling process, energy generation and storage or handling. However, processes in this category may overlap with existing area source fuel and TSDF methods.
Refinery Sludge Dewatering	API separators and dissolved air floatation (DAF) units at refinery wastewater treatment operations generate oily sludges that are dewatered onsite prior to further treatment or disposal. VOC are emitted during the dewatering processes which are not included in emissions from the separators and DAFs.
Waste Incineration (Developing Technologies for Hazardous Waste)	Incineration technologies are currently in use or under development to provide thermal destruction of hazardous waste either at commercial incinerators or onsite. These incinerators may be sources of combustion gases, VOC and other toxic components from the wastestreams.

(continued)

TABLE 3. WORKING LIST OF MISSING/UNACCOUNTED FOR AREA SOURCE CATEGORIES (continued)

WASTE TREATMENT AND DISPOSAL (continued)	
Waste Oil Disposal	Proper and improper disposal of waste oil, specifically motor oils, generates evaporative VOC emissions.

[1]*User's Guide to MOBILE4 (Mobile Source Emission Factor Model).* EPA-AA-TEB-89-1 (NTIS PB89-164271), U.S. Environmental Protection Agency. Office of Air and Radiation. Office of Mobile Sources. February 1989.

SECTION 3

CHARACTERIZATION OF MISSING/UNACCOUNTED FOR SOURCE CATEGORIES

DEVELOPMENT OF TEMPLATE

To facilitate the characterization process and to ensure consistency, a template (protocol) was developed to be used for each category characterization. The template defined the types of information to be collected for the source and provided a common format.

LIST OF SOURCES CHARACTERIZED

Source categories characterized in these work assignment were taken from the list in Table 2. Seventy (70) categories have been characterized and include the following:

- Adhesives and Sealants - Commercial
- Adhesives and Sealants - Consumer
- Aircraft Deicing
- Aircraft Refueling
- Airport Support Vehicles
- Automotive Cleaners/Waxes/Polishes
- Automotive Fluids and Fluid Leaks
- Automotive Rustproofing/Undercoating
- Backyard Charcoal Grills
- Bakeries
- Barge, Tank, Tank Truck, Rail Car and Drum Cleaning
- Breweries
- Catastrophic/Accidental Releases - Rail Car, Tank Truck and Industrial Accidents
- Cigarette Smoke
- Commercial Charbroiling
- Commercial Deep Fat Frying at Restaurants
- Compressed Natural Gas Vehicles
- Cooling Towers
- Diesel Fuel - Evaporative Emissions from Service Station Operations
- Distilleries
- Drinking Water Treatment with Ozone
- Extra High Voltage (EHV) Transmission Lines
- Farming Operations
- Fireplaces
- Grain Grinding and Feed Preparation
- Household Cleaners and Polishes
- Inflight Aircraft
- Innovative Waste Treatment Technologies
- Kerosene Space Heaters
- Laminating

- Landfill Activities - TSP
- Landfill Methane
- Laundry Products - Commercial and Consumer
- Lawn Care Products
- Mobile Sources Evaporative and Running Losses
- Motor Vehicle Racing
- Natural Gas Well Blowouts
- Oil and Gas Production - Field Activity
- Oil and Gas Production - Well Drilling
- Oil Spills
- Package Plants (Wastewater Treatment)
- Personal Products
- Pesticide Application
- Petroleum Vessel Loading and Unloading Losses
- Photocopiers and Laser Printers
- Pulp Bleaching with Ozone
- Recycling Processes
- Refinery Sludge Dewatering
- Refrigerants - Leaking Coolant
- Refrigerated Trucks
- Refrigeration/Air Conditioning Equipment
- Research and Testing Laboratories
- Residential Deep Fat Frying
- Road Construction
- Road Salting and Sanding
- Rocket Launches and Test Firings
- Sandblasting
- Silage Storage
- Small Electric Utility Boilers
- Street Sweeping and Cleaning
- Synthetic Organic Chemical Storage Tanks
- Traffic Painting
- Ultraviolet (UV) and Electron Beam (EB) Curable Coating
- Vehicle Lubricating
- Vehicle Repair
- Waste Incineration: Developing Technologies for Hazardous Waste
- Waste Oil Disposal
- Welding
- Wineries
- Wood Stoves

CHARACTERIZATION ACTIVITIES

Each of the 70 area source categories was characterized using the template. Information for the characterizations was derived from a number of sources, many of which had been identified during the search phase of this project. The principal sources of information were available literature, industry and trade association publications and contacts, and knowledgeable federal and state personnel.

Available literature was identified based on the original literature search and also included reference materials related to the specific process(es). These documents included EPA and other government reports, journal and conference reports and trade association reports and bulletins. *AP-42* (*Compilation of Air Pollutant Emission Factors*, Fourth Edition and Supplements, September 1985 through September 1991) was consulted for emission factor data.

Where applicable, trade associations were contacted for information. In some cases, association contacts were able to offer unpublished or otherwise unavailable test reports and clarify process descriptions. If the information could be obtained quickly, published materials were requested.

Federal and state personnel were identified through the category identification phase, guidance from the EPA project team or through a particular knowledge gained from experience in Federal Implementation Plan (FIP), SIP or NAPAP programs. Agencies contacted included OAQPS, Environment Canada, state agencies including CARB and regional agencies such as the South Coast (California) Air Quality Management District (SCAQMD). These contacts provided process descriptions, emission factors and activity data, emissions estimates and comments on a number of source categories.

RESPONSIVENESS TO REVIEWER COMMENTS

During the development of the template and the characterization of source categories, completed draft characterizations were distributed through the Work Assignment Manager to the EPA project team for review. Comments were received regarding both the template format and the content of specific characterizations.

Substantive comments on several draft source characterizations were received from Sue Kimbrough (EPA/AEERL) and Jerry Gipson (EPA/AREAL). The comments principally concerned category description, process breakdown and methodology. In most cases, addressing these comments required further research and/or presentation of more detail. In a few instances, information needed to fully address comments was not available. All comments have been retained in the project file for future reference.

DISCUSSION OF RESULTS

Characterization of the seventy source categories revealed a broad range of source types and availability of information sources. Research indicates that the sources may lack applicable emission factors and/or current activity data for the development of emissions estimation strategies. In some cases (e.g., backyard charcoal grilling), state agencies such as CARB have begun to study these sources for inclusion in state or local inventories and can provide their research. Trade associations may maintain industry statistics, research and testing divisions useful to source description, emission factor development

and activity data identification. However, most of the source categories lack a current emissions estimation methodology adequate for NEDS or SIP applications.

The information presented in these characterizations is intended to provide an initial overview of the process and its emissions, an indication and/or summary of the data available from standard reference materials and primary contacts, alternate methodology development strategies and a basis for ranking these source categories for methodology development. Once the source categories are ranked, research directed at methodology development will be able to focus on each source category individually and provide a more exhaustive search of available resources, where warranted.

Additional work on missing and unaccounted for source categories may involve data gathering and analysis, measurements and other research activities.

EPA welcomes reader comments on this document and on previously uninventoried categories in general. This may include identification of additional source categories and input and data on information, emission factors and methodologies for all categories. Please address all comments to Sue Kimbrough, U.S. Environmental Protection Agency, Air and Energy Engineering Research Laboratory, MD-62, Research Triangle Park, NC, 27711.

APPENDIX

MISSING/UNACCOUNTED FOR SOURCE CATEGORY CHARACTERIZATIONS

This Appendix contains the 70 source category characterizations developed under Work Assignments 0/107, 0/113 and 1/101 under EPA Contract No. 68-D9-0173. The source category characterizations are presented in the order in which the categories appear in Table 3. All characterizations contain the following information:

- definition/description of the category and activity
- process breakdown (if applicable)
- reason for considering the category
- pollutants emitted
- estimate of the pollutant levels
- point/area source cutoff
- level of detail of information available
- level of detail required by users
- emission factor requirements
- regional, seasonal or temporal characteristics
- urban or rural characteristics
- methodology
- references

The reference section includes characterization references and bibliographic sources.

BAKERIES

Definition/description of category and activity

Bakeries emit VOC, primarily ethanol formed by yeast fermentation of bread or dough (straight or sponge*), during the baking process. Small baking operations, such as retail in-store and neighborhood bakeries fall outside traditional NEDS and SIP methodologies. Ethanol is emitted during the baking process through a vent with any combustion product gases.

Process breakdown

Standard Industrial Classification (SIC)	Source Classification Code (SCC)	Description
2051, 2052	3-02-032-01	Bread Baking: Sponge-Dough Process
	3-02-032-02	Bread Baking: Straight-Dough Process
	3-02-032-99	Other Bakery Emissions (Not Classified)

Reason for considering the category

Since only commercial bakeries fall within the NEDS and SIP point source methodologies, there has been concern that a substantial component of overall emissions from in-store and neighborhood baking operations may be missing.

Pollutants emitted

VOC (Ethanol)

Estimate of the pollutant levels

1985 NAPAP Inventory: 50,000 TPY non-point source bakeries (U.S. total)

SCAQMD: 2,000 TPY non-point source bakeries

Point/area source cutoff

Large commercial baking operations may have emissions exceeding 100 TPY and should be considered point sources. In-store and neighborhood baking operations are usually emit for less than 100 TPY. Data from Chicago area commercial bakeries indicate that these bakeries emit 30 to 150 TPY ethanol; smaller operations are expected to have fewer emissions, although more data are necessary to provide a per bakery estimate.

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*Straight-dough refers to a process by which ingredients are mixed, allowed to ferment and then baked. Sponge-dough requires mixing and fermentation of some ingredients, with the remainder of the ingredients added just prior to baking.

Level of detail of information available

AP-42 emissions factors for sponge- and straight-dough processes:
0.5 lbs ethanol per 1,000 lbs bread produced (straight)
5 to 8 lbs ethanol per 1,000 lbs bread produced (sponge)

National sales data for retail, wholesale, food service and in-store bakeries

Emission factors from the American Institute of Baking (AIB)
lbs ethanol/1,000 lbs bread = 0.0402 + 0.0446[(% yeast)X(total proofing/fermentation time)]

SCAQMD has the only identified inventory including these small bakeries. Its methodology uses the CARB emission factor (based on *AP-42*) and an estimate of bread production. South Coast has been contacted for further information.

Level of detail required by users

Emissions by county

Bread production by county or state (sponge- and straight-dough) or average yeast content and fermentation times

Emission factor requirements

Ethanol emissions per unit of bread baked for both sponge- and straight-dough

Regional, seasonal or temporal characteristics

Uniform schedule

Urban or rural characteristics

Urban and suburban areas

Methodology

The current *AP-42* emission factor is based on only a few tests. A technical bulletin from the AIB described using experimental results to derive a relation between ethanol emissions and process parameters. AIB's research identified the two key variables as initial yeast content and total proofing/fermentation time. These two variables are likely to be difficult to estimate, although a survey to determine a national or regional average for these variables could be undertaken. AIB data should be reviewed to determine if one or more emission factors may be derived from its work to supersede the *AP-42* factors. Use of *AP-42* or AIB factors requires an estimate of bread production; these data are probably difficult to obtain. It may be possible to obtain sales data which could be used to estimate production. Given the uncertain estimation methodology and the estimated magnitude of the source, the effort needed to develop a workable methodology may be large in comparison to the relatively small emissions.

The AIB, the Retail Bakers of America and the Bakery Production and Marketing Magazine were contacted for further production and sales information. The magazine's June 1990 issue was devoted to retail trends and contained national sales in four categories: retail, wholesale, food service and in-store baked goods sales. CARB and South Coast personnel were contacted for any additional information they may have on methods or existing data sources.

References

1. *Compilation of Air Pollutant Emission Factors*, Fourth Edition and Supplements, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1985 through September 1991.

2. *Methods for Assessing Area Source Emissions in California*, California Air Resources Board, Sacramento, CA, December 1984.

3. Stitley, J.W., et al., *Bakery Oven Ethanol Emissions Experimental and Plant Survey Results*, American Institute of Baking Technical Bulletin 9(12): 1-11, 1987.

4. *Illinois Ozone State Implementation Plan, 1988 Ozone Emissions Inventory for the Chicago Area*, IEPA/APC/90-045, Springfield, IL, December 1989.

5. Telecon. Zimmerman, David, Alliance Technologies Corporation, with Retail Bakers of America, June 1990.

6. Telecon. Zimmerman, David, Alliance Technologies Corporation, with J. Vetter, American Institute of Baking, June 1990.

7. Telecon, Zimmerman, David, Alliance Technologies Corporation, with S. Lutzlw, Bakery Production and Marketing Magazine, July 1990.

BREWERIES

Definition/description of category and activity

VOC emissions from breweries vary depending on brewery size, process and location. Breweries can be classified as large (60,000 barrels per year or more), small (1,000 to 60,000 barrels per year), micro (less than 1,000 barrels per year) and home breweries. The brewing processes used in a small and a large brewing operation in California are shown in Figures 1 and 2, respectively. The emissions points in a small brewery are the fermenters (usually the largest source of vented VOC emissions), brew kettle, hot wort tank, mash tun, lauter tun and the spent grain tank). The fermenter contributes about 93.5 percent of the total VOC emitted from the brewery and the brew kettle accounts for another 4.6 percent of the total VOC emitted. Approximate contributions, by step, to the total daily VOC emissions from a large brewery are as follows: brew kettle, 45.9 percent; strainmaster, 17.8 percent; beechwood chip washer, 10.8 percent; waste beer sump, 8.8 percent; activated carbon regeneration, 8.7 percent; mash cooker, 7.8 percent; and rice cooker, 0.2 percent.[1,2]

Process breakdown

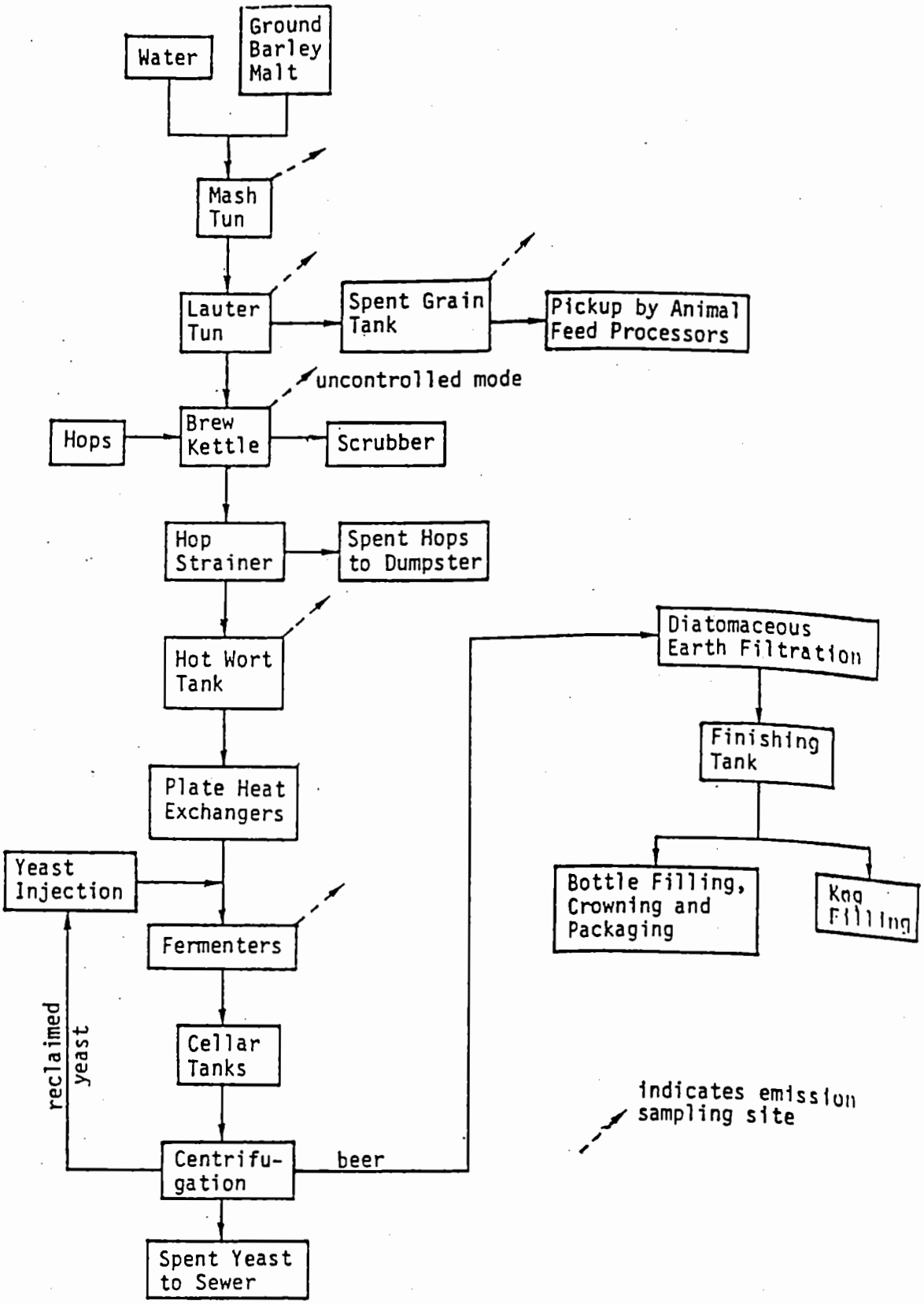
Brewery process steps vary according to brewery size.

Small Breweries

The steps in the brewing process at a small brewery are shown in Figure 1. The malt (barley and water) is mixed in the mash tun where starch is converted to fermentable sugars. Emissions from this process occur mainly by convection through a stack. After mashing is complete, the extract (wort) is separated from insoluble grain residues in the lauter tun. Emissions from this process are vented to a stack in the same way as the mash tun emissions. The spent grains are transferred to a holding tank where fugitive VOC are emitted. The extract is then boiled in the brew kettle and the hops are added to the extract to impart the bitter flavor to the beer. Other undesirable natural hydrocarbons formed in this process are typically boiled off from the kettle and are emitted by convection through a stack. The hops are then filtered out from the hot wort which is then cooled in a holding tank. Fugitive VOC from this step are vented off. The cooled wort is aerated and transferred to the fermenters. The fermentation process varies by brewery. Fermentation may be carried out in open tanks or in closed tanks (which trap the evolving carbon dioxide). The fermentation room is usually the largest source of vented VOC emissions from a small brewery.[1,2]

Large Breweries

The process steps in a large brewery are shown in Figure 2. Large breweries often employ the double mash method, in which the rice and barley malts are cooked separately and then combined. The emissions from these two processes are mechanically vented through separate stacks or a single stack. The wort from these two processes is separated in the strainmaster, which is similar to the lauter tun in a small brewery. The spent grain is hauled away from a holding tank which vents passive emissions which are subsequently vented to the atmosphere. The strainmaster itself also mechanically vents emissions through a stack to the atmosphere. The wort is then transferred via a holding tank to the brew kettle, which is typically the largest VOC emissions source in a large brewery. These emissions are vented mechanically through a stack. After boiling, the wort is cooled and aerated by gravity flow of the wort descending through a countercurrent stream of sterile air. Evaporative gases are exhausted to the atmosphere through a stack. In a large brewery, the wort is fermented in a closed room, which prohibits



Source: Reference 2 Reprinted with permission. California Air Resources Board, 1983.

Figure 1. Brewing process flow diagram - Anchor Brewing Company.

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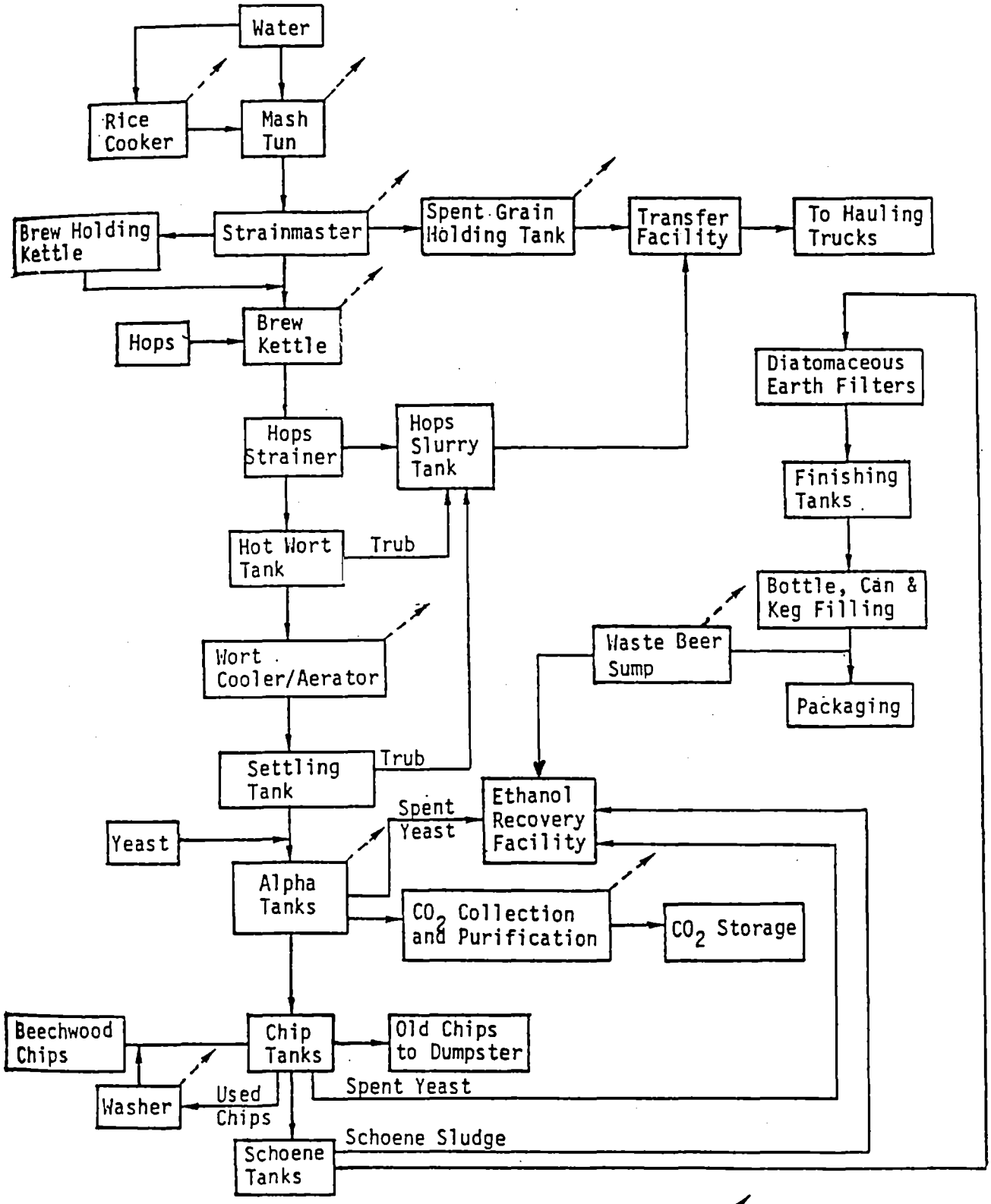

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Source: Reference 2

Figure 2. Brewing process flow diagram - Facility A.

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the escape of fermentation gases. The carbon dioxide (CO_2) and VOC generated from fermentation are passed through a CO_2 purification system and subsequently an activated carbon bed where the volatile organics are driven to the atmosphere. After fermentation, the brew is pumped to aging tanks where beechwood chips are used to enhance secondary fermentation. When aging is completed, the beechwood chips are collected in a tank and washed. This washer is another significant source of emissions in a large brewery and these emissions are often vented to the atmosphere through roof openings.[1,2]

Reason for considering the category

VOC emissions from breweries have traditionally been considered negligible and have focused primarily on the ethanol emissions from the fermentation process (*AP-42*, Section 6.5). Other process-specific emissions from both large and small brewing operations are not well-documented. These emissions are suspected of contributing to the atmospheric burden of VOC in ozone non-attainment areas, since these breweries are typically located in urban areas. In addition to commercial breweries, micro breweries located in urban areas accounted for 0.25 million barrels of beer production in 1989. There were an estimated 1.5 million home brewers in the United States in 1989, brewing about 75 gallons of beer per person annually.[3]

Pollutants emitted

VOC (including ethanol, ethyl acetate, myrcene and some other higher alcohols) from the various brewing process steps; dimethyl sulfide emissions from the brew kettle, the strainmaster and the mash cooker; additional VOC from spent grain drying after fermentation

Estimate of the pollutant levels

CARB estimated that for a small brewery with annual beer production of 29,500 barrels, the total VOC emissions were 2.8 TPY. For a large brewery with annual beer production of more than 60,000 barrels, the total VOC emissions were 7.8 TPY. Annual VOC emissions from breweries in the State of California have been estimated to be 42.6 tons for 1982.[2]

Point/area source cutoff

A review of the Aerometric Information Retrieval System (AIRS) SCC listing showed SCCs for grain handling, drying spent grain, brewing, aging and for the malt dryer.[4] The 1985 NAPAP inventory shows a total of 19 breweries in the point source inventory emitting a total of 1,055.54 TPY of VOC and 1,126 TPY of TSP.[5] CARB classifies large breweries as those exceeding a production capacity of 60,000 barrels per year. With the emission factors given in the next section, it is likely that some breweries, though considerably large emitters of VOC, may not be in the point source inventory because of the 100 TPY NEDS cutoff. These breweries should be included in the area source inventory.

Level of detail of information available

Some emission factors have been provided by EPA for breweries (see Section 6.5 of *AP-42*). However, these emission factors are limited to particulate matter emitted from grain handling and drying spent grain, as well as some VOC emissions from drying spent grain. These emission factors are given below.

Process	Emissions
Grain Handling	3 lbs particulate/ton
Spent Grain Drying	5 lbs particulate/ton
Spent Grain Drying	2.63 lbs VOC/ton

CARB has provided the following emission factors:

Small Breweries

Process	Emissions (lbs VOC/1,000 bbls)
Mash Tun	0.403
Lauter Tun	0.194
Brew Kettle	3.771
Hot Wort Tank	0.797
Fermentation Room Exhaust	51.578
Spent Grain Holding Tank	0.060

Large Breweries

Process	Emissions (lbs VOC/1,000 bbls)
Mash Cooker	0.275
Rice Cooker	0.005
Strainmaster/Lauter Tun	0.631
Brew Kettle	1.634
Activated Carbon Regeneration	0.660
Beechwood Chip Washer	0.963

Emission factors for home brewing and micro breweries are unavailable.

The Beer Institute in Washington, DC and the Federal Bureau of Alcohol, Tobacco and Firearms have statistics on annual beer production and consumption by region and state.[6]

The Institute of Fermentation and Brewing Studies in Boulder, CO has statistics on beer production from micro breweries and home brewers.[3]

Level of detail required by users

Emissions by county

Emissions from home brewing and micro brewery operations

Number of breweries

Amount of beer produced per brewery or average amount for each major type of brewery (i.e., large, small, micro)

Emission factor requirements

Although emission factors are available for the various process steps at large and small brewing operations, emission factors need to be developed for micro and home brewing operations.

Regional, seasonal or temporal characteristics

Large breweries typically operate 24 hours per day year round. Smaller breweries usually operate on an eight-hour per day schedule, for about three or four days per week.

Urban or rural characteristics

Principally an urban source

Methodology

The current methodology for estimating emissions from breweries is limited by the availability of emission factors in *AP-42*, since emission factors are available for only two processes, grain handling and spent grain drying. The emission factors developed by CARB are more indicative of the emissions from a brewery. State and county emissions can be estimated using these emission factors and the beer production estimates for the United States from the Beer Institute and the Bureau of Alcohol, Tobacco and Firearms. State beer production can be assigned to the county based on SIC employment from *County Business Patterns*.[7]

References

1. *Compilation of Air Pollutant Emission Factors*, Fourth Edition and Supplements, AP-42, U.S.Environmental Protection Agency, Research Triangle Park, NC, September 1985 through September 1991.

2. *Characterization of Fermentation Emissions from California Breweries*, California Air Resources Board, Sacramento, CA, October, 1983.

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5. Saeger, M. *et al.*, *The 1985 NAPAP Emissions Inventory,(Version 2): Development of the Annual Data and Modelers' Tapes*, EPA-600/7-89-012a (NTIS PB91-119669), U.S. Environmental Protection Agency, Research Triangle Park, NC, November 1989.

6. Telecon. Chadha, Ajay, Alliance Technologies Corporation, with Philip C. Katz, Beer Institute, Washington, DC. How to locate beer production statistics. June 19, 1990.

7. *County Business Patterns*, U.S. Department of Commerce, Bureau of the Census, Washington, DC. Annual Publication.

DISTILLERIES

Definition/description of category and activity

Ethanol emissions are the largest component of the VOC emitted from distilleries. Distilleries produce both grain alcohol for industrial and fuel purposes and distilled spirits, such as whiskey and brandy, for consumption purposes. Distilled spirits are the yields of the distillation of various fermented products. Figure 1 shows the flow chart for gin and whiskey production. Brandy is distilled from wine or from the wine pulp left behind after racking or straining. The starting processes for whiskey and brandy are analogous to beer and wine production, respectively. In addition to these initial processes, distilled spirits manufacturing involves both distilling and aging steps.[1,2]

Process breakdown

The emissions points in the distilled spirits manufacturing process are likely to be the same as in breweries and wineries, with the aging process as an additional source of emissions. Aging of distilled spirits involves storing the whiskey in white oak barrels at a certain temperature and humidity. Evaporation of the contents during the aging process occurs through the ends of the barrel.[2]

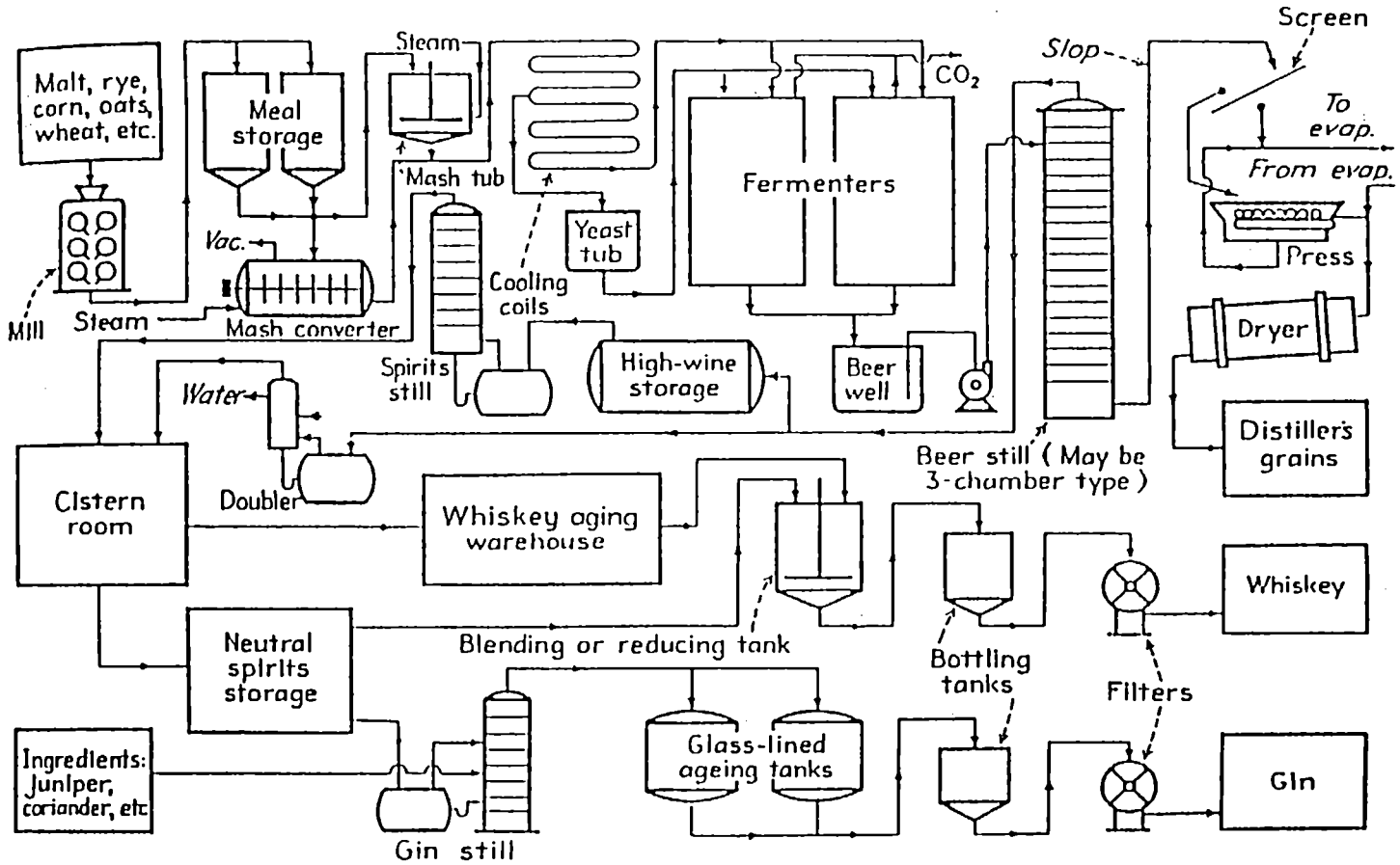
Reason for considering the category

Emissions from distilleries are poorly characterized, both for distilled spirits and grain alcohol production. Some attempt has been made to calculate VOC emissions from the aging process during whiskey production (see *AP-42*, Section 6.5); however, these emission factors are based on certain engineering judgments and have not been verified. Alcohol production (distilled and grain alcohol) in the United States is fairly significant, as shown in Table 1.[3]

TABLE 1. ALCOHOL PRODUCED IN THE UNITED STATES IN 1989[a]

Alcohol Type	Gallons
U.S. Production of Distilled Spirits	
Whiskey	38,946,409
Rum	776,957
Brandy	7,565,823
Gin	6,226,242
Vodka	2,929,684
U.S. Production of Grain Alcohol (potable and non-potable)	480,082,492
Total U.S. Production of Alcohol	536,527,607

[a]In addition to the licensed production of distilled spirits, there is a fairly significant production of untaxed alcohol or "moonshine," which can be referred to as home distilling. No estimate can be made of the amount of alcohol produced by this method, but it could be assumed that this is probably of a regional nature and predominates in the poorer regions of the country.



Source: Reference 2

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Figure 1. Flow chart for the production of distilled liquors.

Pollutants emitted

Mostly ethanol from the fermentation and aging processes

Estimate of the pollutant levels

The only emission factor available for whiskey fermentation and production is given in *AP-42*. It is estimated that ten pounds of VOC are emitted per barrel (50 gallons) of whiskey aged over one year. Fermentation tanks for whiskey and brandy production yield about three pounds of VOC per 1,000 gallons of alcohol produced.[4]

Point/area source cutoff

If a distillery emits more than ten TPY VOC, it would be considered a point source. Using available emission factors, a distillery which stored over 670,000 gallons of whiskey per year would emit approximately 100 TPY. There are 29 distilleries listed in the 1985 NAPAP point source inventory emitting a total of 23,807 TPY of VOC, averaging about 820 TPY of VOC per facility.[5]

Level of detail of information available

Since it is a heavily regulated and taxed industry, state level revenues collected for production are available from the Bureau of Alcohol, Tobacco and Firearms.

Total U.S. production of alcohol on annual basis is available from the Distilled Spirits Council of the United States.[6]

Level of detail required by users

Amount distilled per county or state

Number of barrels distilled per facility or average barrels per facility

Number of distilleries per county

Emission factor requirements

Development of emission factors by process type for the various production stages, based on observed emissions rather than just engineering judgment

An estimate of home distilling emission factors

Regional, seasonal or temporal characteristics

Home distilling operations may exhibit regional differences.

Urban or rural characteristics

Probably an urban and semi-rural source

Methodology

The current methodology for calculating VOC emissions from a distillery uses the *AP-42* emission factor for the whiskey aging process. Whiskey and gin are distilled from a brew, thus it would be necessary to include emission factors for breweries to estimate the total VOC emissions from a distillery. The statistics on the total amount of spirits distilled in the various states on a monthly basis are available from the Bureau of Alcohol, Tobacco and Firearms. These production figures can be assigned to various counties using SIC employment in *County Business Patterns*.[7] Multiplying these production figures by the emission factors will give the total amount of VOC emitted for a particular county.

References

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SILAGE STORAGE

Definition/description of category and activity

The principal gases produced in silos during the silage-making process are CO_2 and NO_x, including nitrous oxide (N_2O), nitric oxide (NO) and nitrogen dioxide (NO_2). These silo gases are formed within the porous silage mass and ultimately diffuse into the silo headspace as the new silage settles. These gases are typically heavier than air and so displace the air in the silo headspace as they are vented through the top of the silos. CO_2 is the end-product from oxidation of the plant material by bacteria as part of the ensiling process. NO_x is formed through three processes: (1) in a plant when it is exposed to some adverse weather condition, such as a drought followed by periods of rainfall; (2) through addition of fertilizer; and (3) through addition of material to the silage. The amount of silo gases formed varies with the type of silage material (e.g., alfalfa, soybean, corn, etc.). The methods of silage making also vary by region. In some parts of the country, silage is made by digging a hole in the ground, lining and filling the pit, and then covering the silage material with a plastic sheet. In other regions, silage is stored in the solid structure silos.[1,2,3,4]

Process breakdown

Not applicable

Reason for considering the category

There are no recent estimates of the amount of crops that is ensiled in the United States. However, the U.S. *Census of Agriculture* provides state and county estimates of the quantity and acres of crops harvested for silage.[5] The size of the dairy industry in the United States, which is the ultimate consumer of the silage, indicates that silage production itself is not insignificant. By all indications, the ensiling process results in CO_2 and NO_x emissions. The NO_x emissions are important precursors in the formation of photochemical smog, and thus any inventory which accounts for silage storage emissions would reflect the NO_x emissions in the area more accurately.

Pollutants emitted

Pollutants emitted from silage storage include CO_2, NO, NO_2 and some N_2O.

Estimate of the pollutant levels

No estimate of pollutant level is currently available.

Point/area source cutoff

Silage storage is not considered a point source.

Level of detail of information available

Emissions from silage storage vary with crop, the type of additive used in the ensiling process and the type of structure used to house the silage. Some early measurements made by Peterson *et al.* for the emissions from various crops used in silage (without any additives) are given below.[2]

2,537 ml of CO_2/kg of alfalfa
16.7 ml of NO_2/kg of alfalfa

1,950 ml of CO_2/kg of soybean
0.14 ml of NO_2/kg of soybean

710 ml of CO_2/kg of corn
0.67 ml of NO_2/kg of corn

Reference 5 contains the following information on the amount of crops harvested for silage in the United States in 1982:

Crop Harvested for Silage	Amount
Alfalfa hay	71,676,848 dry tons
Small grain hay	4,675,040 dry tons
Tame hay	34,817,835 dry tons
Wild hay	8,326,005 dry tons
Corn silage or green chop	110,733,566 dry tons
Sorghum for dry forage	265,548 dry tons
Sorghum for silage	7,827,178 dry tons

The national totals given above have been further resolved into county level harvests.

Level of detail required by users

Emissions by county

Crops harvested for silage by crop type per county

Emission factor requirements

Amount of pollutant emitted per unit crop type

Regional, seasonal or temporal characteristics

Silage storage principally occurs during winter months.

Urban or rural characteristics

Principally a rural source

Methodology

County-wide estimates of each crop type harvested for silage are readily available from the *Census of Agriculture*. Multiplying these estimates by the appropriate emission factors will provide county-wide emissions estimates of various gases produced from the silage storage. However, emission factors should be developed for all crop types.

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WINERIES

Definition/description of category and activity

Ethanol emissions from wineries result from entrainment of ethanol by carbon dioxide during the fermentation process. Although this is the primary source of ethanol emissions in the wine production process, other emissions occur whenever wine is exposed to air, such as in transferring or racking, blending and storage for aging purposes. Factors affecting ethanol emissions include fermenting parameters, process equipment design, handling techniques and temperatures.[1,2]

Process breakdown

The first step of wine production entails crushing the harvested grapes and extracting the juice. In making white wine, the skins and other remaining solids are first filtered out. Next, yeast is added to the mixture which is then fermented in large, usually stainless steel, tanks. Red wine is fermented with the juice containing the skins and the solids to add color to the wine. White wines are usually fermented at a temperature of about 55°F; the holding tank may have to be cooled to keep the temperature constant. Fermentation results in liberation of CO_2 from the mixture, which entrains a certain amount of ethanol to the atmosphere. Entrainment of ethanol increases with increase in fermentation temperature. Hence, red wine, which is typically fermented at about 80°F, would result in higher emissions than white wine. The ethanol emitted from fermentation is usually vented to the atmosphere through openings in the roof. After fermentation, the mixture is filtered through a drag screen or is centrifuged (pomace press) to extract the remaining solids, before the wine is transferred for aging. Fugitive ethanol emissions from these two processes and from bottling are greater than ethanol losses during aging. During aging, the contact between the wine and air is minimized to avoid oxidation of ethanol to acetic acid.[1,2]

Reason for considering the category

Currently the wine industry does not control the ethanol emitted during the fermentation process. In addition to the fermentation process emissions, fugitive emissions of ethanol also occur during storage and handling processes. Ethanol is a precursor in ozone formation.

Pollutants emitted

Mostly ethanol (VOC) from the fermentation process and from storage and handling of the wine

Estimate of the pollutant levels

The Wine Institute provided the following 1989 bulk wine production statistics (including white, red and dessert wines) from the four states (California, New York, Washington and South Carolina), which together account for almost 99 percent of the total wine production in the United States:[3]

California	371,000,000 gallons
New York	23,700,000 gallons
Washington	6,800,000 gallons
South Carolina	3,400,000 gallons

Since these figures do not reflect the production of different types of wines, any emissions estimates using the emission factors given below in the **Level of detail of information available** section, which are specific to white and red wine production, cannot be used. Thus, no reliable estimate exists of the VOC emissions from wineries.

Point/area source cutoff

A review of the AIRS SCC listing for winery operations showed SCCs for the aging and fermentation of wine at 52°F and 80°F.[4] However, most winery sources are not large enough to be included in the point source inventory. A review of the point source listing in the 1985 NAPAP inventory does not show inclusion of any wineries.[5] Estimated emissions from wineries indicate that wineries would most likely be classified as area sources.

Level of detail of information available

Traditionally, the following *AP-42* emission factors have been used to estimate emissions from wineries.

Fermentation Process	Emissions (lbs EtOH/1,000 gallons fermented)
White wine @ 52°F	1.06
Red wine @ 80°F	4.79

At other conditions, *AP-42* emission factors for wine can be calculated using the following equation:

$$EF = [0.136T - 5.91] + [(B-20.4)(T - 15.21)(0.00685)] + [C]$$

where: EF = emission factor, (lbs EtOH/1,000 gallons)
T = fermentation temperature, (°F)
B = initial sugar content, (°Brix)
C = correction factor; zero for white wine, 2.4 for red wine (lbs/1,000 gallons)

CARB has provided the following emission factors:

Fermentation Process	Emissions (lbs EtOH/1,000 gallons grape juice)
White wine @ 56°F	2.6
White wine @ 60°F	1.4
Red wine @ 83°F	7.8
Red wine @ 72°F	10.5

Fugitive Sources	Emissions
Drag Screen	0.5 lbs EtOH/1,000 gallon grape juice
Pomace Press	0.02 lbs EtOH/ton of pomace
Wine Bottling	0.1 lbs EtOH/1,000 gallon wine

The Wine Institute in San Francisco, CA has total U.S. wine production estimates by state.

The Federal Bureau of Alcohol, Tobacco and Firearms has annual wine production statistics by state.[6]

Level of detail required by users

Emissions by county

Estimates of red and white wine production by county or state

Emission factor requirements

Emission factors are available for the various process steps in winery operations. However, since emissions from winery operations are primarily concentrated in four states, detailed information could be obtained about locations of these wineries and their production of the various wines.

Regional, seasonal or temporal characteristics

Ethanol emissions are usually greatest during the fermentation period, which generally occurs between late August and early October.

Urban or rural characteristics

Principally a rural source

Methodology

The emission factors for wine production are currently available from *AP-42* and CARB. These emission factors may need further verification to ensure that they reflect the average wine making conditions. State-level wine production estimates can be obtained from the Bureau of Alcohol, Tobacco and Firearms. However, these figures do not distinguish between types of wines (red and white). Thus, some strategy will have to be adopted to apportion wine production figures to the two different types of wine. State estimates of wine production can be apportioned to various counties based on the SIC employment in *County Business Patterns*. These county estimates can be multiplied by the emission factors to estimate county-level emissions from wineries.

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CATASTROPHIC/ACCIDENTAL RELEASES - RAIL CAR, TANK TRUCK, AND INDUSTRIAL ACCIDENTS

Definition/description of category and activity

Catastrophic releases from rail car, tank truck and industrial accidents are usually chemical spills, with or without combustion. The emissions depend on the material released, remediation efforts and weather conditions.

Process breakdown

Air pollutants from catastrophic and accidental releases may enter the atmosphere through evaporation or combustion of solid or liquid materials, or release of gaseous materials.

Reason for considering the category

Catastrophic releases often involve large quantities of releases, often over a very short period of time, potentially representing a significant portion of an area's total emissions. These emissions are not represented in the current area source emissions inventory methodology.

Pollutants emitted

The nature of catastrophic releases makes precise description of the released materials difficult. VOC species emitted are dependent on the material released. VOC, NO_x and CO emissions are possible if combustion takes place. Air toxics may also be emitted.

Estimate of the pollutant levels

The levels of pollutants vary widely from year to year. Due to the nature of the activity, it is very difficult to estimate annual emissions.

Point/area source cutoff

Unless the release occurs at a source otherwise counted as a point source, catastrophic releases are not included in the point source inventories.

Level of detail of information available

Releases of hazardous chemicals are required by law to be reported to the National Response Center (NRC). The NRC compiles data on reported releases; access to these data is guaranteed by the Freedom of Information Act. The compliance rate for this legislation is expected to be fairly high, especially for large spills. Rule effectiveness is expected to be between 0.85 and 0.95. Data reported for each accident include, but are not restricted to, the following:[1]

- date of release
- material released
- media affected (water, air, etc.)
- mode (train, ship, truck, etc.)
- location

Agencies requesting information from the NRC should send a written request to the following address:

National Response Center
U.S. Coast Guard Headquarters
Room 2611
2100 2nd Street S.W.
Washington, DC 20593

The NRC operates a toll-free accident reporting service ((800)424-8802).

State environmental or hazardous material management agencies may have additional information.

Level of detail required by users

Area-specific release data (amount, type, remediation efforts, date of release)

Emission factor requirements

The releases reported to the NRC should be examined individually to determine the volatility of the material, effect of remediation and climate.

Regional, seasonal or temporal characteristics

No regional, seasonal or temporal effects on release are expected. Seasonal climate variations will effect volatilized emissions.

Urban or rural characteristics

No urban or rural preference is expected.

Methodology

- request reports on chemical releases in the study area from the NRC
- estimate potential air pollutant emissions from the chemical release report
- contact local officials to determine effectiveness of remediation for the releases and rule effectiveness for reporting requirement
- adjust potential emissions to reflect remediation effort
- adjust potential emissions to reflect rule effectiveness

References

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NATURAL GAS WELL BLOWOUTS

Definition/description of category and activity

Natural gas well blowouts are unexpected and uncontrolled releases of gas from exploratory and production wells. Gas wells release primarily methane to the atmosphere. Blowouts have been defined technically as "events where encountered formation pressure exceeds the mud column pressure allowing the formation fluid to flow uncontrolled out of the hole, into the sea or air."[1] The amount of gas released and the time required to contain the release depend on the nature of the particular field (e.g., formation pressure), the design of the drilling and well rig, and local environmental conditions. OCS blowouts are of particular concern to the industry due to the special equipment and stresses of OCS drilling and the complexity of containing releases.

Process breakdown

Blowouts may occur at wells on the OCS or inland during exploration, development, production or work-over (maintenance and remedial work) phases. Drilling and non-drilling blowouts are generally differentiated in the industry.[1]

Reason for considering the category

Potential sources of methane emissions to the global environment are currently under study. Processing and transporting natural gas contributes a significant quantity of methane emissions from fugitive releases. Releases at the well due to extraordinary circumstances such as blowouts have not been studied.

Pollutants emitted

Primarily methane and small amounts of H_2S, ethane and propane

Estimate of the pollutant levels

The total number of producing wells in 1988 was about 270,000.[2,3] Statistics in the 1988 *Natural Gas Annual* indicate that 145,525 MMCF of natural gas were vented or flared in 1988. According to the American Gas Association (AGA) this estimate of 145,525 MMCF includes all losses associated with production, including fugitive and flared gas.[4] The AGA assumes this is an overestimate of these losses, but no other data exist. This quantity translates to three million tons of methane in 1988 (based on 0.0425 pounds methane per cubic foot) and represents an overestimate. Losses due to blowout are included in this figure, but these losses represent an undetermined fraction. The Natural Gas Suppliers Association has also been contacted but was not able to provide a better estimate.

A rough per-well estimate based on estimated volumes from offshore wells in the North Sea indicates that a typical blowout may release 100 tons of methane in the first 20 days after blowout. Eight tons are released on the initial day, diminishing to about four tons on the twentieth day. After 20 days, release rates decay by about 0.002 tons per day.[1] Blowout frequency has been estimated based on the number of wells and the frequency of blowout for each phase (Table 1).[1] However, OCS blowout rates and loss volumes may be much different than onshore wells.

TABLE 1. FREQUENCY OF OCS GAS WELL BLOWOUTS[1]

WELL PHASE	BLOWOUT FREQUENCY
Exploration Drilling	6.3×10^{-3} to 1.4×10^{-2} per well
Developmental Drilling	1.6×10^{-3} to 3.9×10^{-3} per well
Production	4.5×10^{-5} to 2.0×10^{-4} per well-year
Work-over	1.2×10^{-4} to 3.3×10^{-4} per well-year

Point/area source cutoff

Methane emissions are exempted from NEDS and SIP inventories. However, some blowouts are large enough to merit consideration as point sources if methane is inventoried. Smaller blowouts may fall beneath point source criteria, but estimation of emissions through an emission factor rather than well-specific data is not possible at this time.

Level of detail of information available

Wells

Number of producing gas wells by year [2,3]
Number of gas wells drilled each year [3]
Production of gas wells by state [2,3]
Location of gas wells by state [3]
Total vented and flared natural gas by state [3]

Blowouts

Estimated blowout frequency (OCS) [1]
  Historical record of OCS blowouts [1]
Gas well blowouts associated with oil spills [5]
Models and algorithms to calculate gas volume lost during a blowout [1,6]

Level of detail required by users

Number and locations of blowouts in the United States

Number and locations of exploratory drill sites and producing wells

Emissions per blowout or well-specific data to estimate emissions

Emission factor requirements

Blowout frequency per well phase onshore

Emissions per blowout

Percent emissions due to blowout based on total vented and flared natural gas

Regional, seasonal or temporal characteristics

Confined to gas-producing states, primarily the Gulf states and California

Urban or rural characteristics

Rural and offshore

Methodology

Current data are insufficient to estimate natural gas losses from well blowouts in the United States except on a well-by-well basis. However, even well-by-well estimates require significant knowledge of the drill rig and field formation.[6] The AGA, the Interstate Natural Gas Association and the Natural Gas Supply Association have recently developed a research agenda for natural gas emissions. This group has identified exploration, development and production losses as research topics. They are currently embarking on this research.[7] Studies done in Norway have used a study of OCS blowouts in the United States to estimate the frequency of blowouts based on the number of wells in service.[1] Similar studies of onshore well blowouts need to be done.

Several factors need to be considered when analyzing existing gas and oil blowout data and research results. First, changes in drilling environments and technologies affect blowout frequency. Second, with a rising demand for natural gas, harsher environments may be explored and lifetimes of existing rigs may be extended. Conventional production in new regions and unconventional production from sources such as tight sands may effect both the frequency and magnitude of natural gas losses. If estimation of methane losses from natural gas blowouts is important, this research into methane losses could be coordinated with the program underway at the AGA.

To be treated as an area source, an estimate of the total natural gas lost due to blowouts is necessary. If this figure were available or estimable, losses could be apportioned to states (or counties) by gas well population. Further apportionment to the county level could be made based on SIC employment in the natural gas drilling sector.

References

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OIL SPILLS

Definition/description of category and activity

Oil spills involve oil tanker accidents (running aground on sandbars, ice floes or contacting other vessels), tanker truck accidents and spills and blowouts from oil rigs or pipelines in coastal and inland areas. The types of fuels spilled may range from thick unrefined crude oils to highly volatile fuels such as gasoline. Emissions are influenced to a large extent by the type of fuel, the form of cleanup, the effects of dispersion and weathering processes. Evaporation of spills produces local VOC emissions. If spills are contained, emissions may be minimized. If spills catch fire, additional SO_2, CO, CO_2, PM, NO_x and VOC emissions may result.

Process breakdown

Pollutants from oil spills may be emitted to the atmosphere due to evaporation or combustion of liquid fuels. Blowouts from pipelines or platforms may be sprayed directly into the atmosphere and onto the water surface as aerosols.

Reason for considering the category

Oil spills can involve large quantities of fuel released over a relatively short time period, potentially having a significant impact on a local area's total emissions. These emissions are not represented in the current NEDS or SIP area source emissions inventory methodologies.

Pollutants emitted

VOC emissions result from blowouts and evaporation of spilled fuel and fuel from blowouts; SO_2, TSP, VOC, NO_x, CO_2 and CO emissions result from combustion of spilled fuel. Other potentially toxic chemical compounds may be released as a result of chemical cleanup of spills.

Estimate of pollutant levels

It is estimated that the incidence of pipeline blowouts is fairly low; however, the incidence of oil spills due to tank truck and tanker accidents is difficult to predict.[1] The NRC should be able to provide annual national totals. CARB made rough estimates of the air emissions from evaporation versus burning of a major (defined as ten million gallons) oil spill.[2] Evaporation of this spill was estimated to cause 5,500 to 13,000 tons of reactive organic gas (VOC), whereas combustion of the spill was estimated to create 1,800 tons of particulate matter, 800 tons of sulfur oxide, 70 tons of NO_x, 760 tons of total organic gas and 580 tons of reactive organic gas.

Point/area source cutoff

Oil spills are currently not accounted for as point or area sources. Blowouts on offshore oil platforms may be treated as point sources. Oil spills from tanker trucks, tankers, and pipeline leaks or explosions may be counted as point sources if individual spills emit more than ten TPY of a particular pollutant. If only aggregate data are available describing the quantity of oil spilled, the source may have to be treated as an area source and emissions allocated based on surrogate activity data.

Level of detail of information available

Releases of hazardous chemicals (including petroleum products) are required by law to be reported to the NRC. The NRC compiles data on reported releases to the environment; access to these data is guaranteed by the Freedom of Information Act. The compliance rate for this legislation is expected to be fairly high, especially for large spills. Rule effectiveness is expected to be between 0.85 and 0.95. Over 50 percent of the information reported to the NRC concerns spills and releases of fuel oil.[3] The data reported for each accident include, but are not restricted to, the following: date of release, material released, media affected (air, water, etc.), mode (train, ship, truck, etc.) and location. Attempts are being made to include the county location also. Monthly and yearly summary statistics are also tabulated. No estimate of the percentage of spills covered by the NRC is available; however, personnel at the NRC did comment that many more reports are filed in the summer than in the winter.[3]

Agencies requesting information from the NRC should send a written request to the following address:

National Response Center
U.S. Coast Guard Headquarters
Room 2611
2100 2nd Street S.W.
Washington, DC 20593

The NRC also operates a toll-free accident reporting service at (800)424-8802.

State environmental or hazardous materials management agencies may have additional information. For example, the North Carolina Division of Environmental Management (DEM) also collects statistics on spills.[4] The State relies on self-reporting by the spillers and collects information on location, time, amount of spill, reason for spill, fate of material if cleaned up and name and address of responsible party. Since 1987, the State has maintained this information in a computerized database; it is believed that, for the past four years, information is fairly comprehensive. Some emergency responses to spills are coordinated at the county level and individual counties may have more information. There is a nominal charge for hard copies of the state information.

Level of detail required by users

For the purposes of the SIP and NEDS inventories, county-level emissions are needed. Users need to know the location of the spill, the type of fuel spilled and the amount spilled, as well as the choice of cleanup strategy (evaporation, chemical treatment or combustion) and the appropriate emission factors for the type of cleanup used. Offshore platforms may be included in a SIP area if emissions are above the point source cutoff. For California, the CAAA explicitly state that OCS oil drilling operations up to 25 miles offshore are included in the inventory area.

Emission factor requirements

Emission factors are needed to describe the evaporation of volatile fuels from surface waters. Combustion emission factors could probably be derived from existing emission factors for carbonaceous species and possibly NO_x.

Regional, seasonal or temporal characteristics

Activity surrounding the production and transport of petroleum products may occur less often in the winter because the viscosity of the oil changes with temperature (i.e., it may take longer to pump and transport the same quantity of product because the oil may be much thicker in winter than in summer).

Regions having a concentration of refineries and production facilities (e.g., Midwest; Texas, Oklahoma and Louisiana; and Montana, Wyoming and California) are likely have a higher incidence of oil spills.

Urban or rural characteristics

It is assumed that tankers carrying crude oil or other petroleum products would not travel particularly close to the coastline except when approaching the port. Most terminals and transfer points for petroleum products are located in urban areas; to the extent that spills are the result of transfers of fuel, these types of spills would be considered urban. However, most of the transportation of large quantities of petroleum products occurs on nonurban roads or in nonurban areas, where larger spills could occur.

Methodology

Based on the currently available information, oil spills would be treated as individual point sources in inventory because aggregate national statistics are not available. Treating spills as individual point sources eliminates the problems of guessing whether the spill was allowed to evaporate, was cleaned up chemically, with absorbent materials, or was allowed to burn off. Once the quantity and type of fuel spilled are known, appropriate emission factors can be used to estimate emissions. Some emission factors for spills which are burned are currently available from *AP-42*.[5] Emission factors for evaporation and clean up are needed to develop emissions estimates for these treatment options.

Researchers in the Department of Chemical Engineering and Applied Chemistry at the University of Toronto studied the volatilization rate of organic pollutants from water. They determined that the rate of reaction of the pollutants is influenced by the presence of microbial populations, incident solar radiation, temperature, pH and other variables.[6] To assess the volatilization rate of materials, the aqueous solubility of the spilled material, the vapor pressure and boiling point, the Henry's Law constant, the octanol water partition coefficient, and the molar volume of the spilled material must be obtained. The report presents a complex series of equations developed from the research.

CARB staff performed a "quick and dirty" analysis of the relative emissions from the burning of a major oil spill on water versus the natural evaporation of a spill the same size. A memorandum from James Boyd (Executive Officer, CARB) to Donald Irwin (Office of Emergency Services, State of California) outlines the assumptions used to determine the CARB emissions estimates as well as the results of the study and a comparison of these results to an analysis by Science Applications, Inc.[2]

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AIRCRAFT DEICING

Definition/description of category and activity

Aircraft deicing is the application of chemicals to aircraft wings to prevent ice formation. The Federal Aviation Administration (FAA) maintains a "clean aircraft" policy that requires aircraft entering the runway area for takeoff to be free of ice.[1] Because the FAA does not mandate deicing under any specific set of weather conditions, predicting the precise conditions at which deicing occurs is difficult.

Process breakdown

Aircraft are routinely sprayed with deicing chemicals (typically propylene glycol or ethylene glycol) during inclement winter periods. These chemicals inhibit ice formation by combining with water to create a mixture with a freezing point considerably lower than that of water. The chemicals are often heated before application, sometimes as hot as 180°F.[1]

Reason for considering the category

Both propylene glycol and ethylene glycol are VOC. Although deicing activity during the ozone season may be negligible, ethylene glycol is included in the list of hazardous air pollutants in Section 112 of the Clean Air Act.

Pollutants emitted

VOC (ethylene glycol, propylene glycol)

Estimate of the pollutant levels

The complex process of estimating evaporation rates from a sprayed material requires a large number of application-specific inputs (e.g., droplet size, temperature and wind speed). While developing an accurate estimate of evaporation rates for these materials is outside the scope of this study, some generalizations may be drawn. The relatively high boiling points of ethylene glycol and propylene glycol (388°F and 372°F, respectively) and the cold weather that dictates their use are factors which minimize airborne emissions of deicing chemicals. Even at hot application temperatures (180°F) the volatility of the materials is quite low (vapor pressure less than ten mmHg). Much of the evaporated deicing chemicals will condense as the vapors cool to ambient temperatures and any precipitation will decrease the amount of airborne chemicals. Qualitatively, only a very small amount of deicing chemicals will remain in the air long enough to affect the air quality outside the boundaries of the airport.

Deicing chemicals may create environmental problems other than air pollution. The mist laden with deicing chemicals may create a hazard for airport personnel applying the materials. The accumulation of deicing chemicals in runoff water may pose a water pollution problem since both ethylene glycol and propylene glycol are soluble in water and not volatile enough to evaporate quickly.

Point/area source cutoff

Preliminary analysis of emissions from aircraft deicing has determined that air emissions from any one airport are likely insufficient to require treatment as point sources.

Level of detail of information available

Information on the quantity of deicing chemicals used at specific airports may be available from state or local airport or transportation authorities. National usage of deicing chemicals at airports may be estimated by industry representatives. Air traffic data at FAA-controlled airports are available from FAA.[2] Regional or state transportation authorities may be able to provide air traffic data for small airports not controlled by FAA.

Level of detail required by users

VOC emissions by county

Deicing agents used by facility or county

Number of flights per airport or county

Number of days requiring deicing per airport or county

Emission factor requirements

Aircraft deicing emission factors are not currently available from EPA. Emission factors should be developed for each deicing agent assuming typical application methods and weather conditions.

Regional, seasonal or temporal characteristics

Emissions from deicing chemicals have significant regional, seasonal and temporal variations. Regional and seasonal variations reflect the need for deicing activity in different climates. Deicing emissions occur primarily during winter months, although some deicing activity may occur in the spring and fall. Deicing emissions will match temporal variations in flight traffic since deicing activity will peak during times of peak air traffic.

Urban or rural characteristics

Commercial and general aviation airports are typically located close to urban areas. Military airports are usually located in rural areas.

Methodology

I. Determine the quantity of deicing chemicals consumed

   A. Obtain consumption data on a state or local level when possible. Data may be available from local or state transportation planning boards or airport commissions.

B. If no local data are available, apportion national consumption to study-area airports.

1. Collect the data for allocation:

   a. national aircraft deicing chemical consumption (from industry representatives)

   b. heating degree days at all FAA-controlled airports (from *County and City Data Book*[3])

   c. annual number of flights at all FAA-controlled airports (from *FAA Air Traffic Activity*[2])

2. Apportion national deicing chemical consumption to the study area:

$$Q_{local} = \frac{Q_{national} \times HDD_{local} \times FLTS_{local}}{HDD_{national} \times FLTS_{national}}$$

where:

Q_{local}	=	the quantity of deicing chemicals used in the study area
$Q_{national}$	=	the quantity of deicing chemicals used nationally
HDD_{local}	=	the number of heating degree days in the study area
$HDD_{national}$	=	the number of heating degree days in the cities with FAA-controlled airports
$FLTS_{local}$	=	the number of flights at the study airport
$FLTS_{national}$	=	the number of flights at U.S. FAA-controlled airports

C. Calculate emissions from deicing.

1. Emission factor: Before this methodology can be executed, more work is required to develop an emission factor that accounts for the site specific factors that affects emissions from deicing (e.g., application and ambient temperature, droplet size of spray, fraction absorbed into the ground, etc.). This emission factor would likely have the dimensions of mass VOC emissions per mass of deicing compounds applied.

2. Multiply the emission factor and quantity of deicing materials consumed to estimate emissions.

References

1. Telecon. Winkler, David, Alliance Technologies Corporation, with George Legaretta, U.S. Federal Aviation Administration. Aircraft deicing. November 1, 1990.

2. *FAA Air Traffic Activity*, U.S. Department of Transportation, Federal Aviation Administration, Washington, DC. Annual publication.

3. *County and City Data Book*, U.S. Department of Commerce, Bureau of the Census, Washington, DC. Annual publication.

AIRPORT SUPPORT VEHICLES

Definition/description of category and activity

Airport support vehicles include self-propelled vehicles used at airports in support of aircraft activity. Commercial aircraft are served by many types of motor vehicles, including food service vans and trucks, baggage transfer carts and aircraft tugs.

Process breakdown

Most airport support vehicles are powered by gasoline engines and operate solely within the confines of the airport facility.[1] This equipment uses the typical automotive internal combustion engine technologies.

Reason for considering the category

Airport support vehicles' internal combustion engines are sources of VOC, NO_x and CO emissions. These vehicles are not usually registered as highway vehicles and are not usually registered with state Departments of Transportation or Motor Vehicles. Gasoline consumed by these vehicles is not reported as a nonhighway fuel and is not accounted for in the mobile sources inventory. Aircraft service vehicles are potentially significant sources of criteria air pollutants in many metropolitan areas with busy airports.

Pollutants emitted

VOC, NO_x, CO, aldehydes, SO_x, particulate matter

Estimate of the pollutant levels

National gasoline consumption by airport support vehicles may be estimated using fuel consumption data from a surveyed airport. This estimate assumes that fuel consumption by support vehicles at an airport is proportional to the airport's air traffic activity. The airport used in this estimate is the Greensboro-High Point, NC, Regional Airport.

Greensboro fuel consumption (gallons per month):[1]	3,000
Greensboro fuel consumption (gallons per year):	36,000
Greensboro flight activity (operations per year):[2]	151,081
U.S. flight activity (operations per year):[2]	57,937,965

U.S. fuel consumption can be estimated as follows:

U.S. fuel consumption = (Greensboro fuel consumption) x (U.S. flight activity/Greensboro flight activity)
= 3,000 x (57,937,965/151,081)
= 13.8×10^6 gallons gasoline/year

Since *AP-42*[3] does not provide emission factors for airport support vehicles, emission factors for industrial equipment are used to calculate annual emissions.

Pollutant	Emission Factor (lb/10^3 gallons fuel)	Emissions (tons/year)
CO	3940	27,186
VOC	132	911
NO_x	102	704
Aldehydes	4.35	30
SO_x	5.31	37
Particulates	6.41	44

Point/area source cutoff

The number and diversity of air pollution sources at airports have discouraged the treatment of airports as point sources. The relatively small size and mobility of airport service vehicles encourage the treatment of these sources as area or off-highway mobile sources.

Level of detail of information available

Reference 2 provides air traffic activity at all FAA-controlled airports. Data on fuel consumption by airport service vehicles are not specifically reported to state or federal agencies, but data at each airport may be available from the airline or airlines which provide gasoline for service vehicles.

Level of detail required by users

VOC, CO, NO_x, aldehyde, SO_x, particulate emissions by county

Gasoline consumed by airport service vehicles within each county

Flight traffic data for each airport

Emission factor requirements

No emission factors specifically developed for airport support vehicles are currently available. These vehicles should be studied more closely to determine appropriate emission factors and to determine more reliably the vehicle population and technology. Areas to study include the current and projected market shares of vehicles by fuel type, emissions controls, operating cycles, engine characteristics, etc.

Regional, seasonal or temporal characteristics

Airport support vehicle emissions are higher during periods of increased air travel. Regional differences in air traffic are determined by the concentration of air traffic at the airports in the study area. The temporal variation for national air traffic is determined by major airline schedules, with activity greatly decreased at night. The main seasonal peak in air traffic is during summer months, but a secondary peak occurs during the winter holiday season.[4] Areas with high military or other non-commercial flight activity may exhibit unique seasonal or temporal characteristics. State or local transportation officials should be consulted to determine the specific air traffic characteristics of the region being studied.

Urban or rural characteristics

Commercial and general aviation airports are typically located close to urban areas. Military airports may be located in rural or urban areas.

Methodology

I. Determine the fuel sales

   A. Survey airports in the study area to determine the fuel consumed by airport support vehicles.
   B. If survey results are incomplete, use available data to estimate consumption in the study area, then apportion area-wide fuel consumption to the airports of interest according to air traffic (e.g., passengers).

II. Develop emission factors (emission factors should be determined from *AP-42*)

   Although emission factors for this category of vehicles are not specifically discussed in *AP-42*, emission factors are available for industrial equipment.

III. Estimate annual emissions

   A. Fuel sales data from Step I
   B. Emission factors Step II
   C. Multiply fuel sales by the emission factor

IV. Distribute annual emissions temporally according to guidance by state or local transportation officials.

References

1. Telecon. Winkler, David, Alliance Technologies Corporation, with Gary Edwards, Eastern Airlines Station Manager, Greensboro-High Point Regional Airport. Airport support vehicles. January 3, 1991.

2. *FAA Air Traffic Activity*, U.S. Department of Transportation, Federal Aviation Administration, Washington, DC. Annual publication.

3. *Compilation of Air Pollutant Emission Factors*, Fourth Edition and Supplements, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1985 through September 1991.

4. *Petroleum Marketing Annual 1988*, U.S. Department of Energy, Office of Oil and Gas, Energy Information Administration, Washington, DC, October 1989.

AIRCRAFT REFUELING

Definition/description of category and activity

Fuel dispensed into aircraft fuel tanks displaces vapors remaining in the tank to the atmosphere. This vapor displacement caused by aircraft refueling is an area source of VOC emissions.

Process breakdown

Jet kerosene (used primarily by commercial turbojet and turboprop aircraft), jet naphtha (used primarily by military aircraft) and aviation gasoline (used by aviation reciprocating engines) are the three most common types of aircraft fuels used in the United States. Emissions occur when vapor-laden air in a partially empty fuel tank is displaced to the atmosphere when the tank is refilled. The quantity of vapor displaced depends on the fuel temperature, fuel vapor pressure, aircraft fuel tank temperature and fuel dispensing rate.

Reason for considering the category

Whereas automobile refueling emissions are a major consideration of current SIP methodologies, aircraft refueling emissions are not specifically discussed. No aircraft refueling emissions controls are currently in place. Nonattainment areas may want to assess the benefits of vapor recovery for aircraft refueling.

Pollutants emitted

VOC

Estimate of the pollutant levels

The U.S. aviation industry consumed over twenty billion gallons of aviation fuels in 1988, resulting in emissions of approximately 6,700 tons of VOC.[1] EPA's methodology for estimating emission factors from splash filling fuel storage tanks (as presented in *AP-42*[2]) was used to estimate emission factors for uncontrolled aircraft refueling. Table 1 includes the results of this analysis.

Point/area source cutoff

Aircraft refueling emissions are not currently included in point source inventories. Commercial and general aviation aircraft primarily consume jet kerosene and naphtha and may not contribute enough emissions to be treated as point sources. Military bases consume large quantities of jet naphtha, a more volatile fuel than aviation gasoline or jet kerosene, and may be treated as point sources.

TABLE 1. NATIONAL AIRCRAFT REFUELING EMISSIONS

Material Characteristic/Data	Jet Kerosene	Jet Naphtha	Aviation Gasoline
Assumed Temperature (T, °R)	520	520	520
Reid Vapor Pressure (RVP, psi)	-	-	6.25[3]
True Vapor Pressure (P, psi)[2]	0.0085	1.3	3
Saturation Factor (S)[2]	1.45	1.45	1.45
Molecular Weight (M)[2]	130	80	69
Emission Factor (12.46xSxPxM/T) (lb VOC/thousand gallons fuel)	0.038	3.613	7.192
Volume Fuel Sold[1] (1988, thousand gallons)	17,316,402	2,812,508	353,737
U.S. 1988 Annual Emissions (tons of VOC)	332	5,081	1,272

CUMULATIVE 1988 U.S. ANNUAL EMISSIONS: 6,686 tons VOC/yr

Level of detail of information available

Reference 1 provides the quantities of aviation fuels sold in each state. Fuel use data specific to particular airport facilities may be available from state or local airport regulatory agencies. Fuel characteristics data are available from Reference 2. Air traffic data at FAA-controlled airports are available from FAA.[4] Regional or state transportation authorities may be able to provide air traffic data for small airports not controlled by FAA.

Level of detail required by users

VOC emissions by county

Aviation fuel use by county

Type of fuel used at each facility studied

Availability of vapor recovery systems during refueling process

Flight traffic data for each airport

Temperature data for the study area

Emission factor requirements

Aircraft refueling emission factor estimation methodologies are not directly discussed in *AP-42*. Extension of the automobile refueling emission factor estimation methodology to estimate aircraft refueling emission factors requires data for fuel use and fuel characteristics.

Regional, seasonal or temporal characteristics

Aircraft refueling emissions increase during periods of increased air travel. Regional differences in air traffic are determined by the concentration of air traffic at the airports in the study area. The temporal variation for national air traffic is determined by major airline schedules, with activity greatly decreased at night. The main seasonal peak in aircraft fuel consumption is during summer months, but a secondary peak occurs during the winter holiday season.[1] Areas with high military or other non-commercial flight activity may exhibit unique seasonal or temporal characteristics. State or local transportation officials should be consulted to determine the specific air traffic characteristics of the region being studied.

Urban or rural characteristics

Commercial and general aviation airports are typically located close to urban areas. Military airports may be located in rural or urban areas.

Methodology

I. Determine the fuel sales (from distributors)

A. Obtain state sales of each fuel type from Reference 1. (National fuel sales data are also available from Reference 1.)

B. Obtain local fuel sales data from local airport officials.

C. Local fuel sales may be estimated by apportioning the state fuel sales to the airports being studied according to flight activity data from Reference 4.

II. Develop emission factors

A. Determine the fuel study temperature (T) in °R (°R = °F + 460)

B. Determine the fuel true vapor pressure (P) in psia using Table 4.3-2 from *AP-42*

C. Use a saturation factor (S) of 1.45 (from Table 4.4-1 of *AP-42*)

D. Use the following data for fuel molecular weight (M) in lb/lbmol (from Table 4.3-1 of *AP-42*)

1.	Jet kerosene:	130
2.	Jet Naphtha:	80
3.	Aviation Gasoline:	69

E. Use the following equation to estimate the emission factor (pounds VOC per 1,000 gallons fuel throughput)

$$EF = \frac{(12.46 \times S \times P \times M)}{T}$$

III. Estimate annual emissions

A. Obtain fuel sales data from Step I

B. Obtain emission factors Step II

C. Multiply fuel sales by the corresponding fuel emission factor

IV. Distribute annual emissions temporally according to guidance by state or local transportation officials.

References

1. *Petroleum Marketing Annual 1988*, U.S. Department of Energy, Office of Oil and Gas, Energy Information Administration, Washington, DC, October 1989.

2. *Compilation of Air Pollutant Emission Factors*, Fourth Edition and Supplements, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1985 through September 1991.

3. Avalone, Eugene A. and Theodore Baumeister III, eds. *Marks' Standard Handbook for Mechanical Engineers*, Ninth Edition, McGraw-Hill Book Company, New York, NY, 1986.

4. *FAA Air Traffic Activity*, U.S. Department of Transportation, Federal Aviation Administration, Washington, DC. Annual publication.

LAWN CARE PRODUCTS

Definition/description of category and activity

Organic gas emissions result from evaporation of solvents and carriers of organic chemicals in lawn care products, primarily in pesticides and fertilizers. This category includes the application of lawn care products to residential, commercial and parks and recreation property and golf courses.

Process breakdown

Lawn care products are usually manually applied to residential and commercial lawns, parks and recreation properties and golf courses. Evaporation of solvents and carriers of organic chemicals may release VOC to the atmosphere. In addition, application of lawn care products may be a source of TSP and PM_{10}.

Reason for considering the category

Emissions from fertilizers and pesticides have traditionally been estimated from agricultural activity. Lawn care chemical use has been poorly characterized and may be included in the generic category of commercial and consumer solvent use. In nonattainment areas, the predominance of urban over agricultural land use increases the importance of studying urban fertilizer and pesticide emissions. The proliferation of lawn care services may be increasing the consumption of (and, therefore the emissions from) these products. More work specifically targeting this source category should yield improvements in the precision of the inventory.

Pollutants emitted

VOC from volatilized petroleum-based solvents and carriers are the primary pollutants emitted. Application processes may also be a source of TSP and PM_{10}.[1]

Estimate of the pollutant levels

The Massachusetts Department of Food and Agriculture has identified the following emission factors:[2]

Land Use	Emissions (lbs VOC/acre)
Residential lawns	1.8
Parks and recreation	1.5
Golf courses	9.0
Commercial	9.0

No reliable national land use data were identified.

Point/area source cutoff

Lawn care products are not considered point sources.

Level of detail of information available

Land use statistics may be available through local metropolitan planning organizations or land use maps. Specific application rates may be available through county extension agents or state university schools of agriculture (agronomy). Local landscaping firms may provide valuable location-specific guidance. A detailed and more resource-intensive method of estimating emissions from pesticide application is used by CARB.[3]

Level of detail required by users

VOC emission factors for the county by land use (quantity VOC per acre)

Land use statistics

Emission factor requirements

Application rate by land use type for the study area

Market share of inorganic pesticides and fertilizers in the study area

Regional, seasonal or temporal characteristics

Greater emissions (consumption) in the growing season

Consumption may vary significantly between and within regions

Urban or rural characteristics

Principally an urban source

Methodology

- Consult with county agents, agronomists from state universities and local landscape professionals to determine chemical application rates in the study area.
- Consult with local planning agencies or zoning authorities to determine local land usage.
- If planning and zoning officials are unable to provide any land usage statistics, consult local real estate industry representatives to estimate the average size and acreage of a single family dwelling unit in the study area. The difference in these two figures approximates the average acreage for residential lawns. Local lawn care practices may be estimated by lawn care professionals in the study area. Area golf courses may be surveyed by telephone to determine their acreage and pesticide usage. State and local parks officials should be able to provide information about area parks acreage and pesticide usage.
- Determine the lawn care chemical usage by multiplying the application rates and lawn, golf course and recreational facility acreage. Sum the usage from these categories to estimate total lawn care chemical consumption.

- Following guidance found in *Procedures for the Preparation of Emission Inventories for Precursors of Ozone, Volume I* pertaining to estimating emissions from pesticides, a factor of 0.90 represents the volatile organic fraction of pesticides.[4]

- Multiply the 0.90 factor by the total lawn care chemical consumption to estimate VOC emissions from lawn care chemicals.

References

1. Telecon. Winkler, David, Alliance Technologies Corporation, with Jim Brooks, Professional Lawn Care Association of America. Air pollutant emissions from lawn care products. July 13, 1990.

2. Telecon. Winkler, David, Alliance Technologies Corporation, with Ken Santlal, Commonwealth of Massachusetts, Department of Environmental Quality Engineering, Division of Air Quality Control. Massachusetts methodologies for estimating emissions from pesticides. April 2, 1990.

3. *Methods for Assessing Area Source Emissions in California*, California Air Resources Board, Emission Inventory Branch, Stationary Source Control Division, Sacramento, CA, December 1982.

4. Kersteter, Sharon L. *Procedures for the Preparation of Emission Inventories for Precursors of Ozone, Volume I*, EPA-450/4-88-021 (NTIS PB89-152409), U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1988.

PESTICIDE APPLICATION

Definition/description of category and activity

The application of commercial, municipal and agricultural pesticides can result in VOC, TSP and PM_{10} emissions. Pesticides broadly include any substances used to kill or retard the growth of insects, rodents, fungi, weeds or microorganisms. Pesticides fall into three basic categories: synthetics, nonsynthetics (petroleum products) and inorganics. Formulations are commonly made by combining synthetic materials with various petroleum products. The synthetic pest killing compounds in such formulations are labeled as "active" ingredients; the petroleum product solvents acting as carriers or diluents for the active ingredients are labeled "inert."

Process breakdown

The application of pesticides may be divided into those applied for agricultural, municipal and commercial purposes. Agricultural pesticides are applied both aerially and from the ground. TSP and PM_{10} emissions may result from the impact of the pressurized ground application system. Municipal application includes roadside spraying for mosquito control, but does not address spraying in parks (those emissions are considered under lawn care products). Commercial application of pesticides is classified as that conducted by pest-control services such as Terminex and Orkin; it does not include individual consumer spraying of household products like Raid, since that is accounted for in the consumer products category. VOC are of primary concern in all cases and should be estimated both for active ingredients and solvent (inert) carriers. Pesticide application may be further broken down by chemical formulation or brand name.

Reason for considering the category

The highly volatile nature of pesticides and their widespread use suggest that pesticides may contribute a substantial quantity of VOC to atmospheric pollution. In addition, ground application of agricultural pesticides can disrupt soil particles, increasing airborne concentrations of particulate matter and PM_{10}.

Pollutants emitted

VOC, TSP, PM_{10}

Estimates of pollutant levels

References 1, 2, 3, 4, 5 and 6 include estimates of VOC emissions derived from pesticide application. These estimates are summarized in Table 1. Particulate matter emissions have not been quantified in previous studies.

Point/area source cutoff

Residential pesticide application should be considered an area source, as should small municipal and agricultural applications. Large farms may release more than ten TPY VOC and should be considered point sources.

TABLE 1. ESTIMATES OF POLLUTANT LEVELS

Source	Year	Region	Use	Emissions	Units	Compound	Product	Comments
1	1986	CA	Consumer/commercial	3000.41	TPY	VOC	insect sprays	low estimate
1	1986	CA	Consumer/commercial	13613.93	TPY	VOC	insect sprays	high estimate
1	1986	CA	Consumer/commercial	0.67	lbs/capita	VOC	insect sprays	average
1	1986	CA	Consumer/commercial	3605.25	TPY	VOC	herb. & fung.	high estimate
1	1986	CA	Consumer/commercial	0.15	lbs/capita	VOC	herb. & fung.	average
1	1986	NJ	Consumer/commercial	845.57	TPY	VOC	insect sprays	low estimate
1	1986	NJ	Consumer/commercial	3836.65	TPY	VOC	insect sprays	high estimate
1	1986	NJ	Consumer/commercial	0.56	lbs/capita	VOC	insect sprays	average
1	1986	NJ	Consumer/commercial	1016.02	TPY	VOC	herb. & fung.	high estimate
1	1986	NJ	Consumer/commercial	0.12	lbs/capita	VOC	herb. & fung.	average
1	1986	NY	Consumer/commercial	1254.72	TPY	VOC	insect sprays	low estimate
1	1986	NY	Consumer/commercial	5693.1	TPY	VOC	insect sprays	high estimate
1	1986	NY	Consumer/commercial	0.64	lbs/capita	VOC	insect sprays	average
1	1986	NY	Consumer/commercial	1507.65	TPY	VOC	herb. & fung.	high estimate
1	1986	NY	Consumer/commercial	0.14	lbs/capita	VOC	herb. & fung.	average
2	1989	New England	Consumer/commercial	0.041	lbs/capita	VOC	insect sprays	low estimate
2	1989	New England	Consumer/commercial	0.428	lbs/capita	VOC	insect sprays	mid-point
2	1989	New England	Consumer/commercial	0.815	lbs/capita	VOC	insect sprays	high estimate
2	1989	Mid. Atlantic	Consumer/commercial	0.041	lbs/capita	VOC	insect sprays	low estimate
2	1989	Mid. Atlantic	Consumer/commercial	0.428	lbs/capita	VOC	insect sprays	mid-point
2	1989	Mid. Atlantic	Consumer/commercial	0.815	lbs/capita	VOC	insect sprays	high estimate
2	1989	E.N. Central	Consumer/commercial	0.038	lbs/capita	VOC	insect sprays	low estimate
2	1989	E.N. Central	Consumer/commercial	0.404	lbs/capita	VOC	insect sprays	mid-point
2	1989	E.N. Central	Consumer/commercial	0.769	lbs/capita	VOC	insect sprays	high estimate
2	1989	W.N. Central	Consumer/commercial	0.038	lbs/capita	VOC	insect sprays	low estimate
2	1989	W.N. Central	Consumer/commercial	0.404	lbs/capita	VOC	insect sprays	mid-point
2	1989	W.N. Central	Consumer/commercial	0.769	lbs/capita	VOC	insect sprays	high estimate
2	1989	S. Atlantic	Consumer/commercial	0.059	lbs/capita	VOC	insect sprays	low estimate
2	1989	S. Atlantic	Consumer/commercial	0.622	lbs/capita	VOC	insect sprays	mid-point
2	1989	S. Atlantic	Consumer/commercial	1.186	lbs/capita	VOC	insect sprays	high estimate
2	1989	E.S. Central	Consumer/commercial	0.059	lbs/capita	VOC	insect sprays	low estimate
2	1989	E.S. Central	Consumer/commercial	0.622	lbs/capita	VOC	insect sprays	mid-point

(continued)

TABLE 1. ESTIMATES OF POLLUTION LEVELS (continued)

Source	Year	Region	Use	Emissions	Units	Compound	Product	Comments
2	1989	E.S. Central	Consumer/commercial	1.186	lbs/capita	VOC	insect sprays	high estimate
2	1989	W.S. Central	Consumer/commercial	0.059	lbs/capita	VOC	insect sprays	low estimate
2	1989	W.S. Central	Consumer/commercial	0.622	lbs/capita	VOC	insect sprays	mid-point
2	1989	W.S. Central	Consumer/commercial	1.186	lbs/capita	VOC	insect sprays	high estimate
2	1989	Mountain	Consumer/commercial	0.040	lbs/capita	VOC	insect sprays	low estimate
2	1989	Mountain	Consumer/commercial	0.418	lbs/capita	VOC	insect sprays	mid-point
2	1989	Mountain	Consumer/commercial	0.797	lbs/capita	VOC	insect sprays	high estimate
2	1989	Pacific	Consumer/commercial	0.040	lbs/capita	VOC	insect sprays	low estimate
2	1989	Pacific	Consumer/commercial	0.418	lbs/capita	VOC	insect sprays	mid-point
2	1989	Pacific	Consumer/commercial	0.797	lbs/capita	VOC	insect sprays	high estimate
2	1989	U.S.	Consumer/commercial	0.180	lbs/capita	VOC	moth control	low estimate
2	1989	U.S.	Consumer/commercial	0.184	lbs/capita	VOC	moth control	mid-point
2	1989	U.S.	Consumer/commercial	0.188	lbs/capita	VOC	moth control	high estimate
2	1989	U.S.	Consumer/commercial	0.000	lbs/capita	VOC	herb. & fung.	low estimate
2	1989	U.S.	Consumer/commercial	0.156	lbs/capita	VOC	herb. & fung.	mid-point
2	1989	U.S.	Consumer/commercial	0.313	lbs/capita	VOC	herb. & fung.	high estimate
3	1990	NYCMA	Household	5	TPY	VOC	Pet insecticides	
3	1990	NYCMA	Commercial	32	TPY	VOC	Pet insecticides	
3	1990	NYCMA	Household	33	TPY	VOC	Insect Repellents	
3	1990	NYCMA	Commercial	15	TPY	VOC	Insect Repellents	
3	1990	NYCMA	Household	413	TPY	VOC	Other Insecticides	
3	1990	NYCMA	Commercial	619	TPY	VOC	Other Insecticides	
3	1990	NY	Household	12	TPY	VOC	Pet insecticides	
3	1990	NY	Commercial	70	TPY	VOC	Pet insecticides	
3	1990	NY	Household	69	TPY	VOC	Insect Repellents	
3	1990	NY	Commercial	30	TPY	VOC	Insect Repellents	
3	1990	NY	Household	717	TPY	VOC	Other Insecticides	
3	1990	NY	Commercial	1064	TPY	VOC	Other Insecticides	
4	1988	U.S.	Agricultural	1.8	lb/yr/harv.acre	PR VOC	Pesticides	low estimate
4	1988	U.S.	Agricultural	4.5	lb/yr/harv.acre	PR VOC	Pesticides	high estimate
5	1979	CA	Agricultural	27008.98	TPY	TOG	47092 Pesticide	
5	1979	CA	Domestic	1818.87	TPY	TOG	47100 Pesticide	

(continued)

TABLE 1. ESTIMATES OF POLLUTION LEVELS (continued)

Source	Year	Region	Use	Emissions	Units	Compound	Product	Comments
5	1979	CA	Unspecified	1369.78	TPY	TOG	47118 Pesticide	
5	1979	CA	Agricultural	63507.54	TPY	TOG	47126 Pesticide	
5	1979	CA	Domestic	2997.19	TPY	TOG	47134 Pesticide	
5	1979	CA	All	96702.36	TPY	TOG	Pesticides	total of above 5
7	1977	CA	All	182019000	lbs/yr	TOG	Form. 10 Pesticides	

Level of detail of information available

Estimating emissions levels for all application methods described above requires similar types of information, although the formulation and application quantities may differ. These data include: quantity used (weight or volume per unit area); type of pesticide applied (VOC content); vapor pressure of pesticide; average ambient temperature during month of application; adjusted water evaporation rate in pounds per acre; average relative humidity during the month; and molecular weight of compound.

All data necessary to calculate VOC emissions from pesticide application on a county basis are available, though in some cases their reliability is questionable. Table 2 summarizes the data available from the References 1 through 14. Methodologies are described in References 2 and 7. Usage statistics for agricultural purposes are compiled in the National Pesticide Usage Database, compiled by Leonard Gianessi of Resources for the Future.[13] This database is disaggregated into county use for 25 widely used agricultural pesticides, but statistical significance may be limited to the state level. Reference 9 contains nonagricultural use statistics. Reference 7 includes very complete formulation and chemical properties data on a compound-specific basis. Thomson's handbooks on agricultural chemicals list recommended application levels, also on a compound-specific basis.[6] Mean monthly temperature, relative humidity, and water evaporation data are available from National Oceanic and Atmospheric Administration's *Local Climatological Data* monthly reports.[15] Pesticide use per person, available in Reference 1, may be combined with U.S. Census data to estimate geographical distribution of residential pesticide use, by county.

Notably lacking in the literature is an investigation into the different emission factors which might be calculated for aerial (as opposed to ground) application of agricultural chemicals. Harold Collins of the National Agricultural Aviation Association stated that 30 percent of all agricultural pesticides are applied aerially. He also said that the exact same formulations and levels of active ingredients are used aerially as are used during ground applications. The quantity of diluent may vary with the application method, but quantities do not exceed the manufacturer's recommendations. These are included in Reference 8. It is reasonable to expect that a greater proportion of pesticides evaporates when applied aerially.

No studies have been performed estimating PM_{10} and TSP emissions or emission factors associated with the ground application of agricultural pesticides. Presumably, particulate emissions are a function of silt content, number of days with at least 0.01 inch of precipitation per year, pressure of application and volume of application.

Level of detail required by users

VOC emissions per county for commercial pesticide use

VOC emissions in lbs/acre harvested for agricultural pesticide use

VOC emissions per county for municipal pesticide use

TSP, PM_{10} emissions in lbs/acre harvested for agricultural ground application of pesticides

Regional, seasonal or temporal characteristics

Greater emissions (consumption) occur during growing season (spring and summer) for commercial, agricultural and municipal pesticide applications.

TABLE 2. PESTICIDE DATA AVAILABILITY

Source	Year	State/Region	Methodology	Usage	Appl. Level	Agric.	Cons.	Comm.	MW	VP	RER	Formulation	Emissions	By County
1	1986	US	X	X			X	X	X	X	X		X	
2	1989	US	X	X			X	X	X	X	X	X	X	
3	1990	NY	X	X			X	X				X	X	X
4	1988	US	X		X	X								
5	1982	CA	X	X		X	X	X					X	X
6	1978	Fresno Cty, CA	X	X	X	X	X	X	X	X	X	X	X	X
7	1980	CA	X	X	X	X	X	X	X	X	X	X	X	X
8	1989	US			X	X	X	X				X		
9	1981	US		X			X							
11	1988	US		X		X	X	X						
12	1989	US		X		X								
13	1988	US	X	X		X						X		X
14	1989	US		X		X						X		

Urban or rural characteristics

Rural areas may have greater emissions due to intensive agricultural pesticide use.

Methodology

A methodology for estimating VOC emissions from commercial, municipal and agricultural use of pesticides is described by Leung et al.[7] This methodology depends primarily on the model developed by Hartley for pesticide volatilization from surface deposits. The basic emission rate is derived from physical properties such as quantity of pesticide applied, vapor pressure and average ambient temperature during application. After the initial rate is established, emissions are considered to follow a time-course through each month which is first order or a summation of two first order time-courses.

Presently no methodology exists for estimating TSP and PM_{10} emissions resulting from ground application of pesticides. A first step towards developing such a methodology would involve calculating an emission factor. Parameters to be considered in the emission factor include silt content, number of days with at least 0.01 inch of precipitation per year, pressure of application and volume of application. Presumably county-level usage data could be combined with agricultural census data, and then multiplied by the emission factor to estimate TSP and PM_{10} emissions in pounds per acre harvested.

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AUTOMOTIVE CLEANERS/WAXES/POLISHES

Definition/description of category and activity

Automotive cleaners, waxes and polishes are any consumer product used on or in mobile equipment (e.g., automobiles, buses, motorcycles, vans, heavy off-highway vehicles, etc.). Automotive cleaners, waxes and polishes include, but are not limited to, the following products: insect and tar removers, chrome and metal polishes; leather or vinyl cleaners; wheel cleaners; engine degreasers; carburetor-choke cleaners; and brake cleaners.[1,2]

Process breakdown

Automotive cleaning, waxing and polishing products are classified as either aerosols or nonaerosols. These two categories can be further broken down as aerosol propellants, aerosol solvents and nonaerosol solvents. Propellants are used to propel aerosol products from containers, solubilize active ingredients and serve as part of the diluent system. Solvents solubilize the product ingredients and affect the evaporation rate of the product.

Reason for considering the category

Aerosol propellants and solvents and nonaerosol solvents contain VOC that evaporate on use and are carried into the atmosphere. In the atmosphere, VOC photochemically react to produce ozone and secondary particulate matter. Automotive cleaners, waxes and polishes represent significant sources of unaccounted VOC.

Pollutants emitted

VOC

Estimate of the pollutant levels

AP-42 has calculated national emissions and per capita emission factors for commercial and consumer solvents.[1] Automotive cleaners, waxes and polishes are not specifically categorized. However, *AP-42* lists polishes and waxes which are included in this unaccounted VOC source. The evaporative emissions from commercial and consumer solvent use for nonmethane VOC are as follows:

- National emissions for polishes and waxes are 53,000 TPY.
- Automotive cleaners, waxes and polishes per capita emission factors are 0.49 pounds per year or 1.3×10^{-3} pounds per day.

VOC emissions estimated for consumer product categories are listed in Reference 3. Table 1 shows the total VOC content for 49 consumer product categories for New York State, as estimated by Science Applications International Corporation, Pacific Environmental Services and CARB. The values provided by CARB were estimated using state population ratios and a recent CARB staff report on proposed consumer product regulations. The automotive cleaners, waxes and polishes are represented in Table 1 by numbers 6, 14, 15, 16 and 28. Estimated total VOC emissions from automotive cleaners, waxes and polishes in New York are 3,097 tons per year.

TABLE 1. ANNUAL TONS VOC FOR NEW YORK STATE[3]

#	PRODUCT CATEGORY	SAIC 1986	% of TOTAL	CUMULAT. %	PES 1990	CARB 1990
1	Spray Paints, Primers, Varnishes	4,190	15.5	15.5	7,211	
2	Hair Sprays	2,911	10.8	26.3	10,260	10,900
3	All Purpose Cleaners	2,526	9.4	35.7	6,574	1,200
4	Insect Sprays	2,214	8.2	43.9	1,781	100
5	Room Deodorants & Disinfectants	1,758	6.5	50.4	6,964	2,000
6	Car Polishes & Waxes	1,658	6.1	56.5		
7	Adhesives (excludes industrial)	1,602	5.9	62.5	2,044	
8	Caulking & Sealing Compounds	995	3.7	66.2		
9	Moth Control Products	877	3.3	69.4		
10	Window & Glass Cleaners	840	3.1	72.5		500
11	Herbicides & Fungicides	754	2.8	75.3		
12	Personal Deodorants	699	2.6	77.9		
13	Auto Antifreezes	487	1.8	79.7		
14	Carburetor & Choke Cleaners	439	1.6	81.4		
15	Brake Cleaners	431	1.6	83.0		
16	Engine Degreasers	421	1.6	84.5		1,100
17	Engine Starting Fluids	397	1.5	86.0		
18	Rug & Upholstery Cleaners	389	1.4	87.4		
19	Lubricants & Silicones	382	1.4	88.8		
20	Metal Cleaners & Polishes	276	1.0	89.9		
21	Waxes & Polishes	273	1.0	90.9		700
22	Tile & Bathroom Cleaners	247	0.9	91.8		100
23	Styling Mousse	227	0.8	92.6		100
24	Windshield Deicer	209	0.8	93.4		
25	Pharmaceuticals	209	0.8	94.2		
26	Insect Repellants	165	0.6	94.8	99	
27	Starch & Fabric Finish	153	0.6	95.4		
28	Auto Cleaners	148	0.5	95.9		
29	Floor Waxes & Polishes	127	0.5	96.4		600
30	Colognes	127	0.5	96.8		
31	Shaving Lathers	120	0.4	97.3		60
32	Animal Insecticides	107	0.4	97.7	82	
33	Aftershaves	86	0.3	98.0		
34	Undercoatings	79	0.3	98.3		
35	Shoe Polishes, Waxes, & Colorants	77	0.3	98.6		
36	Oven Cleaners	76	0.3	98.9		200
37	Paints-other related products	71	0.3	99.1		
38	Perfumes	57	0.2	99.3		
39	Spot Removers	50	0.2	99.5		
40	Waxes & Polishes Liquids	41	0.2	99.7		
41	Hair Care Products - Shampoos	37	0.1	99.8		
42	Carpet Deodorizers	29	0.1	99.9		
43	Suntan Lotions	16	0.1	100.0		
44	Depilatories	5	0.0	100.0		
45	Anti-static Sprays	1	0.0	100.0		
46	Prewash Stain Removers	0	0.0	100.0		500
47	Drain Openers	0	0.0	100.0		
48	Windshield Washer Fluid					5,700
49	Nail Polish Remover					300
	TOTALS	26,979	100.0			

California has taken a lead in developing consumer product emissions inventories and control measures to reduce VOC emission from consumer products.[2] Table 2 presents aerosol propellant and solvent emissions estimates for eight consumer product categories and 29 subcategories including automotive and industrial products. VOC emissions from propellants and solvents are estimated at 56 tons per day (TPD). Of these, solvent emissions comprise 70.5 percent (39.3 TPD) and propellant emissions comprise 29.5 percent (16.4 TPD). The automotive cleaners, waxes and polishes account for approximately 48.2 percent (7.9 TPD) of total propellant and 11.8 percent (9.0 TPD) of total solvent emissions.

Automotive product emissions may be apportioned on the basis of automobile-related activity. There were approximately 135,671,000 automobiles and light-duty trucks registered in the United States in 1986. Per-vehicle emission factors were derived by dividing total VOC emissions by this number. National 1986 VOC emissions and per-vehicle emission factors are as follows:

- Car Polishes and Waxes: 50,391 TPY or 0.743 lb/year/vehicle
- Carburetor and Choke Cleaners: 13,093 TPY or 0.193 lb/year/vehicle
- Brake Cleaners: 9,824 TPY or 0.145 lb/year/vehicle
- Engine Degreasers: 5,192 TPY or 0.077 lb/year/vehicle

Point/area source cutoff

Due to the nature of the use of automotive cleaners, waxes and polishes, this category is considered an area source.

Level of detail of information available

The CAAA require EPA to prepare a report to Congress on VOC in consumer and commercial products and to promulgate regulations that would reduce VOC emissions from these products. It is assumed that the inventory will be developed from individual brand formulations and sales volumes and that these data will be obtained by a survey of the manufacturers. The best four major studies publicly available are listed below and include information on comprehensive inventories of VOC from consumer and commercial products.

- *Photochemically Reactive Organic Compounds Emissions from Consumer and Commercial Products*[3]
- *Compilation and Speciation of National Emissions Factor for Consumer/Commercial Solvent Use*[5]
- *Analysis of Regulatory Alternatives for Controlling Volatile Organic Compounds (VOC) Emissions from Consumer and Commercial Products in the New York City Metropolitan Area (NYCMA)*[6]
- *Expansion of the New York Study: Evaluation of VOC Emission Reduction Alternatives from Selected Consumer and Commercial Products*[7]

TABLE 2. AVERAGE ANNUAL DAY VOC EMISSIONS FROM AEROSOL CONSUMER PRODUCTS IN CALIFORNIA AND THE SOUTH COAST AIR BASIN (SCAB)[2,a]

CONSUMER PRODUCT CATEGORY/ SUBCATEGORY	1987 CALIFORNIA EMISSIONS				1987 SCAB EMISSIONS	
	PROPELLANT EMISSIONS, TPD[b]	SOLVENT EMISSIONS, TPD[b]	PERCENT OF TOTAL PROPELLANT EMISSIONS	PERCENT OF TOTAL SOLVENT EMISSIONS	PROPELLANT EMISSIONS, TPD[b]	SOLVENT EMISSIONS, TPD[b]
Paints and Finishes						
· Aerosol paints/primers/varnishes	10.67	17.38	26.00	16.92	4.71	7.66
· Other	0.26	0.43	0.63	0.42	0.11	0.19
· Subtotals	10.93	17.81	26.63	17.34	4.82	7.85
Household products						
· Room deodorants/disinfectants	1.78	7.11	4.34	6.92	0.79	3.13
· Cleaners	2.58	4.65	6.29	4.53	1.14	2.05
· Laundry products	0.57	5.48	1.39	5.34	0.25	2.42
· Other	2.40	1.44	5.85	1.40	1.06	0.63
· Subtotals	7.33	18.68	17.87	18.19	3.24	8.23
Personal care products						
· Shaving lathers	0.79	0.00	1.92	0.00	0.35	0.00
· Hair sprays	6.62	18.81	16.13	18.32	2.92	8.30
· All other hair products	0.26	0.93	0.63	0.91	0.11	0.41
· Medicinals and pharmaceuticals	0.20	0.96	0.49	0.93	0.09	0.42
· Colognes/perfumes/aftershaves	0.08	0.47	0.19	0.46	0.03	0.21
· Deodorants and antiperspirants	5.35	2.23	13.04	2.17	2.36	0.98
· Other aerosol products, suntan preps, lotions	0.05	0.25	0.12	0.24	0.02	0.11
· Subtotals	13.35	23.65	32.52	23.03	5.88	10.43
Automotive and industrial						
· Refrigerants	0.00	4.94	0.00	4.81	0.00	2.18
· Aerosol windshield/lock deicers	0.00	1.35	0.00	1.31	0.00	0.59
· Cleaners	0.10	0.22	0.24	0.21	0.04	0.10
· Engine degreasers	0.41	3.55	1.00	3.46	0.18	1.57
· Lubricants and silicones	1.61	6.53	3.92	6.36	0.71	2.88
· Spray undercoats	0.26	0.16	0.63	0.16	0.11	0.07
· Tire inflatants and sealants	0.42	0.10	1.02	0.10	0.18	0.05
· Carburetor and choke cleaners	0.59	4.30	1.44	4.19	0.26	1.90
· Brake cleaners	0.13	1.14	0.32	1.11	0.06	0.50
· Engine starting fluids	0.00	2.54	0.00	2.47	0.00	1.12
· Other	0.44	2.54	1.07	2.47	0.19	1.12
· Subtotals	3.96	27.37	9.64	26.65	1.73	12.08

(continued)

TABLE 2. AVERAGE ANNUAL DAY VOC EMISSIONS FROM AEROSOL CONSUMER PRODUCTS IN CALIFORNIA AND THE SOUTH COAST AIR BASIN (SCAB)[2,a] (continued)

CONSUMER PRODUCT CATEGORY/ SUBCATEGORY	1987 CALIFORNIA EMISSIONS				1987 SCAB EMISSIONS	
	PROPELLANT EMISSIONS, TPD[b]	SOLVENT EMISSIONS TPD[b]	PERCENT OF TOTAL PROPELLANT EMISSIONS	PERCENT OF TOTAL SOLVENT EMISSIONS	PROPELLANT EMISSIONS, TPD[b]	SOLVENT EMISSIONS, TPD[b]
Animal Products						
· Veterinarian and pet products	0.10	0.73	0.24	0.71	0.04	0.32
Food products						
· All types (including pan sprays)	0.15	1.16	0.37	1.13	0.07	0.51
Miscellaneous						
· Other aerosol products not listed above	1.50	3.01	3.65	2.93	0.66	1.33
Consumer pesticides						
· Space insecticides	2.89	6.55	7.04	6.38	1.27	2.89
· Residual insecticides	0.83	3.74	2.02	3.64	0.37	1.65
· Subtotals	3.72	10.29	9.06	10.02	1.64	4.54
Grand totals	41.04	102.70	99.98[c]	100.0	18.08	45.29

[a]Emissions are based on California Air Resources Board estimates. Emissions estimates are based on the assumptions that (1) all propellants and solvents used in consumer products will eventually evaporate to the atmosphere and participate in photochemical reactions that produce ozone and (2) total organic compound emissions equal total volatile organic compound emissions.
[b]TPD = tons per average annual day.
[c]Total does not sum to 100 percent because of independent rounding.

Level of detail required by users

Method 1

VOC emissions by county

Automotive cleaners, waxes, polishes consumed by county

Emissions per product

Method 2

VOC emission by county

Number of vehicles registered per county

Per-vehicle VOC emission factor

Emission factor requirement

VOC emission factor by product or by vehicle

Regional, seasonal or temporal characteristics

Some products, such as exterior waxes and polishes may exhibit regional and seasonal variations in use.

Urban or rural characteristics

Automotive cleaners, waxes, and polishes are used in urban, suburban and rural areas. Emissions vary directly with population and numbers of automobiles.

Methodology

Method 1

- Compile a list of all the automotive cleaning products and their manufacturers.
- Determine sales volumes for each automotive cleaning product per county.
- Conduct laboratory testing, use existing emission factors to "generalize" VOC content by product and assume 100 percent volatilize, and determine emissions from each automotive product.
- Calculate total annual emissions for each automotive product. Multiply the emission factor by the sales in each county.

Method 2

- Compile a list of all the automotive cleaning products and their manufacturers.

- Determine sales volumes for each automotive cleaning product per county.
- Determine the number of vehicles registered in each county.
- Conduct laboratory testing or use existing VOC per-vehicle emission factors to determine emissions from each automobile.
- Calculate total annual emissions for each county. Multiply per-vehicle emission factors by the number of registered vehicles in each county.

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AUTOMOTIVE FLUIDS AND FLUID LEAKS

Definition/description of category and activity

Automotive fluids include brake fluid, steering fluid, transmission fluid, windshield washing fluid, windshield deicers, crankcase oil, engine starting fluids, engine coolant and gas-line antifreeze. Additives such as oxidation inhibitors, rust inhibitors, antiwear agents, detergents and dispersants, pour-point depressants, viscosity index improvers and foam inhibitors are added in varying combinations to most automotive fluids. The compositions of these additives are described below, followed by descriptions of automotive fluids ingredients.

Oxidation inhibitors are generally organic compounds containing sulfur, nitrogen and phosphorus, or alkyl phenols. Rust inhibitors are mildly polar organic acids such as alkyl succinic or organic amines. Antiwear agents are composed of fatty acids, esters, ketones, sulfur or sulfur dioxide mixtures, organic chlorine compounds (such as chlorinated wax), organic sulfur compounds (such as sulfurized fats and sulfurized olefins), chlorine-sulfur compounds, organic phosphorus compounds (such as tricresyl phosphate, thiophosphates and phosphites) and organic lead compounds.[1]

Detergents and dispersants often make up two to 20 percent of automotive lubricants and are primarily composed of sulfonates, calcium/barium salts of petroleum mahogany sulfonic acids, phosphonates, thiophosphonates and polymers containing oxygen or nitrogen-bearing comonomers. Pour-point depressants are usually polymethacrylates or polymers formed by condensation of wax with naphthalene or phenols. Viscosity index improvers are linear polymers and foam inhibitors are methyl silicone polymers.[1]

Engine coolants are composed of glycols, five to 77.5 percent water, 2.5 to 4.5 percent borax, caustic soda, sodium mercaptobenzothiazole, nitrites, nitrates, silicates, benzotriazole, silicones, mineral oils, organic phosphates, alkyl lactates, castor oil soaps or calcium acetate and trace amounts of pigments or dyes. Windshield washer fluid is composed of zero to 50 percent water; 30 to 90 percent methyl alcohol, ethylene glycol, isopropyl alcohol or propylene glycol; zero to one percent potassium phosphate; zero to five percent surfactants; and trace amounts to two percent dyes. Gas-line antifreeze is composed of 20 to 40 percent toluene, acetone, propanol, xylene or isopropanol and 60 to 90 percent isopropanol, propanol or methanol.[2] Windshield deicing fluids are also predominantly composed of ethylene glycol and propylene glycol.[1]

The primary ingredient in brake fluids is diacetone alcohol, frequently in combination with castor oil. These compounds are being replaced by hexylene glycol. Although information on the composition of power steering fluid is not readily available, the compositions of other automotive lubricants are described in the *Encyclopedia of Chemical Technology.*[1] Crankcase oils are well-fractionated and refined cuts from paraffin-base, mixed base or cycloparaffinic crude oils. The best grades of oils are derived from paraffinic or solvent-refined mixed base crudes. Crank case oils often contain one to two percent zincdithiophosphate or terpene. Transmission and axle lubricants are generally well-refined heavy lubricating oils containing film-strength improvers or extreme pressure additives. They may contain between 0.5 and 1.0 percent phenolic and aromatic antioxidants. Antifriction bearing and chassis greases are usually derived from medium and high viscosity, well-refined lubrication oils, gelled by the addition of metallic soaps or other thickeners.[1]

Process breakdown

VOC emissions from automotive fluids are associated with draining, refilling, overfilling or replacing fluids and from running and standing losses. Evaporative losses of these automotive fluids are likely to negligible.

Reason for considering the category

The compounds in automotive fluids are largely hazardous, composed of toxic and ignitable chemicals. Given the dominance of the automobile in American life, all aspects of their pollutant contributions should be thoroughly evaluated. Furthermore, because automotive fluids release VOC which photochemically react with NO_x to form ozone, human health effects merit further consideration. Specifically, elevated ozone levels have been linked to increased rates of pulmonary infection, decreased pulmonary function and more frequent angina and asthma attacks in susceptible individuals.

Pollutants emitted

VOC

Estimate of the pollutant levels

Annual VOC emissions from engine coolants, engine starting fluids and windshield deicers in New York State are estimated at 487, 397 and 209 TPY, respectively. These three sources represent 4.1 percent of total VOC emissions in New York.[3] EPA estimates reactive VOC levels of 0.63 pounds per capita per year for windshield washing fluids.[4] This factor yields a national level of VOC emissions from windshield washing fluids of 81,900 TPY for 1990, assuming an annual growth rate of 1.8 percent.[5] Estimates for pollutant levels associated with brake fluids, steering fluids, transmission fluid, crankcase oil and windshield deicers are not readily available.

Point/area source cutoff

Emissions from automotive fluids and fluid leaks occur both at the point of application (mainly service stations and residences) and at the vehicle. Emissions levels are likely to be low, yet very widely distributed. Therefore, these sources should be addressed as area sources.

Level of detail of information available

It is likely that data on automotive fluid use will be derived from vehicular use data, such as those provided by References 6 and 7. In addition, values for total number of vehicles by county are available from each state's Department of Motor Vehicles. In 1988, 141,251,695 passenger cars and taxis were registered in the United States. Total VMT for cars was 2,025,586.[6] Total bus VMT was estimated to be 7,830 for 1988, based on state motor vehicle registration data. Total truck VMT was estimated to be 580,802.[7]

It is also necessary to determine usage rates for each automotive fluid per automobile. Simmons Market Research Bureau, Inc. reports that 34.4 percent of the U.S. population changes radiator coolant during any one-year period.[8] Two to four gallons of coolant are used per application.[2] The quantity of fluid used per application depends on the type of fluid. One and a half to three quarts of windshield washer fluid is used per application; product labels specify one pint of gas-line antifreeze per application.[9] For the one to 15 percent of car owners using gas-line antifreeze, gas-line antifreeze may be applied once every eight to ten gallons, two to four fill-ups or 1,000 miles.[2]

Alternatively, total usage can be calculated at a national level and then scaled to a per capita level. C.H. Kline reported 1.72 million gallons of gas-line antifreeze used or sold in 1981, extrapolating from 1974 data and assuming a two percent annual growth rate.[10] Similarly, C.H. Kline reported 18.4 million gallons of windshield washer fluid sold in 1981.[10] In 1988, Simmons reported that 86,698,000 gallons of antifreeze and 26,788,000 cans of gasoline additives had been purchased by consumers in the United States during

the preceding year. Simmons also reported that 102,353,000 quarts of crankcase oil had been purchased during the preceding six months.[11] Specific data on use of brake fluid, steering fluid and transmission fluid are not readily available.

Emissions per volume of automotive fluid must be determined from field experiments, since few emission factors have yet been developed. Only EPA provides a per capita emission factor estimate for VOC derived from windshield washing fluid.[4]

Level of detail required by users

Vehicles per county

Fluid use per vehicle by fluid type

Emissions per volume of fluid by fluid type

Emission factor requirements

VOC and PM_{10} emissions per county, by fluid type, pollutant type, vehicle class and running/standing/refilling mode

Regional, seasonal or temporal characteristics

Emissions from engine coolants and antifreeze may be greater during summer and winter months, respectively, but emissions from other automotive fluids are likely to be constant throughout the year. Emissions may peak during rush hours due to vehicle activity and engine temperature.

Urban or rural characteristics

It cannot be readily determined whether automotive fluid use on a per capita basis varies by location (urban or rural).

Methodology

- Determine the number of vehicles per county, by vehicle class.
- Determine the amount of fluid used per vehicle, by fluid type and vehicle class.
- Develop emission factors through field studies to determine emissions per unit volume of automobile fluid. Factors may be broken down by fluid type, pollutant type and running/standing/refilling mode.
- Compute pollutant emissions per county by fluid type, pollutant type, vehicle class and running/standing/refilling mode.

References

1. *Encyclopedia of Chemical Technology*, Third edition. John Wiley and Sons, New York, NY, 1981.

2. JRB Associates. *Generic Premanufacture Notification Information for Antifreeze Components and Additives*, Draft Final Report, McLean, VA, 1983.

3. Jones, A. *et al.*, *Photochemically Reactive Organic Compound Emissions from Consumer and Commercial Products*, EPA-902/4-86-001 (NTIS PB88-216940), U.S. Environmental Protection Agency, New York, NY, November 1986.

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6. Skinner, S.K and T.P. Dungan. *National Transportation Statistics Annual Report*, DOT-TSC-RSPA-90-2, U.S. Department of Transportation, Transportation Systems Center, Cambridge, MA, 1990.

7. *Highway Statistics 1988*, FHWA-PL-89-003, U.S. Department of Transportation, Federal Highway Administration, Washington, DC, 1989.

8. Simmons Market Research Bureau, Inc. *1978/1979 Selective Markets and the Media Reaching Them -- Automotive Marketing*, Volume 24, New York, NY, 1978.

9. Chemical Specialties Manufacturing Association. *Ethylene Glycol Base Antifreeze Surveys*, Washington, DC, 1982.

10. C.H. Kline and Company. *Multi-client Survey, Gas-line Antifreeze Windshield Washer Antifreeze*, Fairfield, NJ, 1975.

11. Simmons Market Research Bureau, Inc. *Study of Media and Markets*, New York, NY, 1988.

AUTOMOTIVE RUSTPROOFING/UNDERCOATING

Definition/description of category and activity

Automotive rustproofing is the application of solvent-based coatings into vehicle cavities to prevent cars from rusting. This activity should be performed within the first three months. Automotive undercoating is applied to the underside of vehicles for noise deadening. This category covers the application of rustproofing and undercoating materials after a car leaves the plant, such as at a dealership or body shop.

Process breakdown

Surface coating of automobiles and light trucks during the manufacturing process is covered by SIC codes 3711 and 3713.[1] Undercoating and rustproofing of vehicles after they leave the plant are not specified by SIC or SCC code.

Reason for considering the category

VOC emissions from rustproofing currently are not included in the inventories, although they may be accounted for in solvent use.

Pollutants emitted

VOC, including aromatic and aliphatic hydrocarbons, are emitted. Other pollutants, including silicates and lead, may also be emitted.

Estimate of the pollutant levels

Based on available formulation and consumption data, it is estimated that 1,710 TPY of VOC are emitted from undercoatings.[2]

Point/area source cutoff

Since emissions from a single source, such as a dealership or body shop, would probably not exceed 10 TPY, this category should be considered an area source.

Level of detail of information available

EPA has published formulation profiles for a number of solvent-based consumer goods including aerosol undercoatings. There is only one profile for undercoating formulations. The range of percent VOC by weight for undercoatings is estimated at 25 to 85 percent.[2]

Data on consumer demand for undercoatings are not available on a regional basis. Estimates for consumption of undercoatings are available only for California, New Jersey and New York. These estimates are based on the population each state and national consumption of undercoatings in 1984.

Demand for undercoating may be available from supply vendors or from dedicated operations (e.g., Ziebart).

Compounds in undercoatings include iron oxides, silicates, lead or lead salts, zinc and zinc salts, titanium dioxide, alkyd and phenolic resins, fish and vegetables oils, and aromatic and aliphatic hydrocarbons.

Level of detail required by users

County population

Number of vehicles undercoated/rustproofed per year per county

Amount of undercoating/rustproofing material consumed per county

Emission factor requirements

Formulation profiles of undercoatings

Percentage of undercoatings consumed by formulation

Per capita consumption data for different regions

Regional, seasonal or temporal characteristics

There are no data available on regional or seasonal consumption of rustproofing and undercoating material. Rustproofings are used to protect a car from rusting caused by climate, salts on roads and exposure to sea spray (salt). Consumption of rustproofing materials may be higher in coastal areas and in the colder, wetter regions (e.g., New England and the Midwest) during the months preceding winter.

Urban or rural characteristics

Emissions from this source will vary by vehicle population in an area. It is unknown whether consumer demand for rustproofing and undercoating shows any urban versus rural difference.

Methodology

To determine emissions from undercoatings, emission factors representing the formulations of these products must be developed. EPA has developed a profile for one formulation of undercoating; however, a representative emission factor cannot be developed without data on formulations of other undercoatings and market share of each of these formulations. In addition, estimates of consumption by region are needed to account for varying consumer demand for these products.

A survey of automotive shops may yield data on types and amounts of undercoatings used. This survey would have to be performed in all regions of the country to determine if the climate of a region affects the level of consumption of these products. Regional estimates of consumption and product formulation can be applied to population data to estimate emissions for the area under study.

References

1. Stockton, M.B. and Stelling, J.H.E. *Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory*, EPA-600/7-87-015 (NTIS PB87-198735), U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1987.

2. *Compilation and Speciation of National Emission Factors for Consumer/Commercial Solvent Use*, EPA-450/2-89-008 (NTIS PB89-207203), U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1989.

DIESEL FUEL - EVAPORATIVE EMISSIONS FROM SERVICE STATION OPERATIONS

Definition/description of category and activity

Volatile organic gas emissions result from the evaporation of diesel fuel due to the loading and unloading of diesel fuel at service stations. Diesel evaporative emissions at service stations can be separated into four categories: filling underground storage tanks, underground tank breathing and emptying, displacement losses during vehicle refueling operations and spillage.

Process breakdown

Evaporative emissions from filling underground diesel storage tanks are generated when diesel vapors in the tank are displaced to the atmosphere by the diesel fuel being loaded into the tank. Loading loss emissions are dependent on fuel temperature, vapor pressure, method and rate of filling and tank configuration.

Underground tank breathing emissions occur daily and are attributable to diesel evaporation, barometric pressure changes and diurnal temperature changes. Diesel evaporation is a function of the frequency with which diesel fuel is withdrawn from the tank, allowing fresh air to enter the tank.

Displacement loss emissions during vehicle refueling operations occur as vapors are displaced from the motor vehicle tank by dispensed diesel. The quantity of displaced vapors depends on diesel temperature, motor vehicle tank temperature, diesel vapor pressure and dispensing rate.

Spillage emissions include prefill and postfill nozzle drip and spit-back and overflow from the vehicle's fuel tank filler pipe during filling. The amount of spillage can depend on several variables, including service station business characteristics, tank configuration and operator techniques.

Reason for considering the category

VOC emissions from diesel refueling at service stations have traditionally been considered negligible since the vapor pressure of diesel is significantly less than the vapor pressure of gasoline. Emissions from diesel refueling may be of some importance due to large quantities of diesel fuel (17.6 billion gallons per year) transferred during service station and vehicle refueling. Emission factors for diesel refueling are not currently included in the MOBILE4 emission factors model.[1] VOC from diesel evaporation are precursors in ozone formation.

Pollutants emitted

VOC unbranched paraffins (i.e., heptane, octane, nonane, n-decane, n-undecane, n-dodecane, n-tridecane, n-tetradecane and n-pentadecane)

Estimate of the pollutant levels

There has been no attempt to quantify evaporative diesel emissions from service station refueling at the national or county level. An attempt has been made to estimate diesel emission factors for evaporative losses for this characterization. Table 1 lists the current *AP-42* emission factors available for gasoline loading losses and the estimated diesel evaporative losses (emission factors) from service station operations.[2] Total diesel evaporative losses from service station operations are estimated to be

approximately 6,800 TPY for 1987 using the guidance available in Reference 3. Table 2 lists evaporative diesel emissions from service station operations for the individual emissions categories.

Point/area source cutoff

Service station operations having emissions that exceed the point source cutoff for an inventory (100 TPY for NEDS) are considered point sources. Using estimated emission factors shown in Table 1, a service station which sells 258 million gallons of diesel fuel per year would emit approximately 100 TPY and would be considered a point source.

Level of detail of information available

AP-42 emission factors for filling underground storage tanks:

0.014 lbs VOC/1,000 gallons transferred (submerged loading - dedicated normal service)
0.03 lbs VOC/1,000 gallons transferred (splash loading - dedicated normal service)

State sales data for total diesel fuel are available from *Highway Statistics*[4] and from state fuel tax offices.

Level of detail required by users

Diesel fuel sales at a county or state level

Type of filling (fuel loading)

Emission factor requirements

Development of diesel emission factors for underground tank breathing and emptying losses, vehicle refueling displacement losses and, especially, spillage losses, based on observed emissions rather than just engineering judgement.

Regional, seasonal or temporal characteristics

Emissions from fuel loading are higher in the summer due to higher diesel fuel temperatures. Emissions from tank breathing and emptying are a function of average ambient diurnal temperature change.

Urban or rural characteristics

An urban and rural source

Methodology

Presently no methodology exists for estimating evaporative diesel emissions from service station operations. The emission factors developed for diesel refueling may need further verification to ensure that they reflect actual refueling conditions. The methodology used to estimate evaporative gasoline emissions from service station activities can be used to estimate evaporative diesel emissions. County-wide diesel evaporative emissions can be estimated by apportioning state sales of diesel fuel to the

TABLE 1. COMPARISON OF GASOLINE AND DIESEL EVAPORATIVE EMISSION FACTORS FROM SERVICE STATION OPERATIONS[2]

Emission Source	Gasoline Emission Rate mg/liter Throughput	Gasoline Emission Rate lb/10³ gal Throughput	Diesel Emission Rate mg/liter Throughput	Diesel Emission Rate lb/10³ gal Throughput
Filling underground tank[a]				
Submerged filling	880	7.3	2.8	0.0231
Splash filling	1,380	11.5	4.0	0.0334
Balanced submerged filling	40	0.3	0.14	0.0012
Underground tank breathing and emptying[b]	120	1.0	1.0	0.0086
Vehicle refueling operations				
Displacement losses[c] (uncontrolled)	1,320	11.0	4.0	0.0334
Displacement losses (controlled)	132	1.1	0.4	0.0033
Spillage[d]	80	0.7	80	0.7

[a]Emissions from filling underground tanks were calculated using the AP-42 loading equation:

$$L_L = 12.46 \frac{SPM}{T} \quad (1)$$

where: L_L = Loading loss, lb/10³ gal of liquid loaded
M = Molecular weight of vapors, lb/lb-mole
P = True vapor pressure of liquid loaded, psia
T = Temperature of bulk liquid loaded, °R (°F + 460)
S = Saturation factor

Gasoline loading loss emissions were calculated for a gasoline temperature of 60°F and RVP of 10. Diesel loading loss emissions were calculated for distillate fuel no. 2 and a temperature of 60°F.

[b]Includes any vapor loss between underground tank and gas pump. The diesel emissions factor was estimated by assuming underground tank breathing and emptying losses are similar to breathing loss emissions from a fixed roof tank. Diesel emissions were estimated by taking the gasoline breathing loss emissions factor and adjusting for the difference in vapor pressure of gasoline and diesel with the following equation:

$$\text{Adjustment factor} = \frac{P_{diesel}/(P_A - P_{diesel})^{0.68}}{P_{gasoline}/(P_A - P_{gasoline})^{0.68}}$$

where: P_A = average atmospheric pressure at tank location (psia)
$P_{gasoline}$ = true vapor pressure of gasoline at bulk liquid conditions (psia)
P_{diesel} = true vapor pressure of diesel at bulk liquid conditions (psia)

[c]Uncontrolled diesel displacement losses from refueling are assumed to be equal to losses from splash loading. Assume controlled diesel emissions from refueling (displacement losses) have a control efficiency of 90 percent.

[d]Assume spillage from diesel refueling is equal to spillage from gasoline refueling.

TABLE 2. DIESEL EVAPORATIVE EMISSIONS FROM SERVICE STATION OPERATIONS

Emission Source	Emissions[a] Tons per year
Filling underground tank - splash loading	294
Underground tank breathing and emptying	76
Vehicle refueling operations - Displacement losses (uncontrolled)	294
Spillage	6,166
Total Emissions	6,830

[a]Assumes diesel fuel accounts for 95 percent of the total diesel and liquified petroleum gas consumption in 1987.

county level based on vehicle-miles travelled and multiplying by the appropriate emission factor. Apportioning state diesel fuel sales to the county level could also be based on total mileage, county population, county vehicle registration and service station employment.

References

1. *User's Guide to MOBILE4 (Mobile Source Emission Factor Model).* EPA-AA-TEB-89-1 (NTIS PB89-164271), U.S. Environmental Protection Agency. Office of Air and Radiation. Office of Mobile Sources. February 1989.

2. *Compilation of Air Pollutant Emission Factors*, Fourth Edition and Supplements, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1985 through September 1991.

3. Kersteter, Sharon L. *Procedures for the Preparation of Emission Inventories for Precursors of Ozone, Volume I, Third Edition*, EPA-450/4-88-021 (NTIS PB89-152409), U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1988.

4. *Highway Statistics*, U.S. Department of Transportation, Federal Highway Administration, Washington, DC. Annual publication.

VEHICLE LUBRICATING

Definition/description of category and activity

Activities in this category are limited to lubrication or greasing. Lubrication is the application of a substance of low viscosity between two adjacent solid surfaces (one of which is in motion) to reduce friction, heat and wear between the surfaces.

A *lubricating grease* is a mixture of a mineral oil or oils with one or more soaps. The most common soaps are those of sodium, calcium, barium, aluminum, lead, lithium, potassium and zinc. Oils thickened with residuum, petrolatum or wax may be called greases. Some form of graphite may be added. Greases range in consistency from thin liquids to solid blocks and in color from transparent to black. Grease specifications are determined by the speed, load, temperature, environment and metals in the desired application.[1,2]

Synthetic lubricants are any of a number of organic fluids having specialized and effective properties that are required in cases where petroleum-derived lubricants are inadequate. Each type has at least one property not found in conventional lubricants. The major types are polyglycols (hydraulic and brake fluids), phosphate esters (fire-resistant), dibasic acid esters (aircraft turbine engines), chlorofluorocarbons (aerospace), silicone oils and greases (electric motors, antifriction bearings), silicate esters (heat transfer agents and hydraulic fluids), neopentyl polyol esters (turbine engines) and polyphenyl ethers (excellent heat and oxidation resistance, but poor low temperature performance).[3]

Process breakdown

Emissions from automotive lubricants are associated with refilling or replacing and emissions from standing losses.

Reason for considering the category

The compounds in automotive lubricants are largely hazardous, composed of toxic and ignitable chemicals. Lubricating grease and synthetic lubricants contain VOC that evaporate on use and are carried into the atmosphere. VOC photochemically react in the atmosphere to produce ozone and secondary particulate matter. EPA has determined that ozone in the ambient air damages human health and the environment. Over 100 major metropolitan areas, representing one third of the United States population, are exposed to excessive levels of ozone. Lubricating grease may represent a significant source of unaccounted VOC.

Pollutants emitted

VOC
Air toxics

Estimate of the pollutant levels

No estimations are currently available.

Point/area source cutoff

Emissions per vehicle and/or emissions per service station are expected to be less than 10 TPY. This category should be included in the area source inventory.

Level of detail of information available

It is likely that data on automotive fluid use will be derived from vehicular use data, such as those provided by References 4 and 5. In addition, total number of vehicles by county are available from each state's Department of Motor Vehicles. In 1988, 141,251,695 passenger cars and taxis were registered in the United States. Total VMT for cars was 2,025,586.[4] Total bus VMT was estimated to be 7,830 for 1988, based on data on state motor vehicle registration data. Total truck VMT was estimated to be 580,802.[5]

Emissions per volume of automotive fluid must be determined from field experiments, since few emission factors have yet been developed.

Level of detail required by users

Service stations per county

Vehicles serviced per station

Class of vehicle serviced

Fluid use per vehicle

Emissions per volume of fluid

Emission factor requirements

Development of VOC emission factors per county, lubricant type, vehicle class and standing/refilling mode

Regional, seasonal or temporal characteristics

No regional, seasonal or temporal effects are expected.

Urban or rural characteristics

Automotive lubricants are used in urban, suburban and rural areas. Use per vehicle or per capita is expected to vary by area.

Methodology

- Determine the number of service stations per county.
- Determine the number of vehicles serviced by vehicle class.
- Determine the amount of fluid used per vehicle, by fluid type and vehicle class.

- Develop emission factors through field studies to determine emissions per unit volume of fluid used. This factor may be broken down by fluid type, pollutant type and standing/refilling mode.
- Compute pollutant emissions per county broken down by fluid type, pollutant type, vehicle class and standing/refilling mode.

References

1. Gressner, H. *The Condensed Chemical Dictionary*, Van Nostrand Reinhold Company Incorporated, New York, NY, 1981.

2. *Encyclopedia of Chemical Technology*, Third Edition, John Wiley and Sons, New York, NY, 1981.

3. *Chemical and Process Technology Encyclopedia*, McGraw-Hill, Incorporated, New York, NY, 1974.

4. Skinner, S.K and T.P. Dungan. *National Transportation Statistics Annual Report,* U.S. Department of Transportation, Transportation Systems Center, Washington, DC, 1990.

5. *Highway Statistics,* U.S. Department of Transportation, Federal Highway Administration, Washington, DC. Annual publication.

VEHICLE REPAIR

Definition/description of category and activity

Vehicle repair activities generate emissions from solvents used to clean carburetors, brakes and engines and from engine starting fluids. These activities may be performed by consumers or by service stations. Composition of automobile starting fluids, automotive brake cleaners, engine degreasers and carburetor and choke cleaners are listed in Table 1. VOC emissions result from evaporation of solvents and propellants, primarily butane, in automotive cleaning products.[1,2]

Process breakdown

Automotive repair cleaning products are manually applied by professional mechanics and vehicle owners. The automotive cleaning products mentioned above are usually in the form of aerosol cans. Evaporation of organic solvents and propellants releases VOC to the atmosphere.

Reason for considering the category

VOC emissions from vehicle repair have traditionally been considered negligible. Recent studies have shown that national VOC emissions from carburetor and choke cleaners, brake cleaners, engine degreasers and engine starting fluids are 13,093 TPY, 9,824 TPY, 5,192 TPY and 9,034 TPY, respectively. Many of the VOC used for vehicle repair are precursors in ozone formation.

Pollutants emitted

VOC, including the following compounds:[1]

- Acetone
- Aliphatic hydrocarbons
- Aromatic 150 solvent
- Butane
- Butyl cellosolve
- Complex amines
- Cresylic acid
- Cresol (o-,m-,p-)
- o-Dichlorobenzene
- Ethanolamine
- Ethyl alcohol
- Ethylene dichloride
- Ethyl ether
- Heavy aromatic naphtha
- Isomers of xylene
- Isopropyl alcohol
- Kerosene
- Methyl alcohol
- Methylene chloride
- Mineral spirits
- Perchloroethylene
- Pine oil
- Tetrahydrofurfuryl
- Toluene

Estimate of the pollutant levels

National VOC estimates for solvents used in automotive repair in 1986 are 37,143 tons per year.[3]

TABLE 1. FORMULATION PROFILES FOR AUTOMOBILE STARTING FLUIDS, AUTOMOTIVE BRAKE CLEANERS, ENGINE DEGREASERS AND CARBURETOR CLEANERS[1]

Species Name	Percent by Weight
Carburetor and Choke Cleaners	
Formulation 1	
Butane	12.00
Ethylene dichloride	63.00
Cresol	25.00
Formulation 2	
Aliphatic hydrocarbons	88.00
N-Butane	12.00
Formulation 3	
N-Butane	24.00
Ethyl alcohol	11.00
Ethylene dichloride	30.00
Cresol (o-,m-,p-)	35.00
Formulation 4	
Methyl alcohol	11.11
Tetrahydrofurfuryl alcohol	11.11
Acetone	5.56
Isomers of Xylene	33.33
Toluene	38.89
Formulation 5	
Methylene chloride	42.10
Cresylic acid	15.80
Complex Amines	0.53
o-Dichlorobenzene	41.57
Brake Cleaners	
Formulation 1	
Methyl alcohol	100.00
Formulation 2	
Ethyl alcohol	100.00
Formulation 3	
Isopropyl alcohol	100.00

(continued)

TABLE 1. FORMULATION PROFILES FOR AUTOMOBILE STARTING FLUIDS, AUTOMOTIVE BRAKE CLEANERS, ENGINE DEGREASERS AND CARBURETOR CLEANERS[1] (continued)

Species Name	Percent by Weight
Engine Degreasers	
Formulation 1	
Isopropyl alcohol	100.00
Formulation 2	
Kerosene	100.00
Formulation 3	
Aromatic 150 solvent	100.00
Formulation 4	
Mineral spirits	100.00
Formulation 5	
Heavy aromatic naphtha	100.00
Formulation 6	
Pine oil	37.27
Kerosene	59.04
Ethanolamine	3.69
Formulation 7	
Kerosene	87.03
Butyl cellosolve	2.22
Ethanolamine	1.48
Perchloroethylene	9.28
Formulation 8	
Butyl cellosolve	25.00
Kerosene	75.00
Formulation 9	
Butyl cellosolve	100.00
Engine Starting Fluids	
Ethyl ether	100.00

Point/area source cutoff

Emissions from automotive repair should be considered in the area source inventory since emissions from any one point would not exceed the point source cutoff.

Level of detail of information available

The number of registered vehicles by county is available from state Departments of Motor Vehicles. National VOC estimates for service stations, emissions per vehicle registered and per capita emissions are listed in Table 2.

TABLE 2. VOC EMISSION FACTORS FOR AUTOMOTIVE PRODUCTS[3]

Product	National VOC Emissions (tons/year)	LB/YR VOC Per Vehicle Registered	LB/YR VOC Per Capita
Carburetor and Choke Cleaners	13,093	0.193	0.109
Brake Cleaners	9,824	0.145	0.082
Engine Degreasers	5,192	0.077	0.043
Engine Starting Fluid	9,034	0.133	0.075

Level of detail required by users

Population data by county or the number of registered vehicles by county

Emission factor requirements

Amount of VOC emitted per repaired vehicle

Regional, seasonal or temporal characteristics

None known

Urban or rural characteristics

These activities occur in both urban and rural areas, but are population (human and/or vehicle) dependent.

Methodology

Since county-wide vehicle registrations are available from state Departments of Motor Vehicles, multiplying the number of registrations by the appropriate emission factors will provide county-wide emissions estimates of VOC from automobile repair. However, these emission factors were developed using sales data and may not reflect the actual VOC emissions from automobile repair.

References

1. Jones, A. *et al.*, *Photochemically Reactive Organic Compound Emissions from Consumer and Commercial Products*, EPA-902/4-86-001 (NTIS PB88-216940), U.S. Environmental Protection Agency, New York, NY, November 1986.

2. *Technical Support Document for a Proposed Regulation to Reduce Volatile Organic Compound Emissions from Consumer Products*, California Air Resources Board, Solvents Control Section, Criteria Pollutants Branch, Sacramento, CA, August 1990.

3. *Compilation and Speciation of National Emission Factors for Consumer/Commercial Solvent Use. Information Complied to Support Urban Air Toxics Assessment Studies*, EPA-450/2-89-008 (NTIS PB89-207203), U.S. Environmental Protection Agency, Research Triangle Park, NC. April 1989.

COOLING TOWERS

Definition/description of category and activity

VOC and TSP emissions from the vented vapors of cooling systems due to process contaminants in the cooling water; anti-fouling, anti-scaling, anti-corrosion or other water conditioning additives; and/or suspended and entrained organics and particulate matter (drift) are carried in the warm vapors. Cooling towers considered include utility cooling towers, industrial process cooling water towers, commercial cooling towers (e.g., dry cleaners) and 'comfort' cooling towers (i.e., cooling towers used to maintain a specified environment or refrigeration system).[1,2] In particular, chlorination of fresh waters as a biocide produces volatile trihalomethanes (THM) such as chloroform, trichloroethylene, tetrachloroethylene, etc., that are released to the atmosphere.[3,4]

Process breakdown

Emissions are released from the cooling tower outlet, usually a stack or vent (particulate and VOC), and from evaporation from the cooling pond (where applicable).

Reason for considering the category

Cooling towers have not traditionally been considered emissions sources except in large industrial processes, but are a ubiquitous source (200,000 to 300,000 'comfort' towers in the United States) in urban areas and may release organic and particulate toxics to the atmosphere. The volume of water used for cooling is large and the potential for emissions is therefore significant.

Pollutants emitted

VOC (including chloroform) through volatilization and drift, TSP from drift

Estimate of the pollutant levels

50 to 110 kg THM/yr/utility tower (SCAQMD estimates 0.4 TPY chloroform, the principal species, from utilities in the South Coast Air Basin (SCAB).)[3]

7,000 to 200,000 kg Cr/year - 'comfort' cooling towers[2]

0.0034 to 0.034 lb $CHCl_3$/lb chlorine equivalent for chlorinated industrial (and utility) cooling waters, or about 4.1 lb $CHCl_3$ per thousand gallons per minute for large cooling operations. SCAB estimates 2.3 TPY chloroform in the South Coast Air Basin from industrial sources.

Refinery Cooling Towers:	6 lbs VOC/MG cooling water
	10 lbs VOC/1,000 bbls refinery feed

Point/area source cutoff

Industrial cooling towers (e.g., refineries) are properly coded in the point source inventory. A review of the NEDS SCC listing showed cooling tower SCCs only for refineries.[5] Also, small industrial sources (less

than 100 TPY) which use cooling towers to maintain cold storage, small chemical manufacturers and even large utilities may be missing from the point source inventory. Part of the reason for their absence is that the tower as an individual point source emits less than 10 TPY.

Level of detail of information available

EPRI likely has information on the number of and the emissions from utility cooling towers.

State-level 'comfort' cooling tower numbers probably can be derived from Reference 2, but growth in their numbers is unknown.

Emission Factors: Chloroform emission factor, VOC emission rate from utilities, industrial emission factors from NEDS point source factors

Level of detail required by users

Emissions by county

TSP and VOC emission factors by cooling tower type

Number, type and throughput (gpm) of cooling towers per county

Other contaminants in the cooling water streams subject to evaporation and entrainment

Emission factor requirements

Total TSP and VOC emission factors by cooling tower type per tower or per throughput

Regional, seasonal or temporal characteristics

Greater emissions (use) in the cooling season

Urban or rural characteristics

Principally an urban source

Methodology

Existing information sources would provide a methodology to estimate VOC emissions from utility and industrial cooling towers when these populations have been defined. 'Comfort' cooling tower VOC emissions estimates could be based on the utility sources, but would overestimate emissions in cases where chlorine is not used as a biocide. No information on TSP from cooling towers was found.

References

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ADHESIVES AND SEALANTS - COMMERCIAL

Definition/description of category and activity

Commercial use of solvent-based adhesives and sealants takes place primarily in the service and construction sectors. Commercial adhesives include structural glues used for a variety of purposes, including wood bonding. Commercial sealants include sealants used for roof repair, gutter and drain sealing, glazing, general crack repair and joint sealing, bathroom caulking and swimming pool repair.

Process breakdown

Adhesive and sealant production is covered by SIC 2891. Consumption is covered in the point source inventory by SCC 4-02-007-01.

Reason for considering the category

Solvent-based adhesive, caulk and sealant use is currently not included in emissions inventories. The emission factor for adhesives, caulks and sealants is based on VOC emissions per ton applied; however, there is no emission factor associated with SCC 4-02-007-01.

Pollutants emitted

VOC, including isopropyl alcohol and isomers of xylene from sealants and caulks and acetone, alcohol 740 P, amyl acetate, L-camphor, ethylene glycol, nitropropane (1-,2-), petroleum oil, toluene and tricresol phosphate from adhesives[1]

Estimate of the pollutant levels

National emissions of VOC from caulks and sealants were estimated at 22,667 tons for 1986; emissions from adhesives were estimated at 9,350 tons in 1986.[1] While it is difficult to separate consumer, commercial and industrial uses of these products, consumer use is estimated at about five percent of total adhesives.[1,2] The application of a product bought at a hardware store or "do-it-yourself" supply channel would be considered as a consumer, rather than commercial, application. Additionally, some of the construction application of adhesives would be considered a commercial source. This includes adhesives used in installing floors, laying carpets and papering walls.[3] These factors make it difficult, if not impossible, to estimate the amount of pollutants emitted by commercial applications of adhesives and sealants. Most commercial uses of adhesives and sealants are probably included under consumer use; a few of the applications, such as caulking of windows in a building, may be included under industrial use. The use of consumer adhesives (those sold through do-it-yourself supply channels) was estimated by one source to be 194 million pounds per year; the Predicasts Terminal System U.S. Time Series database shows only 44 million pounds per year of consumer adhesives by households. This difference may be an indication of the amount of household adhesives that is used by the commercial sector.

Point/area source cutoff

Emissions from commercial adhesive and sealant use will probably not exceed ten TPY from any one source. Therefore, these emissions should be included in the area source inventory.

Level of detail of information available

EPA has published speciation profiles for several solvent-based consumer/commercial goods including profiles for caulks, sealants and adhesives. There are three profiles for formulations of consumer sealants and caulks and seven profiles for consumer adhesives. The range of percent VOC by weight for sealants and caulks is zero to twenty percent. Based on equal market shares for each formulation, the average composition of sealants and caulks is six percent isopropyl alcohol and 94 percent isomers of xylene. Unfortunately, data for associating formulations with brand names are not complete nor are data on market share by brands or formulations available. Therefore, it is not possible to develop a composite emission factor for sealants and caulks. Consumer demand for sealants and caulks does not vary between regions in the United States; per capita VOC emissions from caulks are estimated at 0.188 pounds.[1]

The formulations of consumer/commercial adhesives range from zero to 85 percent in VOC content. Of the seven formulations, two contained petroleum oil and two contained toluene. Other VOC, including acetone, amyl acetate, L-camphor, ethyl alcohol 740 P, nitropropane, ethylene glycol and tricresol phosphate, appear in at least one formulation. In the two formulations with petroleum oil, the petroleum oil accounts for 100 percent of the VOC. Toluene accounts for 72 percent, by weight, of the VOC in one of the formulations in which it is found and 100 percent in the other. Formulations are not always associated with brand names and, even when that information is available, data on market share by product name are not readily available. Therefore, at this time it is not possible to determine an average VOC content or a species profile for VOC in consumer/commercial adhesives.

Consumer demand for adhesives varies by region in the United States. This means that per capita VOC emissions from consumer/commercial use of adhesives vary by region. Estimates of VOC emissions from consumer and commercial applications are presented in Table 1. There is not enough information available to separate these numbers into consumer and commercial emissions.

TABLE 1. ESTIMATES OF PER CAPITA VOC EMISSIONS FROM ADHESIVES

Marketing Region	VOC Emissions (lbs/capita)
New England	0.079
Middle Atlantic	0.079
North Central	0.083
South Atlantic	0.070
South Central	0.070
Mountain	0.082
Pacific	0.082

Level of detail required by users

Population of area

Marketing region of area

Amount of adhesives used by the commercial sector that are classified as consumer or industrial applications

Amount of caulks and sealants used by the commercial sector that are classified as consumer or industrial applications

Emission factor requirements

The amount of adhesives consumed by the commercial sector by formulation (this may vary regionally depending on percentage of sales of different brands)

The percentage of sealants and caulks consumed by the consumer sector by formulation (this may vary regionally depending on percentage of sales of different brands)

Regional, seasonal or temporal characteristics

Consumer use of sealants and caulks will probably not vary by geographic area; market surveys indicate that per capita use of caulks and sealants does not vary regionally for consumer use of these products. These "consumer" use data include most commercial usage of adhesives and sealants. There is some variation in use of adhesives in different regions of the United States. The highest per capita use is in the North Central States and the lowest is in the South Atlantic and South Central States. There is approximately a 17 percent difference in amount of adhesives used in the high-consumption and low-consumption states.[1]

Urban or local characteristics

Areas with a large amount of new construction will probably have large amounts of commercial and consumer adhesive and sealant usage associated with caulking of bathrooms, wallpapering and laying carpets.

Methodology

To determine emissions from caulks, sealants and adhesives, emission factors that represent the brands and formulations of these products must be developed. Although EPA has developed emission factors and speciation profiles for different formulations used to make these products, a representative emission factor cannot be developed until information on market share of different brands, and the formulation of these brands, is available. Adhesives is a particularly difficult commercial market to identify because many uses of adhesives are not included in most studies. Estimates of actual use of adhesives range from 20 percent of the figure reported by the U.S. Department of Commerce, Bureau of the Census to many times the officially reported number. Data on commercial/consumer uses and markets for adhesives may not improve; consumer use of adhesives is estimated at only five percent of the total market. Since product composition and market shares for products are subject to constant change, it may not be possible or worthwhile to develop overall speciation profiles for adhesives and sealants.[1]

EPA has presented per capita and by-formulation emission factors. An estimate of VOC emissions from adhesives and sealants can be developed by applying population estimates to the appropriate per capita emission factor. Another, more costly method involves performing a survey of commercial users of solvents and adhesives for each area of interest. Most commercial usage is associated with construction or remodeling of homes. Once the most commonly used product brands have been identified, formulation data may be obtained from an existing source or the manufacturer may be contacted to provide more detailed composition data. A comprehensive survey of commercial users of adhesives and sealants would also help in determining the amount of commercial versus consumer applications of products.

References

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LAMINATING

Definition/description of category and activity

Lamination is the bonding of layers of materials together for structural, protective or decorative purposes. Laminating encompasses commercial and industrial applications, ranging from industrial production of pipe and building materials to commercial activities such as home building. Typical laminating markets are construction and packaging. Laminating products include counter tops, wall panels, cabinetry and specialty packaging. No consumer applications are known. Adhesives used in the laminating process are the sources of VOC emissions. Some particulate matter is also generated from the handling of filler materials and the trimming during finishing operations. Table 1 presents the major industrial laminating processes, polymers and products.

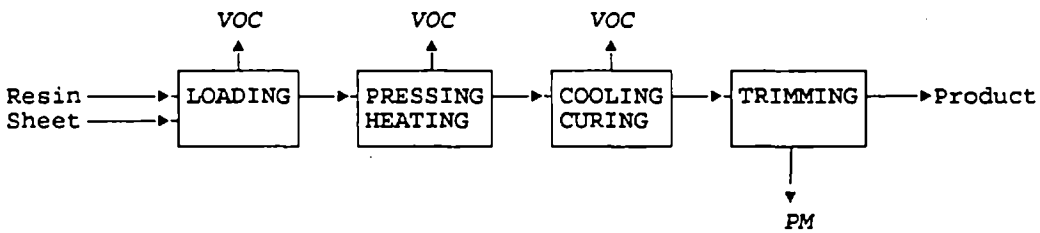
TABLE 1. INDUSTRIAL LAMINATING PROCESSES, POLYMERS AND PRODUCTS

Process	Polymer	Products
Flat Laminate Sheets	Epoxy Resins Melamine Formaldehyde Phenolic Resins Alkyd Polyesters Paper or Cloth Sheets	Counter Tops Furniture Panels Fuse Boxes Terminal Blocks Transformer Insulation Wall and Ceiling Panels Cut-Out Products Printed Circuit Panels
Laminate Rods and Tubes	Epoxy Resins Melamine Formaldehyde Phenolic Resins Alkyd Polyesters Paper or Cloth Sheets	Rods, Tubes and Profile Shapes Tanks Pressure Bottles Pipe (oil, chemical, water and sewage)
Continuous Laminating	Alkyd Resins Chopped Glass Fibers	Awnings Fences Greenhouse Panels Counter Tops Wood Panels Patio Covers Table Tops Truck and Trailer Panels and Liners

Process breakdown

In the point source inventory, laminating is covered solely under SCC 4-02-007-xx (adhesive application). Within existing area source inventories, VOC emissions are allocated from the national solvent total (NEDS) or counted in commercial/consumer solvents from the per capita factor (SIP).

Laminate products are produced from thermosetting resins and filler sheets. Typical resins include alkyd polyesters, epoxies, melamine formaldehyde and phenolic resins. Three major processes are used to produce laminated materials: flat sheet, rod/tube and continuous sheet. Flat sheet is the dominant method and is presented in a simplified diagram below. In an industrial setting, emissions could be vented from the workplace to the atmosphere with or without a control device.



Particulates are generated from the handling and trimming operations. Sources include the additives, the resin and the fibers. Emissions from tube and continuous laminating are generated from similar processes to those detailed above. VOC amounts and species will vary between applications.

Reason for considering the category

Laminating is a VOC source due to solvent content of the adhesive carriers and additives (colorings, plasticizers, hardeners, catalysts, etc.) that are released during the laminating and curing processes. There are currently no point source SCCs specifically for industrial or commercial laminating processes. However, this category is a subset of the commercial adhesives category.

Pollutants emitted

VOC (primary)
PM (secondary)

Estimate of the pollutant levels

EPA estimated emissions from adhesives to be 9,350 tons VOC in 1986.[1] The portion of this amount originating from laminating processes is unknown. Laminating is only one of many uses for these adhesives. No estimate of particulates is available, but particulate emissions are probably very small.

Point/area source cutoff

Industrial applications emitting more than ten TPY VOC should be categorized in point source inventories under solvent emissions from adhesives. Commercial applications are likely to emit less than ten TPY and should be assigned to the area source inventory. No consumer applications are known for this category.

Level of detail of information available

Emissions from laminating are associated with the solvents present in adhesives used during the process. Some adhesives have been characterized for their VOC content, but adhesives used in the laminating

processes have not specifically been addressed. No current breakdown of the amounts of adhesives used in laminating compared to overall solvent uses is available.

Level of detail required by users

Point Source SCCs and emission factors are necessary to properly classify industrial laminating applications. Adhesive consumption and solvent content are required to generate emissions estimates for point sources.

Area Source Information compiled for adhesives will cover laminating emissions. Necessary information for the existing per capita methodology requires population statistics and identification of the specific marketing region. For this specific application, laminating adhesives content and amount consumed need to be identified (by product).

Emission factor requirements

Laminating adhesive formulations and consumption are required to develop product/process-specific emission factors. Formulation and market penetration are probably regionally variable. Alternately, per capita consumption figures and population could be used.

Regional, seasonal or temporal characteristics

No known regional, seasonal or temporal characteristics

Urban or rural characteristics

Sources, especially commercial uses, are likely to be predominantly urban.

Methodology

Current methods used to estimate emissions either allocate national solvent consumption to the area under study based on employment and population statistics or apply a per capita factor to solvent use. Estimating emissions resulting from specific uses (like laminating) in a study area requires emission factors to be determined from formulation data of brand-specific consumption. Potential control of VOC emissions is enhanced by specific information on the uses, requirements and formulations of industrial/commercial processes and products. As a start, survey of the adhesives market should precede determination of specific niches like laminating.

Product-specific information requires formulation testing, market surveys and sales statistics at regional levels to produce the necessary data to estimate emissions in each area of interest. Many of these data may be obtained from manufacturers and trade associations. However, formulations and market shares may be subject to constant change due to economic and technological changes in the market.

References

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2. Jones, A. *et al.*, *Photochemically Reactive Organic Compound Emissions from Consumer and Commercial Products,* EPA-902/4-86-001 (NTIS PB88-216940), U.S. Environmental Protection Agency, New York, NY, November 1986.

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LAUNDRY PRODUCTS
COMMERCIAL AND CONSUMER

Definition/description of category and activity

Some commercial and consumer laundry products contain volatile organics including petroleum distillates and ethanol. These components are emitted to the indoor air as the product is used or vented to the atmosphere. Commercial dry cleaning is a current point and area source category and is therefore excluded from the laundry products category. Initially, an attempt was made to differentiate consumer and commercial products. However, existing inventories and data do not separate these categories. Formulation differences between consumer and commercial products, and the problem of double-counting consumer solvents, indicate that these categories probably should be divided when the supporting data are available.[1]

Process breakdown

Laundry products are further divided by product type. The products identified as potential emissions sources are aerosol starches and sizings, aerosol stain remover, prewashes and liquid laundry detergent. No information on the potential of VOC from fabric softeners or products added to the drying cycle was located. Laundry products are sprayed, poured or rubbed into the fabric or added to washing machines. Solid and powder products have not been associated with emissions of VOC.

Reason for considering the category

Although the VOC content in some laundry formulations may already be accounted for in consumer solvent totals, VOC control strategies are already considering laundry products as an individual emissions source in California.[2] To fully address emissions from commercial and consumer products in SIP inventories and control strategies, these sources need to be enumerated separately.

Pollutants emitted

VOC - including ethanol, nonethyl amine, 1,2-propanediol, trichloroethylene, butane, perchloroethylene, methylene chloride, formaldehyde, isopropyl alcohol, etc.

Estimate of the pollutant levels

Product	Emissions (Estimated)	Basis of Estimate
Liquid Laundry Detergent	7,000 TPY (Ethanol)	Reference 3
Prewash	6,000 TPY	Reference 2
Starch/Fabric Finish	3,000 TPY	Reference 4
Spot Remover	1,000 TPY	Reference 4
TOTAL	17,000 TPY	

These national estimates do not distinguish between consumer and commercial products. The annual national estimates have been based on the source information indicated. However, only Reference 3

supplied national data. The other estimates have been extrapolated from California estimates on the basis of population. The original estimates were made on the basis of product content and annual use.

The estimates presented above are based on the average of the potential emissions data ranges presented in the original documents. Worst case potential emissions are estimated to be about 40,000 TPY based on the high end of ranges given in the literature. For example, one CARB study estimates total prewash, starch and stain remover emissions as 6.6 tons per day, translating to roughly 22,000 TPY on an annual national basis (this estimate excludes liquid laundry detergents).[5] The liquid detergent estimate is based on measured emissions during laundering from washing machines; the other estimates assume 100 percent volatilization of the VOC component. VOC not emitted during the wash cycle would be considered within the wastewater treatment plant.

Point/area source cutoff

There are no current point source categories for laundry products. Emissions per location are likely to be far below point source inventory cutoffs.

Level of detail of information available

Present inventory methods rely on product formulation data, market share and sales data to estimate product VOC content (and therefore emissions) in an area. Inventory studies on laundry products have been done in California, but no laundry product inventories were located for other geographic regions. California is currently planning another survey next year. Market share data must be purchased from one of the national business statistics firms such as Simmons, A.C. Nielson, etc. These data are quite expensive. The *Census of Manufactures* covers soap, cleaners and toilet goods, but this is a measure of production within SIC grouping.[6] Emissions are allocated on the basis of population statistics derived from Census data.

Level of detail required by users

Studies done in one area of the country can be extrapolated to other areas or the nation as a whole on the basis of population. However, the difference in product formulation, market penetration and individual use patterns increase the uncertainty of values derived from this strategy. Even existing studies assume a uniformity of product formulations. In the commercial/institutional sector, many formulations are tailored to the individual cleaning needs of the client and information from each manufacturer of each product would be necessary for a more accurate representation.

Emission factor requirements

VOC content and sales data per product type or individual product are necessary to develop inventories based on use or sales. Alternately, development of per capita and per employee emissions factors may be viable strategies.

Regional, seasonal or temporal characteristics

None

Urban or rural characteristics

No special characteristics

Methodology

Two methods are apparent from the current information available. Any estimate would have to be subtracted from current estimates of "consumer solvents." A rough estimate can be derived based on California emissions data. These data could be used to derive a per capita factor that could be applied for any inventory. This method discounts differences in product formulation, market penetration and individual preferences and does not differentiate commercial and consumer products. Data on bulk products in the *Census of Manufactures* may be used to roughly separate product totals into the two sectors. The method does not recognize that commercial products are often developed to meet client specifications.

A second, more detailed, method would rely on the Soap and Detergent Association to interact with its members and access proprietary formulation and market data to derive emissions estimates. The resolution of these estimates would necessarily be dependent on the available data and the potential uses, but may be on a state, regional or per capita basis. This approach would entail a great deal of effort, although the bulk of the effort could be coordinated through the trade association. Cooperation of the trade association would assure access to confidential data during the development of formulation and market data. In either effort, changes in the regulatory, economic or technological climate would affect application of current data in future years. This method may be able to supply individual commercial and consumer estimates.

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4. Jones, A. *et al., Photochemically Reactive Organic Compound Emissions from Consumer and Commercial Products,* EPA-902/4-86-001 (NTIS PB88-216940), U.S. Environmental Protection Agency, New York, NY, November 1986.

5. *Study of the Efficacy of Aerosol versus Nonaerosol Laundry Products.* ARB/R-87/1317 (PB88-128749), California Air Resources Board, Sacramento, CA, October 1987.

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TRAFFIC PAINTING

Definition/description of category and activity

Highways, roads and parking lots are marked with many different materials, including solvent-borne paints, water-borne paints, thermoplastics, preformed tapes, field-reacted materials and permanent markers.[1] Solvent-borne paints are the most common materials used for traffic marking. The solvents in these and other paints and marking materials constitute an area source of evaporative VOC emissions.

Process breakdown

Solvent-borne paints include a resin, pigment and additives suspended in volatile organic solvents. Water-borne paints contain a much smaller amount of VOC than solvent-borne paints and other marking methods contain negligible quantities of VOC. After the paint is applied to the road surface, the solvent evaporates, resulting in VOC emissions.

Reason for considering the category

Emissions from architectural and industrial surface coating are included in the current SIP inventory guidance. Discussions with EPA personnel indicate that current guidance for estimating emissions from architectural surface coating does not include traffic painting.[2,3] Ongoing efforts to design federal regulations limiting VOC emissions from architectural surface coating are not expected to cover emissions from traffic painting.[3]

Pollutants emitted

VOC

Estimate of the pollutant levels

The U.S. highway system includes over two million lane-miles of highways receiving federal aid.[4] No data estimating the market penetration of the marking materials were found. Using the methodology outlined below, over 112,000 tons VOC per year are potentially emitted from marking federally-aided highways (see Figure 1). This assumes that all highways are marked with solvent-borne materials. This figure does not include special markings for parking lots and intersections.

Point/area source cutoff

Traffic marking is not included in current emissions inventories. Due to the nature of the activity, it should be included as an area source.

Level of detail of information available

State Departments of Transportation may be able to furnish the approximate level of each of the above materials, either in absolute quantities (e.g., gallons) or in relative terms (percent of highways using

LANES AND ACCESS CONTROL		ASSUMED NUMBER OF LANES	MILEAGE	LANE-MILES
Rural:	one-way	1	718	718
	2 lanes	2	593,331	1,186,662
	3 lanes	3	2,159	6,477
	4 or more lanes - undivided	4	6,551	26,204
	divided highways, 4 or more lanes degree of access control			
	none	6	13,777	82,662
	partial	6	5,742	34,452
	full	6	36,830	220,980
			659,108	1,558,155
Urban:	one-way	1	4,239	4,239
	2 lanes	2	121,121	242,242
	3 lanes	3	1,774	5,322
	4 or more lanes - undivided	5	21,533	107,665
	divided highways, 4 or more lanes degree of access control			
	none	6	22,072	132,432
	partial	6	4,979	29,874
	full	6	15,988	95,928
			191,706	617,702
Cumulative:	one-way		4,957	4,957
	2 lanes		714,452	1,428,904
	3 lanes		3,933	11,799
	4 or more lanes - undivided		28,084	133,869
	divided highways, 4 or more lanes degree of access control			
	none		35,849	215,094
	partial		10,721	64,326
	full		52,818	316,908
			850,814	2,175,857

Assumptions:

Emission Factor (lb/mi-yr)[2]:	69
Stripes/lane:	1.5

Results:

Potential Emissions (ton VOC/yr):	112,601

Figure 1. VOC emissions estimate from traffic painting.

each material). Lane-miles by state are available from Reference 3. Emission factors are available from Reference 1.

Level of detail required by users

VOC emissions by county

Lane miles by county or marking materials used by county

Type of marking materials

Commercial and institutional (e.g., parking lot) painting activity

Emission factor requirements

Reference 1 provides the following emission factors:

Material	VOC content lb/gallon	VOC emissions lb/mile-year
Solvent-borne paints	3.15	69
Water-borne paints	0.76	13
Thermoplastics	Negligible	0
Preformed Tapes		
without primer	0	0
with primer	5.3	58
Field-reacted		
Epoxy	0.06	0.25
Polyester	Not tested	0
Permanent Markers	0	0

*No further work on emission factors appear necessary at this time.

Regional, seasonal or temporal characteristics

Highway and roadwork occurs predominantly during the spring, summer and fall months. Local highway authorities should be able to help quantify this variation. A regional variation corresponding to the time suitable for outdoor work is likely, leading emissions to be somewhat consistent on a monthly basis in warm states, while cooler states would have large seasonal variation.

Urban or rural characteristics

Traffic marking activity is greater in urban areas because of the high concentration of paved areas. Highway marking and parking lot marking occurs in both rural and urban areas.

Methodology

I. Highway and road marking

A. Consult with state highway officials to determine the amount of each type of marking material used in each county. If these data are available, implement Step C.

B. If material usage data in gallons are unavailable:

1. Determine (from highway officials) the fraction of marking using each of the marking materials.

2. Using the emission factors for each marking material and their relative amount of use, calculate a weighted average emission factor.

3. Multiply the area's lane-miles data (from Reference 3 or state highway officials) by the weighted average emission factor to determine statewide annual emissions.

4. Proceed with step D below.

C. Multiply the emission factor for each marking material by the amount of that material used. Sum the resulting annual emissions estimates to estimate the annual total VOC emissions from highway marking.

D. Apportion state emissions to the county level according to highway lane miles (data should be available through the state highway departments) or according to population data (from the *Census of Population*[5]) or economic indicators (from *OBERS*,[6] *County Business Patterns*,[7] etc.).

E. Using information provided by state highway departments, apportion emissions on a monthly basis.

II. Nonhighway Marking

A. Survey local distributors of traffic marking paint to determine the amount of each marking material used for highways and roads versus the amount used for nonhighway concerns.

B. Scale up the highway emissions to reflect the total amount of marking materials used in the area.

III. Legislative Controls on Traffic Painting

Although discussions with EPA indicated that ongoing efforts to develop federal regulations restricting VOC emissions from architectural surface coating will not include traffic painting, further research on traffic painting should include contacting EPA's Office of Air Quality Standards - Chemicals and Petroleum Branch to identify any upcoming pertinent federal regulations.

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ADHESIVES AND SEALANTS - CONSUMER

Definition/description of category and activity

Consumer application of adhesives and sealants for woods, plastics, and other materials may be a source of VOC emissions. Consumer adhesives include all adhesives sold through hobby and model shop supply channels and stationery, school, and office supply channels. Consumer sealants include sealants used for roof repair, gutter and drain sealing, glazing, general crack repair and joint sealing, bathroom caulking and swimming pool repair.

Process breakdown

Adhesive and sealant production is covered by SIC 2891. This is a production industrial code. Adhesive consumption is covered in the point source inventory by SCC 4-02-007-01.

Reason for considering the category

Solvent-based adhesive, caulk and sealant use is currently not included in emissions inventories. Emission factors for adhesives, caulks and sealants are based on emissions per ton applied; however, there is no emission factor associated with SCC 4-02-007-01.

Pollutants emitted

VOC, including isopropyl alcohol and isomers of xylene from sealants and caulks; acetone, alcohol 740 P, amyl acetate, L-camphor, ethylene glycol, nitropropane (1-,2-), petroleum oil, toluene and tricresol phosphate from adhesives[1]

Estimate of the pollutant levels

National emissions of VOC from caulks and sealants were estimated at 22,667 tons for 1986; emissions from adhesives were estimated at 9,350 tons in 1986.[1] While it is difficult to separate consumer, commercial and industrial uses of these products, consumer use is estimated at about five percent of the above totals.[1,2] The application of a product bought at a hardware store or "do-it-yourself" supply channel is considered a consumer, rather than commercial, application. Most commercial uses of adhesives and sealants are included under consumer use. These factors make it difficult, if not impossible, to estimate the amount of pollutants emitted by consumer applications of adhesives and sealants.

Point/area source cutoff

Consumer use of adhesives and sealants will probably not result in ten TPY of emissions at any one time or in any one place. Therefore, these emissions should be included as in the area source inventory.

Level of detail of information available

EPA has published speciation profiles for several solvent-based consumer goods, including profiles for caulks, sealants and adhesives. There are three profiles for formulations of consumer sealants and caulks

and seven profiles for consumer adhesives. By weight, VOC comprised zero to twenty percent of sealants profiled. Based on equal market shares for each formulation, the average composition of sealants and caulks is six percent isopropyl alcohol and 94 percent isomers of xylene. Data for associating formulations with brand names are not complete nor are data on market share by brands or formulations available. Therefore, it is not possible to develop a composite emission factor for sealants and caulks.

Consumer demand for sealants and caulks does not vary between regions in the United States; per capita VOC emissions from caulks is estimated at 0.188 pounds.[1]

The formulations of consumer adhesives range from zero to 85 percent in VOC content. Of the seven formulations, two contained petroleum oil and two contained toluene. Other VOC, including acetone, amyl acetate, L-camphor, ethyl alcohol 740 P, nitropropane, ethylene glycol and tricresol phosphate, appear in at least one formulation. In the two formulations with petroleum oil, the petroleum oil accounts for 100 percent of the VOC. Toluene accounts for 72 percent, by weight, of the VOC in one of the formulations in which it is found and 100 percent in the other. Formulations are not always associated with brand names and even when that information is available, data on market share by product name are not readily available. Therefore, at this time it is not possible to determine an average VOC content or a species profile for VOC in consumer adhesives.

Consumer and commercial demand for adhesives varies by region of the United States. Per capita VOC emissions from consumer use of adhesives vary by region from 0.166 pounds per capita to 0.195 pounds per capita. Estimates of VOC emissions from consumer and commercial applications are presented in Table 1. There is not enough information available to separate these numbers into consumer and commercial emissions.

TABLE 1. ESTIMATES OF PER CAPITA VOC EMISSIONS FROM ADHESIVES

Marketing Region	VOC Emissions (lbs/capita)
New England	0.079
Middle Atlantic	0.079
North Central	0.083
South Atlantic	0.070
South Central	0.070
Mountain	0.082
Pacific	0.082

Level of detail required by users

Population of area

Marketing region of area

Emission factor requirements

The amount of adhesives consumed by formulation (this may vary regionally depending on percentage of sales of different brands)

The percentage of sealants and caulks consumed by formulation (this may vary regionally depending on percentage of sales of different brands)

Regional, seasonal or temporal characteristics

Consumer use of sealants and caulks will not vary by geographic area (market surveys indicate that per capita use of caulks and sealants does not vary regionally). There is some variation in use of adhesives in different regions of the United States. The highest per capita use is in the North Central States and the lowest is in the South Atlantic and South Central States. There is approximately a 17 percent difference in amount of adhesives used in the high-consumption and low-consumption states.

Urban or rural characteristics

Per capita emissions from this source do not vary between rural and urban areas.

Methodology

To determine emissions from caulks, sealants and adhesives, emission factors that represent the brands and formulations of these products must be developed. Although EPA has developed emission factors and speciation profiles for different formulations used to make these products, a representative emission factor cannot be developed until information on market share of different brands, and the formulation of these brands, is available. Adhesives is a particularly difficult consumer market to identify because many uses of adhesives are not included in most studies. Estimates of actual use of adhesives range from twenty percent of the figure reported by the U.S. Bureau of the Census to many times the officially reported number. Data on consumer uses and markets for adhesives may not improve; consumer use of adhesives is estimated at only five percent of the total market. Since product composition and market shares for products are subject to constant change, it may not be possible or worthwhile to develop overall speciation profiles for adhesives and sealants.[1]

EPA has presented per capita and by-formulation emission factors. An estimate of VOC emissions from adhesives and sealants can be developed by applying population estimates to the appropriate per capita emission factor. Another, more costly, method involves performing a consumer product survey for each area of interest. This would involve identifying the most important product brands in the area and conducting a shelf survey to determine approximate market shares for each of the products. Once the product brands have been identified, formulation data may be obtained from an existing source or the manufacturer may be contacted to provide more detailed composition data. Per capita consumption estimates would be applied to population estimates to yield an estimate of total product consumed. Total product can then be partitioned by market share of brands and the formulations of the brands to estimate the VOC emissions from the product category.

References

1. *Compilation and Speciation of National Emission Factors for Consumer/Commercial Solvent Use*, EPA-450/2-89-008 (NTIS PB89-207203), U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1989.

2. "Adhesives and Sealants '86: A Chemical Week Special Advertising Section," *Chemical Week*, Vol. 138, No. 12, March 19, 1986.

3. "Adhesives and Sealants: A Booming $4 Billion Business," *Chemical Week*, Vol. 140, No. 10, March 18, 1987.

HOUSEHOLD CLEANERS AND POLISHES

Definition/description of category and activity

Household cleaners and polishes are any consumer products which are intended for household use to clean, disinfect, wash or polish household surfaces, garments or fabrics. These products include, but are not limited to, the following: furniture maintenance products, general purpose cleaners, glass cleaners, toilet bowl cleaners, spot removers, metal polishes and shoe polishes.[1,2]

Process breakdown

Household cleaners and polishes are classified as either aerosols or nonaerosols. These two categories can be further broken down as aerosol propellants, aerosol solvents and nonaerosol solvents. Propellants are used to propel aerosol products from containers, solubilize active ingredients and serve as part of the diluent system. Solvents solubilize the product ingredients and affect the evaporation rate of the product.

Reason for considering the category

Aerosol propellants and solvents and nonaerosol solvents contain VOC that evaporate on use and are carried into the atmosphere. In the atmosphere, VOC photochemically react to produce ozone and secondary particulate matter. Household cleaners and polishes represent significant sources of unaccounted VOC.

Pollutants emitted

VOC

Estimate of the pollutant levels

AP-42 has calculated national emissions and per capita emission factors for commercial and consumer solvents.[1] Household cleaners and polishes are not specifically categorized. However, *AP-42* lists two major categories (household products and polishes and waxes) which include many of the same individual items. The evaporative emissions from commercial and consumer solvent use for nonmethane VOC are as follows:

- National emissions for household products are 201,000 TPY.
- National emissions for polishes and waxes are 53,000 TPY.
- Household product per capita emission factor is 1.9 lb/year or 5.2×10^{-3} lb/day.
- Polishes and waxes per capita emission factor is 0.49 lb/year or 1.3×10^{-3} lb/day.

VOC emissions estimated for consumer product categories are listed in Reference 3. Table 1 shows the total VOC content for 49 consumer product categories for New York State, as estimated by Science Applications International Corporation. Estimates from reports by Pacific Environmental Services and CARB are included for some comparison. The values provided by CARB were estimated using state

population ratios and a recent CARB staff report on proposed consumer product regulations. The household cleaners and polishes are presented in Table 1 by numbers 3, 20, 21, 22, 29, 35, 36, 39, and 40. Estimated total VOC emissions from household cleaners and polishes in New York are 3,693 tons per year.

California has taken a lead in developing consumer product emissions inventories and control measures to reduce VOC emissions from consumer products.[2] Table 2 presents aerosol propellant and solvent emissions estimates for eight consumer product categories and 29 subcategories including household products. However, only household cleaners have been inventoried and included in the category. VOC emissions from propellants and solvents are estimated at about 56 TPD. Of these, solvent emissions comprise 70.5 percent (39 TPD) and propellant emissions comprise 29.5 percent (16 TPD). The household cleaners account for approximately 3.4 percent of total propellant and 4.5 percent of total solvent emissions. As shown in Table 3, the nonaerosol consumer products solvent emissions inventory consists of emissions estimates for five consumer product categories and 40 subcategories including the household products category. Total nonaerosol solvent emissions were about 46 TPD. The household cleaners and polishes accounted for 14.1 percent of the total VOC emissions.[2]

Point/area source cutoff

Due to the nature of use in household products, this category is considered an area source.

Level of detail of information available

The CAAA are expected to require EPA to prepare a report to Congress on VOC in consumer and commercial products and to promulgate regulations that would reduce VOC emissions from these products. It is assumed that the inventory will be developed from individual brand formulations and sales volumes and that these data will be obtained by a survey of the manufacturers. The best four major studies publicly available are listed below and include information on comprehensive inventories of VOC from consumer and commercial products.

- *Photochemically Reactive Organic Compounds Emissions from Consumer and Commercial Products*[5]
- *Compilation and Speciation of National Emissions Factor for Consumer/Commercial Solvent Use*[6]
- *Analysis of Regulatory Alternatives for Controlling Volatile Organic Compounds (VOC) Emissions from Consumer and Commercial Products in the New York City Metropolitan Area (NYCMA)*[7]
- *Expansion of the New York Study: Evaluation of VOC Emission Reduction Alternatives from Selected Consumer and Commercial Products*[8]

Level of detail required by users

VOC emissions by county

Personal product consumption by county

Emissions per personal product

TABLE 2. AVERAGE ANNUAL DAY VOC EMISSIONS FROM AEROSOL CONSUMER PRODUCTS IN CALIFORNIA AND THE SOUTH COAST AIR BASIN (SCAB)[2,a]

CONSUMER PRODUCT CATEGORY/ SUBCATEGORY	1987 CALIFORNIA EMISSIONS				1987 SCAB EMISSIONS	
	PROPELLANT EMISSIONS, TPD[b]	SOLVENT EMISSIONS, TPD[b]	PERCENT OF TOTAL PROPELLANT EMISSIONS	PERCENT OF TOTAL SOLVENT EMISSIONS	PROPELLANT EMISSIONS, TPD[b]	SOLVENT EMISSIONS, TPD[b]
Paints and Finishes						
· Aerosol paints/primers/varnishes	10.67	17.38	26.00	16.92	4.71	7.66
· Other	0.26	0.43	0.63	0.42	0.11	0.19
· Subtotals	10.93	17.81	26.63	17.34	4.82	7.85
Household products						
· Room deodorants/disinfectants	1.78	7.11	4.34	6.92	0.79	3.13
· Cleaners	2.58	4.65	6.29	4.53	1.14	2.05
· Laundry products	0.57	5.48	1.39	5.34	0.25	2.42
· Other	2.40	1.44	5.85	1.40	1.06	0.63
· Subtotals	7.33	18.68	17.87	18.19	3.24	8.23
Personal care products						
· Shaving lathers	0.79	0.00	1.92	0.00	0.35	0.00
· Hair sprays	6.62	18.81	16.13	18.32	2.92	8.30
· All other hair products	0.26	0.93	0.63	0.91	0.11	0.41
· Medicinals and pharmaceuticals	0.20	0.96	0.49	0.93	0.09	0.42
· Colognes/perfumes/aftershaves	0.08	0.47	0.19	0.46	0.03	0.21
· Deodorants and antiperspirants	5.35	2.23	13.04	2.17	2.36	0.98
· Other aerosol products, suntan preps, lotions	0.05	0.25	0.12	0.24	0.02	0.11
· Subtotals	13.35	23.65	32.52	23.03	5.88	10.43
Automotive and industrial						
· Refrigerants	0.00	4.94	0.00	4.81	0.00	2.18
· Aerosol windshield/lock deicers	0.00	1.35	0.00	1.31	0.00	0.59
· Cleaners	0.10	0.22	0.24	0.21	0.04	0.10
· Engine degreasers	0.41	3.55	1.00	3.46	0.18	1.57
· Lubricants and silicones	1.61	6.53	3.92	6.36	0.71	2.88
· Spray undercoats	0.26	0.16	0.63	0.16	0.11	0.07
· Tire inflatants and sealants	0.42	0.10	1.02	0.10	0.18	0.05
· Carburetor and choke cleaners	0.59	4.30	1.44	4.19	0.26	1.90
· Brake cleaners	0.13	1.14	0.32	1.11	0.06	0.50
· Engine starting fluids	0.00	2.54	0.00	2.47	0.00	1.12
· Other	0.44	2.54	1.07	2.47	0.19	1.12
· Subtotals	3.96	27.37	9.64	26.65	1.73	12.08

(continued)

TABLE 2. AVERAGE ANNUAL DAY VOC EMISSIONS FROM AEROSOL CONSUMER PRODUCTS IN CALIFORNIA AND THE SOUTH COAST AIR BASIN (SCAB)[2,a] (continued)

CONSUMER PRODUCT CATEGORY/ SUBCATEGORY	1987 CALIFORNIA EMISSIONS				1987 SCAB EMISSIONS	
	PROPELLANT EMISSIONS, TPD[b]	SOLVENT EMISSIONS TPD[b]	PERCENT OF TOTAL PROPELLANT EMISSIONS	PERCENT OF TOTAL SOLVENT EMISSIONS	PROPELLANT EMISSIONS, TPD[b]	SOLVENT EMISSIONS, TPD[b]
Animal Products						
· Veterinarian and pet products	0.10	0.73	0.24	0.71	0.04	0.32
Food products						
· All types (including pan sprays)	0.15	1.16	0.37	1.13	0.07	0.51
Miscellaneous						
· Other aerosol products not listed above	1.50	3.01	3.65	2.93	0.66	1.33
Consumer pesticides						
· Space insecticides	2.89	6.55	7.04	6.38	1.27	2.89
· Residual insecticides	0.83	3.74	2.02	3.64	0.37	1.65
· Subtotals	3.72	10.29	9.06	10.02	1.64	4.54
Grand totals	41.04	102.70	99.98[c]	100.0	18.08	45.29

[a]Emissions are based on California Air Resources Board estimates. Emissions estimates are based on the assumptions that (1) all propellants and solvents used in consumer products will eventually evaporate to the atmosphere and participate in photochemical reactions that produce ozone and (2) total organic compound emissions equal total volatile organic compound emissions.
[b]TPD = tons per average annual day.
[c]Total does not sum to 100 percent because of independent rounding.

TABLE 3. AVERAGE ANNUAL DAY VOC EMISSIONS FROM NONAEROSOL CONSUMER PRODUCTS IN CALIFORNIA AND THE SOUTH COAST AIR BASIN (SCAB)[2,a]

CONSUMER PRODUCT CATEGORY/ SUBCATEGORY	1987 CALIFORNIA EMISSIONS		1987 SCAB EMISSIONS
	SOLVENT EMISSIONS, TPD[b]	PERCENT OF TOTAL EMISSIONS	SOLVENT EMISSIONS, TPD[b]
Household products			
· Room deodorants and disinfectants	Not estimated		
· Cleaners			
a. window cleaners	2.54	2.38	1.12
b. general cleaners	1.10	1.03	0.48
· Laundry products			
a. spot removers	0.27	0.25	0.12
b. other	Not estimated		
· Waxes and polishes			
a. floor polishes	6.40	6.01	2.82
b. furniture polishes	3.90	3.66	1.72
c. metal polishes	0.59	0.55	0.26
· Ball point and porous tip pens	0.06	0.05	0.03
· Other household products			
a. shoe polishes	0.22	0.21	0.10
b. adhesives and sealants	3.95	3.71	1.74
· Subtotals	19.02	17.85	8.39
Personal care products			
· Pre-shaving	0.53	0.50	0.23
· After shaves	4.22	3.96	1.86
· Hair sprays (pumps)	7.07	6.64	3.12
· Other hair care products			
a. hair tonics	0.05	0.04	0.02
b. shampoos	2.80	2.63	1.24
c. hair rinses	0.21	0.20	0.09
· Medicinals and pharmaceuticals	Not estimated		
· Deodorants and antiperspirants			
a. sticks	5.09	4.77	2.25
b. roll-ons	1.50	1.41	0.66
· Nail care products	1.23	1.16	0.54
· Rubbing alcohols	3.60	3.38	1.59
· Other personal care products			
a. mouthwashes	3.06	2.87	1.35
b. creams	4.08	3.83	1.80
c. suntan lotions	0.83	0.78	0.37
d. hand lotions	1.87	1.76	0.82
e. cleaning lotions	2.54	2.38	1.12
· Subtotals	38.69	36.32	17.06

(continued)

TABLE 3. AVERAGE ANNUAL DAY VOC EMISSIONS FROM NONAEROSOL CONSUMER PRODUCTS IN CALIFORNIA AND THE SOUTH COAST AIR BASIN (SCAB)[2,a] (continued)

CONSUMER PRODUCT CATEGORY/ SUBCATEGORY	1987 CALIFORNIA EMISSIONS: SOLVENT EMISSIONS, TPD[b]	1987 CALIFORNIA EMISSIONS: PERCENT OF TOTAL EMISSIONS	1987 SCAB EMISSIONS: SOLVENT EMISSIONS, TPD[b]
Automotive and industrial			
· Windshield washer fluids	28.63	26.87	12.63
· Cleaners	Not estimated		
· Lubricants and silicones	Not estimated		
· Carburetor and choke cleaners	Not estimated		
· Brake cleaners	Not estimated		
· Engine starting fluids	Not estimated		
· Brake fluids	4.07	3.82	1.79
· Radiator antifreezes	16.15	15.15	7.13
· Subtotals	48.84	45.84	21.55
Consumer pesticides			
· Insect sprays, space insecticides, and residual insecticides	Not estimated		
· Other	Not estimated		
Miscellaneous			
· Pet products	Not estimated		
· Food products	Not estimated		
· Charcoal starter fluids	Not estimated		2.20[c]
Grand totals	106.55	100.00	49.20

[a]Emissions are based on California Air Resources Board (CARB) estimates (except as indicated by footnote c). Emissions estimates are based on the assumptions that (1) all propellants and solvents used in consumer products will eventually evaporate to the atmosphere and participate in photochemical reactions that produce ozone and (2) total organic compound emissions equal total volatile organic compound (VOC) emissions.
[b]TPD = tons per average annual day. The CARB estimated total nonaerosol emissions to be 47.00 TPD in 1987. The CARB estimate did not include emissions estimates for charcoal starter fluids. Therefore, the column showing percent of total emissions was based on 47.00 TPD.
[c]The South Coast Air Quality Management District estimated VOC emissions from charcoal starter fluid to be 2.0 TPD in 1985, 2.5 TPD in 2000, and 2.8 TPD in 2010. Emissions for 1987 were estimated to be 2.2 TPD based on linear extrapolation between the 1985 and 2000 emissions values.

Emission factor requirements

VOC emissions by household cleaner and polish type

Regional, seasonal or temporal characteristics

No regional or seasonal variability occurs.

Urban or rural characteristics

Household cleaners and polishes are used in urban, suburban and rural areas. Emissions vary directly with population.

Methodology

- Compile a list of all the household cleaners and polishes and their manufacturers.
- Determine sales volumes for each household product per county.
- Conduct laboratory testing or use existing emission factors to determine emissions from each household product. (Could also use generalized formulation data to develop product-type emission factors.)
- Calculate total annual emissions for each household product. Multiply the emission factor by the sales in each county.

References

1. *Compilation of Air Pollutant Emission Factors*, Fourth Edition and Supplements, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1985 through September 1991.

2. Letter and Attachments from Delao, Andrew P., California Air Resources Board to Strait, Randy, Alliance Technologies Corporation. Consumer Product Emission Estimate Methodologies. November 9, 1989. Section 3-6 Solvent Use - Aerosol Consumer Products and section 4-1, Pesticide Application-Aerosol Consumer Product Pesticides.

3. Memorandum from Ryan, Ron, Alliance Technologies Corporation, to Moore, Bruce and Al Vervaert, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Issues for Consumer Products Inventory Protocol. September 28, 1990.

4. Memorandum from Walata, Stephen and Ron Ryan, Alliance Technologies Corporation, to Bruce Moore, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Manufactures and Distributors of Consumer Products. October 1, 1990.

5. Jones, A. *et al.*, *Photochemically Reactive Organic Compounds Emissions from Consumer and Commercial Products*, EPA-904/4-86-001 (NTIS PB88-216940), U.S. Environmental Protection Agency, Research Triangle Park, NC, November 1986.

6. *Compilation and Speciation of National Emissions Factor for Consumer/Commercial Solvent Use*, EPA-450/2-89-008 (NTIS PB89-207203), U.S. Environmental Protection Agency, Research Triangle Park, NC, April, 1989.

7. *Analysis of regulatory alternatives for Controlling Volatile Organic Compounds (VOC) Emissions from Consumer and Commercial Products in the New York City Metropolitan Area (NYCMA)*, Pacific Environmental Services, January 1990.

8. *Expansion of the New York Study: Evaluation of VOC Emission Reduction Alternatives from Selected Consumer and Commercial Products*, Pacific Environmental Services, February 1990.

PERSONAL PRODUCTS

Definition/description of category and activity

Personal products are any consumer products applied to the body of a human being including, but not limited to the following: hair sprays, hair tonics, shampoos, hair rinses, colognes, perfumes, deodorants and antiperspirants, pre-shaves, shaving lathers, after shaves, nail-care products, rubbing alcohols, mouth washes, suntan preps, suntan lotions, hand lotions, cleaning lotions and hand soaps.[1,2]

Process breakdown

Personal products are classified as either aerosols or nonaerosols. These two categories can be further broken down as aerosol propellants, aerosol solvents and nonaerosol solvents. Propellants are used to propel aerosol products from containers, solubilize active ingredients and serve as part of the diluent system. Solvents solubilize the product ingredients and affect the evaporation rate of the product.

Reason for considering the category

Aerosol propellants and solvents and nonaerosol solvents contain VOC that evaporate on use and are carried into the atmosphere. VOC photochemically react in the atmosphere to produce ozone and secondary particulate matter. Personal products represent significant sources of unaccounted VOC.

Pollutants emitted

VOC

Estimate of the pollutant levels

AP-42 has calculated national emissions and per capita emission factors for commercial and consumer solvents.[1] Personal products are not specifically categorized. However, *AP-42* lists toiletries which include many of the same individual items. The evaporative emissions from commercial and consumer solvent use for nonmethane VOC are as follows:

- National emissions for personal products are 145,000 TPY
- Per capita emission factors are 1.4 lb/year or 3.8×10^{-3} lb/day

VOC emissions estimated for consumer product categories are listed in Reference 3. Table 1 shows the total VOC content for 49 consumer product categories for New York State, as estimated by Science Applications International Corporation, Pacific Environmental Services and CARB. The values provided by CARB were estimated using state population ratios and a recent CARB staff report on proposed consumer product regulations. The personal care products are represented in Table 1 by numbers 2, 12, 23, 25, 30, 31, 33, 38, 41, 43, 44 and 49. Estimated total VOC emissions from personal care products in New York are 4,494 tons per year.

California has taken the lead in developing consumer product emissions inventories and control measures to reduce VOC emission from consumer products. Table 2 presents aerosol propellant and solvent

TABLE 1. ANNUAL TONS VOC FOR NEW YORK STATE[3]

#	PRODUCT CATEGORY	SAIC 1986	% of TOTAL	CUMULAT. %	PES 1990	CARB 1990
1	Spray Paints, Primers, Varnishes	4,190	15.5	15.5	7,211	
2	Hair Sprays	2,911	10.8	26.3	10,260	10,900
3	All Purpose Cleaners	2,526	9.4	35.7	6,574	1,200
4	Insect Sprays	2,214	8.2	43.9	1,781	100
5	Room Deodorants & Disinfectants	1,758	6.5	50.4	6,964	2,000
6	Car Polishes & Waxes	1,658	6.1	56.5		
7	Adhesives (excludes industrial)	1,602	5.9	62.5	2,044	
8	Caulking & Sealing Compounds	995	3.7	66.2		
9	Moth Control Products	877	3.3	69.4		
10	Window & Glass Cleaners	840	3.1	72.5		500
11	Herbicides & Fungicides	754	2.8	75.3		
12	Personal Deodorants	699	2.6	77.9		
13	Auto Antifreezes	487	1.8	79.7		
14	Carburetor & Choke Cleaners	439	1.6	81.4		
15	Brake Cleaners	431	1.6	83.0		
16	Engine Degreasers	421	1.6	84.5		1,100
17	Engine Starting Fluids	397	1.5	86.0		
18	Rug & Upholstery Cleaners	389	1.4	87.4		
19	Lubricants & Silicones	382	1.4	88.8		
20	Metal Cleaners & Polishes	276	1.0	89.9		
21	Waxes & Polishes	273	1.0	90.9		700
22	Tile & Bathroom Cleaners	247	0.9	91.8		100
23	Styling Mousse	227	0.8	92.6		100
24	Windshield Deicer	209	0.8	93.4		
25	Pharmaceuticals	209	0.8	94.2		
26	Insect Repellants	165	0.6	94.8	99	
27	Starch & Fabric Finish	153	0.6	95.4		
28	Auto Cleaners	148	0.5	95.9		
29	Floor Waxes & Polishes	127	0.5	96.4		600
30	Colognes	127	0.5	96.8		
31	Shaving Lathers	120	0.4	97.3		60
32	Animal Insecticides	107	0.4	97.7	82	
33	Aftershaves	86	0.3	98.0		
34	Undercoatings	79	0.3	98.3		
35	Shoe Polishes, Waxes, & Colorants	77	0.3	98.6		
36	Oven Cleaners	76	0.3	98.9		200
37	Paints-other related products	71	0.3	99.1		
38	Perfumes	57	0.2	99.3		
39	Spot Removers	50	0.2	99.5		
40	Waxes & Polishes Liquids	41	0.2	99.7		
41	Hair Care Products - Shampoos	37	0.1	99.8		
42	Carpet Deodorizers	29	0.1	99.9		
43	Suntan Lotions	16	0.1	100.0		
44	Depilatories	5	0.0	100.0		
45	Anti-static Sprays	1	0.0	100.0		
46	Prewash Stain Removers	0	0.0	100.0		500
47	Drain Openers	0	0.0	100.0		
48	Windshield Washer Fluid					5,700
49	Nail Polish Remover					300
	TOTALS	26,979	100.0			

TABLE 2. AVERAGE ANNUAL DAY VOC EMISSIONS FROM AEROSOL CONSUMER PRODUCTS IN CALIFORNIA AND THE SOUTH COAST AIR BASIN[2,a]

CONSUMER PRODUCT CATEGORY/ SUBCATEGORY	1987 CALIFORNIA EMISSIONS				1987 SCAB EMISSIONS	
	PROPELLANT EMISSIONS, TPD[b]	SOLVENT EMISSIONS, TPD[b]	PERCENT OF TOTAL PROPELLANT EMISSIONS	PERCENT OF TOTAL SOLVENT EMISSIONS	PROPELLANT EMISSIONS, TPD[b]	SOLVENT EMISSIONS, TPD[b]
Paints and Finishes						
· Aerosol paints/primers/varnishes	10.67	17.38	26.00	16.92	4.71	7.66
· Other	0.26	0.43	0.63	0.42	0.11	0.19
· Subtotals	10.93	17.81	26.63	17.34	4.82	7.85
Household products						
· Room deodorants/disinfectants	1.78	7.11	4.34	6.92	0.79	3.13
· Cleaners	2.58	4.65	6.29	4.53	1.14	2.05
· Laundry products	0.57	5.48	1.39	5.34	0.25	2.42
· Other	2.40	1.44	5.85	1.40	1.06	0.63
· Subtotals	7.33	18.68	17.87	18.19	3.24	8.23
Personal care products						
· Shaving lathers	0.79	0.00	1.92	0.00	0.35	0.00
· Hair sprays	6.62	18.81	16.13	18.32	2.92	8.30
· All other hair products	0.26	0.93	0.63	0.91	0.11	0.41
· Medicinals and pharmaceuticals	0.20	0.96	0.49	0.93	0.09	0.42
· Colognes/perfumes/aftershaves	0.08	0.47	0.19	0.46	0.03	0.21
· Deodorants and antiperspirants	5.35	2.23	13.04	2.17	2.36	0.98
· Other aerosol products, suntan preps, lotions	0.05	0.25	0.12	0.24	0.02	0.11
· Subtotals	13.35	23.65	32.52	23.03	5.88	10.43
Automotive and industrial						
· Refrigerants	0.00	4.94	0.00	4.81	0.00	2.18
· Aerosol windshield/lock deicers	0.00	1.35	0.00	1.31	0.00	0.59
· Cleaners	0.10	0.22	0.24	0.21	0.04	0.10
· Engine degreasers	0.41	3.55	1.00	3.46	0.18	1.57
· Lubricants and silicones	1.61	6.53	3.92	6.36	0.71	2.88
· Spray undercoats	0.26	0.16	0.63	0.16	0.11	0.07
· Tire inflatants and sealants	0.42	0.10	1.02	0.10	0.18	0.05
· Carburetor and choke cleaners	0.59	4.30	1.44	4.19	0.26	1.90
· Brake cleaners	0.13	1.14	0.32	1.11	0.06	0.50
· Engine starting fluids	0.00	2.54	0.00	2.47	0.00	1.12
· Other	0.44	2.54	1.07	2.47	0.19	1.12
· Subtotals	3.96	27.37	9.64	26.65	1.73	12.08

(continued)

TABLE 2. AVERAGE ANNUAL DAY VOC EMISSIONS FROM AEROSOL CONSUMER PRODUCTS IN CALIFORNIA AND THE SOUTH COAST AIR BASIN (SCAB)[2,a] (continued)

CONSUMER PRODUCT CATEGORY/ SUBCATEGORY	1987 CALIFORNIA EMISSIONS				1987 SCAB EMISSIONS	
	PROPELLANT EMISSIONS, TPD[b]	SOLVENT EMISSIONS TPD[b]	PERCENT OF TOTAL PROPELLANT EMISSIONS	PERCENT OF TOTAL SOLVENT EMISSIONS	PROPELLANT EMISSIONS, TPD[b]	SOLVENT EMISSIONS, TPD[b]
Animal Products						
· Veterinarian and pet products	0.10	0.73	0.24	0.71	0.04	0.32
Food products						
· All types (including pan sprays)	0.15	1.16	0.37	1.13	0.07	0.51
Miscellaneous						
· Other aerosol products not listed above	1.50	3.01	3.65	2.93	0.66	1.33
Consumer pesticides						
· Space insecticides	2.89	6.55	7.04	6.38	1.27	2.89
· Residual insecticides	0.83	3.74	2.02	3.64	0.37	1.65
· Subtotals	3.72	10.29	9.06	10.02	1.64	4.54
Grand totals	41.04	102.70	99.98[c]	100.0	18.08	45.29

[a]Emissions are based on California Air Resources Board estimates. Emissions estimates are based on the assumptions that (1) all propellants and solvents used in consumer products will eventually evaporate to the atmosphere and participate in photochemical reactions that produce ozone and (2) total organic compound emissions equal total volatile organic compound emissions.
[b]TPD = tons per average annual day.
[c]Total does not sum to 100 percent because of independent rounding.

emissions estimates for eight consumer product categories and 29 subcategories including personal products. VOC emissions from propellants and solvents are estimated at approximately 56 TPD. Of these, solvent emissions comprise 70.5 percent (39.3 TPD) and propellant emissions comprise 29.5 percent (16.4 TPD). The personal care products category account for approximately 17.4 percent of total propellant and 23.0 percent of total solvent emissions. As shown in Table 3, the nonaerosol consumer products solvent emissions inventory consists of emissions estimates for five consumer product categories and 40 subcategories including the personal products category. Total nonaerosol solvent emissions were about 46 TPD. The personal care products category accounted for approximately 35 percent of the total nonaerosol VOC emissions.

Point/area source cutoff

Due to the nature of personal product use, this category is considered an area source.

Level of detail of information available

The CAAA require EPA to prepare a report to Congress on VOC in consumer and commercial products and to promulgate regulations that would reduce VOC emissions from these products. It is assumed that the inventory will be developed from individual brand formulations and sales volumes and that these data will be obtained by a survey of the manufacturers. The best four major studies which are publicly available are listed below and include information on comprehensive inventories of VOC from consumer and commercial products.

- *Photochemically Reactive Organic Compounds Emissions from Consumer and Commercial Products*[4]
- *Compilation and Speciation of National Emissions Factor for Consumer/Commercial Solvent Use*[5]
- *Analysis of Regulatory Alternatives for Controlling Volatile Organic Compounds (VOC) Emissions from Consumer and Commercial Products in the New York City Metropolitan Area (NYCMA)*[6]
- *Expansion of the New York Study: Evaluation of VOC Emission Reduction Alternatives from Selected Consumer and Commercial Products*[7]

Level of detail required by users

VOC emissions by county

Personal product consumption by county

Emissions per personal product

Emission factor requirements

VOC emissions by product

TABLE 3. AVERAGE ANNUAL DAY VOC EMISSIONS FROM NONAEROSOL CONSUMER PRODUCTS IN CALIFORNIA AND THE SOUTH COAST AIR BASIN (SCAB)[2,a]

CONSUMER PRODUCT CATEGORY/ SUBCATEGORY	1987 CALIFORNIA EMISSIONS		1987 SCAB EMISSIONS
	SOLVENT EMISSIONS, TPD[b]	PERCENT OF TOTAL EMISSIONS	SOLVENT EMISSIONS, TPD[b]
Household products			
· Room deodorants and disinfectants	Not estimated		
· Cleaners			
a. window cleaners	2.54	2.38	1.12
b. general cleaners	1.10	1.03	0.48
· Laundry products			
a. spot removers	0.27	0.25	0.12
b. other	Not estimated		
· Waxes and polishes			
a. floor polishes	6.40	6.01	2.82
b. furniture polishes	3.90	3.66	1.72
c. metal polishes	0.59	0.55	0.26
· Ball point and porous tip pens	0.06	0.05	0.03
· Other household products			
a. shoe polishes	0.22	0.21	0.10
b. adhesives and sealants	3.95	3.71	1.74
· Subtotals	19.02	17.85	8.39
Personal care products			
· Pre-shaving	0.53	0.50	0.23
· After shaves	4.22	3.96	1.86
· Hair sprays (pumps)	7.07	6.64	3.12
· Other hair care products			
a. hair tonics	0.05	0.04	0.02
b. shampoos	2.80	2.63	1.24
c. hair rinses	0.21	0.20	0.09
· Medicinals and pharmaceuticals	Not estimated		
· Deodorants and antiperspirants			
a. sticks	5.09	4.77	2.25
b. roll-ons	1.50	1.41	0.66
· Nail care products	1.23	1.16	0.54
· Rubbing alcohols	3.60	3.38	1.59
· Other personal care products			
a. mouthwashes	3.06	2.87	1.35
b. creams	4.08	3.83	1.80
c. suntan lotions	0.83	0.78	0.37
d. hand lotions	1.87	1.76	0.82
e. cleaning lotions	2.54	2.38	1.12
· Subtotals	38.69	36.32	17.06

(continued)

TABLE 3. AVERAGE ANNUAL DAY VOC EMISSIONS FROM NONAEROSOL CONSUMER PRODUCTS IN CALIFORNIA AND THE SOUTH COAST AIR BASIN (SCAB)[2,a] (continued)

CONSUMER PRODUCT CATEGORY/ SUBCATEGORY	1987 CALIFORNIA EMISSIONS		1987 SCAB EMISSIONS
	SOLVENT EMISSIONS, TPD[b]	PERCENT OF TOTAL EMISSIONS	SOLVENT EMISSIONS, TPD[b]
Automotive and industrial			
· Windshield washer fluids	28.63	26.87	12.63
· Cleaners	Not estimated		
· Lubricants and silicones	Not estimated		
· Carburetor and choke cleaners	Not estimated		
· Brake cleaners	Not estimated		
· Engine starting fluids	Not estimated		
· Brake fluids	4.07	3.82	1.79
· Radiator antifreezes	16.15	15.15	7.13
· Subtotals	48.84	45.84	21.55
Consumer pesticides			
· Insect sprays, space insecticides, and residual insecticides	Not estimated		
· Other	Not estimated		
Miscellaneous			
· Pet products	Not estimated		
· Food products	Not estimated		
· Charcoal starter fluids	Not estimated		2.20[c]
Grand totals	106.55	100.00	49.20

[a]Emissions are based on California Air Resources Board (CARB) estimates (except as indicated by footnote c). Emissions estimates are based on the assumptions that (1) all propellants and solvents used in consumer products will eventually evaporate to the atmosphere and participate in photochemical reactions that produce ozone and (2) total organic compound emissions equal total volatile organic compound (VOC) emissions.
[b]TPD = tons per average annual day. The CARB estimated total nonaerosol emissions to be 47.00 TPD in 1987. The CARB estimate did not include emissions estimates for charcoal starter fluids. Therefore, the column showing percent of total emissions was based on 47.00 TPD.
[c]The South Coast Air Quality Management District estimated VOC emissions from charcoal starter fluid to be 2.0 TPD in 1985, 2.5 TPD in 2000, and 2.8 TPD in 2010. Emissions for 1987 were estimated to be 2.2 TPD based on linear extrapolation between the 1985 and 2000 emissions values.

Regional, seasonal or temporal characteristics

Some products, such as suntan lotions, may exhibit regional and seasonal variations in use. However, the use of most personal products should not vary with season or region.

Urban or rural characteristics

Personal products are used in urban, suburban and rural areas. Emissions vary directly with population.

Methodology

- Compile a list of all the personal products and their manufacturers.
- Determine sales volumes for each personal product per county.
- Conduct laboratory testing or use existing emission factors to determine emissions from each personal product.
- Calculate total annual emissions for each personal product. Multiply the emission factor by the sales in each county.

References

1. *Compilation of Air Pollutant Emission Factors*, Fourth Edition and Supplements, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1985 through September 1991.

2. Letter and Attachments from Delao, Andrew P., California Air Resources Board to Strait, Randy, Alliance Technologies Corporation. Consumer Product Emission Estimate Methodologies. November 9, 1989. Section 3-6 Solvent Use - Aerosol Consumer Products and section 4-1, Pesticide Application-Aerosol Consumer Product Pesticides.

3. Memorandum from Ryan, Ron, Alliance Technologies Corporation, to Bruce Moore and Al Vervaert, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Issues for consumer products inventory protocol. September 28, 1990.

4. Jones, A. *et al.,Photochemically Reactive Organic Compounds Emissions from Consumer and Commercial Products*, EPA-902/4-86-001 (NTIS PB88-216940), U.S. Environmental Protection Agency, Research Triangle Park, NC, November 1986.

5. *Compilation and Speciation of National Emissions Factor for Consumer/Commercial Solvent Use,* EPA-450/2-89-008 (NTIS PB89-207203), U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1989.

6. *Analysis of Regulatory Alternatives for Controlling Volatile Organic Compounds (VOC) Emissions from Consumer and Commercial Products in the New York City Metropolitan Area (NYCMA)*, Pacific Environmental Services, January 1990.

7. *Expansion of the New York Study: Evaluation of VOC Emission Reduction Alternatives from Selected Consumer and Commercial Products*, Pacific Environmental Services, February 1990.

RESEARCH AND TESTING LABORATORIES

Definition/description of category and activity

Research and testing laboratories are low-level consumers of a wide variety of potentially toxic solvents and chemical substances. Most laboratories are equipped with chemical fume hoods and building exhausts which vent the emissions directly to the atmosphere. These laboratories are located in institutions including universities and other academic institutions, research and development laboratories and commercial laboratories, such as medical testing laboratories.

Process breakdown

Chemicals are likely to be emitted from various laboratory processes. Emissions may result from chemical mixing for experiments or testing; chemical reactions during experiments or testing; glassware and equipment cleaning and washing; and chemical storage (in laboratories and in stock rooms). These emissions are transported to the atmosphere either from the stacks attached to the chemical fume hoods in the building or from the vents used to ventilate the building air. Large medical research facilities are likely to have on-site ethylene oxide sterilizers and toxic waste incinerators which also emit into the atmosphere.

Reason for considering the category

While research and testing laboratories are not required to report any emissions under the requirements of SARA Title III, they have been identified for review under Title III of the CAAA.[1] It is likely that some of these laboratories emit VOC which are considered toxic.[2] On-site incinerators may be permitted by a state regulatory agency, however other point sources of these air toxic emissions are largely unregulated. Many research and development laboratories for industry groups use mini-batch reactors to test process changes. Emissions from these sources are irregular, but can be substantial at times. No accurate inventories exist for the emissions from research and testing laboratories. Other species that may be emitted from some of the laboratories include radioactive materials, however these materials are controlled by Federal Regulations.[2]

Pollutants emitted

VOC may be emitted from solvents such as acetone, chloroform, ethanol, etc., which are usually volatile and potentially toxic. Some combustion pollutants (e.g., CO and NO_x) may also be emitted from on-site incinerators. However, the quantities emitted are likely to be insignificant and are not considered here.

Estimate of the pollutant levels

A recent survey of the University of California campus at San Francisco (UCSF) revealed use of approximately 26 different chemicals.[2] Based on usage data, eleven of these 26 chemicals were sampled at the hood vents, revealing significant emissions as shown in Table 1.

TABLE 1. CHEMICALS EMITTED FROM FUME VENTS AT UCSF[2]

Chemical	Estimate of Campus Usage (ml/week)	Percent Emitted
Acetone	9,075	62
Chloroform	10,635	72
Diethyl ether	18,422	71
Ethanol	20,647	86
Ethyl acetate	3,071	38
Ethylene oxide	20,593	100
Formaldehyde	5,282	100
Hexane	7,929	91
Methanol	23,567	68
Methylene chloride	11,096	87
Xylenes	7,655	47

Point/area source cutoff

Research and testing laboratories should be considered as area sources since the total amount emitted from a facility is unlikely to exceed 100 TPY of any pollutant. Some facilities may emit as much as 25 TPY of total VOC at large research facilities, but not from any one point on campus.

Level of detail of information available

The only data on emissions from a research and testing laboratory are found in the study conducted at UCSF. The National Science Foundation (NSF) publishes several documents, including one which lists the total amount of federal funds for research and development allocated to each state and one which lists the annual NSF awards by state and institution.

Selected retail/wholesale chemical supply companies were contacted for sales data or distribution records by regions. These companies have indicated that they do not reveal such information or have adequate records.

Level of detail required by users

Data on consumption of solvents and other VOC sold in reagent grade to various laboratories on a national, state or county level

Emission factor requirements

Number of research and testing laboratories in the study area and their operating budgets

Emissions of VOC per research lab per dollar spent

Regional, seasonal or temporal characteristics

It is possible that these laboratories may be concentrated mostly in urban areas. Season and temporal characteristics depend on the type of research laboratory. Universities would probably use the bulk of their solvents from September through May. Most research and development laboratories would follow five days per week and eight hours per day schedules.

Urban or rural characteristics

Probably an urban and suburban source

Methodology

To estimate emissions from research and testing laboratories, companies that manufacture reagent grade solvents and other volatile organic compounds should be identified. If these companies can be assured that confidentiality of their sales figures will be maintained, annual estimates of the volume of various solvents sold can be obtained. The species that are consumed in significant quantities can then be identified. These annual volumes can be allocated to various states based on the amount of federal funds allocated to a state for research and development.[3,4] This estimate of state solvent and chemical consumption can then be allocated to each county based on SIC code 873 for employment in the research, development and testing services sector as given in *County Business Patterns*.

References

1. Telecon. Chadha, Ajay, Alliance Technologies Corporation with Calvin Overcash, Glaxo, Inc., Research Triangle Park, NC. Reporting requirements for research and testing laboratories under SARA Title III. September 12, 1990.

2. Schmidt, C.E., L.O. Edwards, R.R. Boyd, J.L. Balzer. *Technical Approach for Conducting an Air Emissions Assessment at a Large Facility with Multiple Point Sources*, In: Measurement of Toxic and Related Air Pollutants, EPA-600/9-89-060 (NTIS PB90-186909), May 1989. Proceedings of the 1989 EPA/AWMA International Symposium.

3. *Federal Funds for Research and Development: Fiscal Years 1988, 1989, 1990,* Volume XXXVIII, NSF 90-306, Detailed Statistical Tables, National Science Foundation, Washington, DC, 1990.

4. *FY 1989 Awards by State and Institution,* NSF 90-2, National Science Foundation, Washington, DC, 1990.

5. *County Business Patterns*, U.S. Department of Commerce, Bureau of the Census, Washington, DC. Annual publication.

OIL AND GAS PRODUCTION - WELL DRILLING

Definition/description of category and activity

Well drilling may be a source of hydrocarbons, particularly methane. Drilling emissions are associated with gas, LPG and liquid fuel lines. Additionally, degassing of drilling fluids may be a source of emissions.[1,2,3]

Process breakdown

Drilling of oil and gas wells is covered by SCCs 3-10-001-02, 3-10-001-99, 3-10-002-04 and 3-10-002-99.

Reason for considering the category

Only emissions of oil refinery activities are included in the NEDS and SIP area source methodologies; activities in oil and gas fields, including drilling, may also be sources of emissions.

Pollutants emitted

VOC, methane, ethane and H_2S and SO_2, CO, CO_2 and NO_x (if gas is flared)

Estimate of the pollutant levels

Emissions from an individual drilling operation will probably not exceed ten tons per year.

Point/area source cutoff

Emissions from an individual drilling operation will most likely be less than ten tons per year and should be included in the area source inventory.

Level of detail of information available

1) The American Petroleum Institute (API) has developed emission factors for each component of gas- and oil-producing facilities. These factors can be used to estimate emissions that occur during drilling. When drilling, the well is capped as soon as an oil and/or gas pocket is hit. In states which allow gas to be flared (such as Indiana and Illinois), drilling emissions may be associated with gas flaring. According to Reference 2, vented emissions are composed of roughly 95 percent methane, four percent non-methane hydrocarbons and one percent other gases. The biggest source of emissions associated with drilling may be the blowing off of gases during the drilling process. States which do not regulate this activity may have higher emissions from oil and gas drilling than states that do not allow the blowing off of gases.

2) In 1985, API published *Well Completion and Footage Drilled in the United States, 1970-1982*.[4] If these data have been updated, the most recent year's data can be used to estimate the number of wells drilled in the United States. This report may contain information on sources of data relating to well drilling.

3) A study by Gebhart and Andersen (Reference 1) presents data on ambient concentrations of hydrogen sulfide in and around working gas wells. This study suggests that H_2S is released from venting of tank and/or production gas. This paper does not include emissions factors, but measures ambient concentrations under different conditions.

Level of detail required by users

Type and number of components of each drilling well in the United States

Number of wells drilled and their location (onshore or offshore) in the year for which emissions estimates are being developed

Whether production and tank gas is vented, flared or captured

Emission factor requirements

Number of wells drilled in each county or state

State regulations relating to flaring of gases that are released during drilling

Regional, seasonal or temporal characteristics

Emissions from this source are limited to states which have exploratory drilling for oil and gas. In 1988, there were 31 states with producing oil wells and 30 states with producing gas wells. The states which have the most drilling activity are Texas, Oklahoma, New Mexico, Ohio, Pennsylvania and West Virginia. In states which do not allow the flaring of gas (such as West Virginia), the emissions associated with drilling may be minimal.

Urban or rural characteristics

Most onshore wells are located in rural areas. Offshore wells may be located off the coast of both urban (e.g., Los Angeles) and rural areas.

Methodology

For states that do not allow venting of gas from drilling, emissions may be computed using the API emission factors. Data needed to apply these emission factors include the number of wells drilled and the components associated with each well. States that allow venting of gas during exploratory drilling may have an additional source of emissions associated with this vented gas. However, data for the emissions from the vented gas may not be readily available.

References

1. Gebhart, D. Howard, "Exposure to Hydrogen Sulfide in the Vicinity of Gas and Oil Wells," presented at the 81st Annual Meeting of the American Pollution Control Association, Dallas, TX, June 1988.

2. Telecon. Lynch, Teresa, Alliance Technologies Corporation, with Mike Uhl, State of West Virginia. Emissions from drilling of oil and gas wells. September 10, 1990.

3. *Fugitive Hydrocarbon Emissions from Petroleum Production Operations*, Volumes I and II, American Petroleum Institute, Washington, DC, March 1980.

4. *Well Completions and Footage Drilled in the United States 1970-1982*, American Petroleum Institute, Washington, DC, 1985.

OIL AND GAS PRODUCTION - FIELD ACTIVITY

Definition/description of category and activity

Field activity components of oil and gas production include extraction operations during which oil and gas are brought to the surface, separation of liquefied petroleum gases and sweetening of natural gas that contains sulfur. The extraction and separation activities result in emissions of ethane, methane, heavier hydrocarbons and H_2S. Sweetening of natural gas emits H_2S and SO_2. Hydrocarbon and H_2S emissions may result from leaks in the component parts of the wellhead and venting of gas during production operations.[1,2]

Process breakdown

Oil and gas production are covered by SCCs 3-10-001-xx and 3-10-002-xx, respectively.

Reason for considering the category

Only emissions from oil refinery activities are currently included within the NEDS and SIP area source methodologies; activities in oil and gas fields may also be sources of emissions. Since a greater percentage of refinery components leak, as compared to production components, use of refinery emission factors to estimate emissions from field activity may result in a 200 to 300 percent overestimation of emissions.

Pollutants emitted

VOC, methane, ethane, H_2S and SO_2

Estimate of the pollutant levels

Although individual wells may release less than ten tons of pollutants per year, an oil and gas field may contain many wells from which total emissions may exceed ten tons per year.

Point/area source cutoff

Oil and gas field activity are currently not included in the point or area source inventories. Although an individual well probably releases less than 25 tons of pollutants per year, an oil and gas field may contain many wells whose emissions would probably sum to greater than 25 tons per year.

Level of detail of information available

1) The *AP-42* emission factor for SO_2 emissions from gas sweetening is 1,685 lbs SO_2 x percent H_2S in the gas (molar basis).[3]

2) API has developed emission factors for each component of oil- and gas-producing facilities. To estimate emissions from a facility, all components at the facility must be inventoried and the corresponding emission factors must be applied. These emissions must then be summed to

determine the total emissions. Emission factors for each component differ by type of production (oil or gas) and the location of the well (onshore or offshore). Thus, if oil and gas production is to be included as a source of emissions, each facility in the state must be inventoried by production type, location of the facility and types and number of components.

3) Radian, Midwest Research Institute and CARB have also studied emissions from oil and gas production. These studies were less comprehensive and had smaller sample sizes than the API study. These studies also include emission factors for different components of oil and gas facilities.

4) The *Natural Gas Annual* publishes data on the number of producing natural gas and condensate wells in each state.[4] These data are updated annually.

5) The *World Oil Magazine* publishes a forecast issue each February which contains data on the number of producing oil wells in each state.[5]

Level of detail required by users

Number of wells in each county

Percent H_2S in gas (molar basis)

Type and number of components per wellhead

Location of well (onshore or offshore)

Type of production (oil or gas)

If gas is vented during production (this may depend on state rules). Additional information on how long and how often gas is vented may also be needed.

Emission factor requirements

Number of production days per year associated with each producing well (This should be 365 days, unless a well is started up or closed off mid-year.)

(API has hydrocarbon field activity emission factors for methane, ethane, butane,propane, pentane, and heavier hydrocarbons.)

Regional, seasonal or temporal characteristics

Production may vary significantly between and within states. In 1988, there were 31 states with producing oil wells; Oklahoma and Texas accounted for almost half of these. In 1988, there were 30 states with producing gas wells; six states (New Mexico, Ohio, Oklahoma, Pennsylvania, Texas and West Virginia) accounted for over three-quarters of the wells.

Urban or rural characteristics

Most onshore wells are located in rural areas. Offshore wells may be located off the coast of both urban (e.g., Los Angeles) and rural areas.

Methodology

- Consult with officials in each state to determine the reporting requirements for oil and gas field activity. For states with strict reporting requirements, there may be enough data to estimate the number of wells per county. For other states, a methodology will have to be developed to estimate county-level activity based on the number of wells in the state. Determine if state laws permit venting of gas during production. One way to estimate the county-level activity for a given state is to correlate the county-level activity to the percentage of state employment for SIC category 1311 in each county. Employment data are found in *County Business Patterns*.

- To determine SO_2 emissions, the average H_2S content of gas in each state must be estimated. Often, the sulfur removed during the sweetening process is sold; therefore, the amount of sulfur that is produced and sold by each county or state may be used to estimate the amount of H_2S in the gas.

- The average number and types of components of a wellhead should be determined by state to verify if the wellhead components vary by state. If these averages cannot be determined and it is believed that there would be variation between states, the number and types of components in each wellhead in each state must be inventoried. API may be able to provide average wellhead composition based on fuel produced and location of the wellhead. State officials should be able to provide information on wellheads in their states. If neither API nor state officials are able to help in determining wellhead profiles in each state, data from wellhead studies by API, CARB and others can be used to estimate the profile.

- After the wellhead profile is determined or estimated for each state, the emission factors reported by API can be applied to estimate total emissions by hydrocarbon group.

References

1. Gebhart, D. Howard, "Exposure to Hydrogen Sulfide in the Vicinity of Oil and Gas Wells," presented at the 81st Annual Meeting of the American Pollution Control Association, Dallas, TX, June 1988.

2. *Fugitive Hydrocarbon Emissions from Petroleum Production Operations*, Volumes I and II, American Petroleum Institute, Washington, DC, March 1980.

3. *Compilation of Air Pollutant Emission Factors*, Fourth Edition and Supplements, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1985 through September 1991.

4. *Natural Gas Annual*, U.S. Department of Energy, Energy Information Administration, Washington, DC. Annual publication.

5. *County Business Patterns*, U.S. Department of Commerce, Bureau of the Census, Washington, DC. Annual publication.

REFRIGERANTS - LEAKING COOLANT

Definition/description of category and activity

Leaking refrigerant coolant refers to upset leaks from all types of refrigeration equipment. These categories include, but are not limited to, servicing and disposal of refrigerators and freezers in the residential sector, servicing and disposal of residential air conditioners, servicing of chillers (large commercial air conditioners), servicing mobile air conditioners and servicing industrial process refrigeration systems.

Process breakdown

Refrigeration and air conditioning systems act to change the condition of the air inside an enclosed space by controlling the air's moisture (humidity) and heat content (temperature). A refrigeration or air conditioning system consists of a compressor, a condenser, an expansion device, an evaporator and a refrigerant. The refrigerant is contained within the sealed vapor-compression refrigeration system.

Hermetically sealed systems are typically used on other smaller capacity refrigerant systems (such as refrigerators and residential air conditioners) and are much less prone to leakage than mobile air conditioners. Most emissions from residential refrigeration and air conditioning occur during disposal and servicing. For residential refrigeration, servicing and disposal emissions represent 1.5 percent and 72 percent, respectively, of the initial refrigerant charge per year. Similarly, for residential air conditioners, servicing and disposal emissions represent ten percent and 66 percent, respectively, of the initial refrigerant charge per year.

Mobile refrigeration systems are designed to operate continuously, constantly recycling coolant. Since a vehicle is subjected to constant vibration and movement while in operation, a mobile refrigeration system is much more likely to develop leaks than any type of stationary air conditioning or refrigeration system. Over time, leaks develop, resulting in CFC emissions and the introduction of moisture and other contaminants into the system. This results in a decrease in air conditioning efficiency and an increase in service and repair of the system. Abnormal leakage from system malfunctions involve the compressor seals, hoses or metal tubing in the system. The largest source of mobile air conditioning emissions results from servicing that requires the opening up of the air conditioning system (thus resulting in the venting of any remaining charge). Auto accidents and vehicle scrappage may emit any remaining refrigerant charge to the atmosphere. CFC emissions from mobile air conditioning include losses from leakage, servicing and accident losses. These emissions represent six, ten and 2.5 percent, respectively, of initial refrigerant charge per year.

Chillers are air conditioning systems used in large commercial and industrial buildings. The cooling system consists of a central unit that chills a secondary refrigerant, typically water or brine, which is circulated to cooling coils throughout the building. Chillers may use either centrifugal or reciprocating compressors. Servicing losses are ten percent of the initial refrigerant charge.

Industrial process refrigeration consists of refrigeration processes in petrochemical or refinery applications, as well as in the processing and storage of volatile organic liquids or compressed gases in paper mills, dairy or meat packing plants and ice manufacture. Industrial refrigeration systems are quite large and are often operated on a continuous basis with little time for unscheduled service or maintenance. Many industrial refrigeration systems are built with multiple-part capacity units so that one failure does not result in complete loss of production. Brine or chilled water is used in many industrial refrigeration systems as a secondary refrigerant since this allows for better load-following capability. CFCs are chosen for industrial refrigeration because of their combination of nontoxicity, nonflammability and high efficiency.

Other refrigerants such as ammonia or hydrocarbons are used in this application to a greater extent because industrial users are more accustomed to handling hazardous materials and can accept a higher risk than commercial or residential users.

Reason for considering the category

EPA may be required to implement CFC emissions reduction targets as a result of global warming and stratospheric ozone depletion concerns. If the use of greenhouse gas and ozone depletion chemicals is banned, some users may substitute CFCs for photochemically volatile organic compounds that participate in ozone formation. Potential CFC emissions per refrigerator or air conditioner are small; cumulative emissions of ozone depletion chemicals are of interest.

Pollutants emitted

nonreactive VOC (CFCs)

NH_3

hydrocarbons

Estimate of the pollutant levels

SCAQMD has estimated CFC emissions from disposal of residential refrigeration and air conditioning and from servicing of refrigerators and air conditioners.[1] Estimates are based on the Rand report *Product Uses and Market Trends for Potential Ozone-Depleting Substances, 1985-2000.*[2] Table 1 lists the amount of CFCs emitted from servicing and disposal of refrigeration and air conditioning systems for the United States in 1985.

TABLE 1. ESTIMATED 1985 REFRIGERATION AND AIR CONDITIONING SYSTEM EMISSIONS

Category	CFC Type	Servicing Emissions (Tons per year)	Disposal Emissions (Tons per year)
Residential Refrigerators	CFC-12	330	1,790
Residential Freezers	CFC-12	220	580
Residential Air Conditioning	HCFC-22	11,100	8,670
Mobile Air Conditioning	CFC-12	17,200	5,300[a]
Retail Store Refrigeration	CFC-12	5,300[b]	NA[c]
Centrifugal Chillers	CFC-11	4,380[b]	NA[c]
Centrifugal Chillers	CFC-12	1,650[b]	NA[c]
Reciprocating Chillers	CFC-12	280[b]	NA[c]
Industrial Process Refrigeration	CFC-12	620[d]	110

[a]Includes CFC emissions from accidents and scrappage.
[b]CFC-11 and CFC-12 1985 sales data represent fugitive, servicing and disposal emissions.
[c]NA - not available.
[d]Includes emissions for use and servicing.

Point/area source cutoff

Emissions from refrigeration and air conditioning systems would be considered point sources. The initial refrigerant charge for refrigeration and air conditioning systems ranges from 7.5 ounces for a refrigerator to 2,000 pounds for an industrial refrigeration system. Disposal and servicing emissions would be only a fraction of the initial charge.

Level of detail of information available

Emission factors for disposal of refrigeration/air conditioning units are available from References 1 and 2 and include the following equipment types: residential refrigerators; residential freezers; residential air conditioners; mobile air conditioning; and industrial refrigeration.

Emission factors for servicing of refrigeration/air conditioning units are available from References 1 and 2 and include the following equipment types: residential refrigerators; freezers and air conditioners; mobile air conditioning; retail store refrigeration; and commercial chillers.

Motor vehicle population by county is available from state Departments of Motor Vehicles.

Number of households by region is available from the U.S. Department of Energy.[3]

Number of retail food stores is available from *County Business Patterns*.[4]

Production and consumption data for refrigerators and freezers are available at the national level from the U.S. Department of Commerce, Bureau of the Census *Current Industrial Reports*.[5]

Level of detail required by users

Number and type of air conditioning and refrigeration units in service at a national, state or county level

Number and type of air conditioning and refrigeration units disposed of in a given year at a national, state or county level

Emission factor requirements

Development of CFC emission factors by refrigeration unit type

Regional, seasonal or temporal characteristics

CFC emissions from upsets (servicing and disposal) are uniform throughout the year. Emissions from air conditioners may exhibit regional and seasonal differences.

Urban or rural characteristics

Refrigeration units may be concentrated in urban areas. Emission rates are not expected to show any urban or rural differences.

Methodology

SCAQMD has developed a methodology for estimating CFC emissions from refrigeration and air conditioning systems.[1] Emission factors are based on engineering judgement. National sales data for refrigeration units by year are available from the U.S. Bureau of the Census. Refrigerator and freezer sales can also be obtained from the Association of Home Appliance Manufacturers. Number of households with air conditioners by region are available from the U.S. Department of Energy. County-level motor vehicle population can be obtained from state Departments of Motor Vehicles. The percent of automobiles with air conditioners will vary by state. The Motor Vehicle Manufacturing Association publishes the number of new vehicles sold with air conditioning systems for the United States. The percent of new automobiles with air conditioning for 1987 is 85 percent.

Emissions from residential refrigerators and freezers can be estimated by several methods. The first method assumes that each household in a given county has one refrigerator and then applies the appropriate emission factor. The second method uses national or state sales data and apportions the number of refrigerators to the county level based on population. Emissions from disposing of refrigerators and freezers can be estimated by using refrigerator and freezer sales data from 15 years ago and assuming all 15-year-old refrigerators and freezers are disposed of in the current year.

Servicing emissions from air conditioners could be estimated by taking the percentage of households with air conditioning units by region and multiplying by the number of households in each county and by the emission factor. Emissions from disposal of air conditioners could be estimated using the same methodology that was developed for refrigerators. The service life of an air conditioning system is ten years.

Disposal and servicing emissions from mobile air conditioning systems by county could be estimated using county level motor vehicle data, the percent of automobiles with air conditioners and the appropriate emission factors.

Servicing emissions from large commercial air conditioners (chillers) by county could be estimated by taking the total floor space of commercial and industrial buildings and applying an emission factor based on cooling capacity.

Servicing emissions from retail food refrigeration could be estimated by county using the number of retail stores in *County Business Patterns* and applying the appropriate emission factor. The number of industrial refrigeration systems for the United States is not known. It will be difficult to estimate county level servicing and disposal emissions for this category.

References

1. Zwiacher, Wayne, et al. *Chlorofluorocarbon Emissions in the SCAQMD*, South Coast Air Quality Management District, Emissions Inventory Unit, El Monte, CA, November 22, 1989.

2. Hammitt, James K., et al. *Product Uses and Market Trends for Potential Ozone-Depleting Substances, 1985-2000*, Rand Corporation, Santa Monica, CA, May 1986.

3. *Housing Characteristics 1987, Residential Energy Consumption Survey*, U.S. Department of Energy, Energy Information Administration, Washington, DC, May 1989.

4. *County Business Patterns*, U.S. Department of Commerce, Bureau of the Census, Washington, DC. Annual publication.

5. *Current Industrial Reports*, U.S. Department of Commerce, Bureau of the Census, Washington, DC. Annual publication.

6. *An Evaluation of Programs for Reduction of Chlorofluorocarbon (CFC) Emissions from Motor Vehicle Air Conditioning Systems, Volume II Technical Analysis*, California Air Resources Board, Sacramento, CA, July 25, 1990.

7. *Highway Statistics*, U.S. Department of Transportation, Federal Highway Administration, Washington, DC. Annual publication.

REFRIGERATION/AIR CONDITIONING EQUIPMENT

Definition/description of category and activity

Emissions from refrigeration and air conditioning equipment refers to (normal) operating fugitive emissions from stationary refrigeration equipment. These categories include, but are not limited to, residential refrigerators, freezers and air conditioners, retail store refrigeration, chillers (large commercial air conditioners) and industrial process refrigeration systems.

Process breakdown

Refrigeration and air conditioning systems act to change the condition of the air inside an enclosed space by controlling the air's moisture (humidity) and heat content (temperature). A refrigeration or air conditioning system consists of a compressor, a condenser, an expansion device, an evaporator and a refrigerant. The refrigerant is contained within the sealed vapor-compression refrigeration system.

Hermetically sealed systems are typically used on other smaller capacity refrigerant systems (such as refrigerators and residential air conditioners) and are much less prone to leakage than non-hermetically sealed systems. Fugitive emissions from refrigerators and freezers are 0.2 percent of the total refrigerant stock per year.

Retail food store refrigeration systems are used to refrigerate food and beverages in display cases and to store meat, produce, dairy products, frozen food and ice cream in walk-in coolers. Emission factors for fugitive emissions from retail food store refrigeration have not been developed.

Chillers are air conditioning systems used in large commercial and industrial buildings. The cooling system consists of a central unit that chills a secondary refrigerant, typically water or brine, which is circulated to cooling coils throughout the building. Chillers may use either centrifugal or reciprocating compressors. Leakage losses are 7.5 percent of the initial refrigerant charge.

Industrial process refrigeration consists of refrigeration processes in petrochemical or refinery applications, as well as in the processing and storage of volatile organic liquids or compressed gases in paper mills, dairy or meat packing plants and ice manufacture. Industrial refrigeration systems are quite large and are often operated on a continuous basis with little time for unscheduled service or maintenance. Many industrial refrigeration systems are built with multiple part-capacity units so that one failure does not result in complete loss of production. Brine or chilled water is used in many industrial refrigeration systems as a secondary refrigerant since this allows for better load-following capability. CFCs are chosen for industrial refrigeration because of their combination of nontoxicity, nonflammability and high efficiency. Other refrigerants such as ammonia or hydrocarbons are used in this application to a greater extent because industrial users are more accustomed to handling hazardous materials and can accept a higher risk than commercial or residential users.

Reason for considering the category

EPA may be required to implement CFC emissions reduction targets as a result of global warming and stratospheric ozone depletion concerns. If the use of greenhouse gas and ozone depletion chemicals is banned, some users may substitute CFCs for photochemically volatile organic compounds that participate in ozone formation. Potential CFC emissions per refrigerator or air conditioner are small; cumulative emissions of ozone depletion chemicals are of interest.

Pollutants emitted

nonreactive VOC (CFCs)

NH_3

hydrocarbons

Estimate of the pollutant levels

The Rand Corporation and EPA have estimated fugitive CFC emissions from residential refrigeration, retail refrigeration and commercial air conditioning.[1] Estimates are based on the Rand report *Product Uses and Market Trends for Potential Ozone-Depleting Substances, 1985-2000.*[1] Table 1 lists the fugitive CFC emissions from refrigeration and air conditioning systems for the United States in 1985.

TABLE 1. ESTIMATED 1985 CFC EMISSIONS FROM REFRIGERATION/AIR CONDITIONING SYSTEMS

Category	CFC Type	Fugitive Emissions (Tons per year)
Residential Refrigerators	CFC-12	63
Residential Freezers	CFC-12	30
Residential Air Conditioning	HCFC-22	NA[a]
Retail Store Refrigeration	CFC-12	5,300[b]
Centrifugal Chillers	CFC-11	4,380[b]
Centrifugal Chillers	CFC-12	1,650[b]
Reciprocating Chillers	CFC-12	280[b]
Industrial Process Refrigeration	CFC-12	620[c]

[a]NA - Not available.
[b]CFC-11 and CFC-12 1985 sales data represent fugitive, servicing, and disposal emissions.
[c]Includes emissions for use and servicing.

Point/area source cutoff

Emissions from refrigeration and air conditioning systems would be considered point sources. The initial refrigerant charge for refrigeration and air conditioning systems ranges from 7.5 ounces for a refrigerator to 2,000 pounds for an industrial refrigeration system. Fugitive emissions would be only a fraction of the initial charge.

Level of detail of information available

Fugitive emission factors for refrigeration/air conditioning units are available from Reference 1 and include the following equipment types: residential refrigerators; residential freezers; commercial chillers; retail store refrigeration; and industrial refrigeration.

Number of households by region is available from the U.S. Department of Energy.[2]

Number of retail food stores is available from *County Business Patterns*.[3]

Production and consumption data for refrigerators and freezers are available at the national level from the U.S. Department of Commerce, Bureau of the Census *Current Industrial Reports*.[4]

Level of detail required by users

Number and type of air conditioning and refrigeration units in service at a national, state or county level

Emission factor requirements

Development of CFC emission factors by refrigeration unit type

Regional, seasonal or temporal characteristics

CFC emissions from leakage are uniform throughout the year. Emissions from air conditioners may exhibit regional and seasonal differences.

Urban or rural characteristics

No urban or rural differences in emission rates are expected; however, refrigeration units may be more concentrated in urban areas.

Methodology

Presently no methodology exists for estimating CFC emissions from air conditioning and refrigeration equipment. SCAQMD is currently developing the first county level CFC emissions inventory.[5] Emission factors developed by the Rand Corporation and EPA are based on engineering judgement. Fugitive emission factors for air conditioners, chillers, retail food refrigeration and industrial process refrigeration have not yet been developed. National sales data for refrigeration units by year are available from the U.S. Bureau of the Census. Refrigerator and freezer sales could also be obtained from the Association of Home Appliance Manufacturers. Number of households with air conditioners by region are available from the U.S. Department of Energy.

Emissions from residential refrigerators and freezers could be estimated by several methods. The first method assumes that each household in a given county has one refrigerator and then applies the appropriate emission factor. The second method uses national or state sales data and apportions the number of refrigerators to the county level based on population.

Fugitive emissions from air conditioners could be estimated by taking the percentage of households with air conditioning units by region and multiplying by the number of households in each county and the emission factor.

Fugitive emissions from large commercial air conditioners (chillers) by county could be estimated by taking the total floor space of commercial and industrial buildings and applying an emission factor based on cooling capacity. Fugitive emissions from retail food refrigeration could be estimated by county using the number of retail stores in *County Business Patterns* and applying the appropriate emission factor.

The number of industrial refrigeration systems in the United States is not known. It will be difficult to estimate county level fugitive emissions for this category.

References

1. Hammitt, James K., et al. *Product Uses and Market Trends for Potential Ozone-Depleting Substances, 1985-2000*, Rand Corporation, Santa Monica, CA, May 1986.

2. *Housing Characteristics 1987, Residential Energy Consumption Survey*, U.S. Department of Energy, Energy Information Administration, Washington, DC, May 1989.

3. *County Business Patterns*, U.S. Department of Commerce, Bureau of the Census, Washington, DC. Annual publication.

4. *Current Industrial Reports*, U.S. Department of Commerce, Bureau of the Census, Washington, DC. Annual publication.

5. Zwiacher, Wayne, et al. *Chlorofluorocarbon Emissions in the SCAQMD*, South Coast Air Quality Management District, Emissions Inventory Unit, El Monte, CA, November 22, 1989.

REFRIGERATED TRUCKS

Definition/description of category and activity

The refrigerated trucks category includes all refrigeration units in trucks and trailers. CFC emissions results from the leakage of refrigerant coolant.

Process breakdown

Mobile refrigeration systems act to change the condition of the air inside the truck or trailer by controlling the air's moisture (humidity) and heat content (temperature). A mobile refrigeration system consists of a compressor, a condenser, an expansion device, an evaporator and a refrigerant. The refrigerant, usually CFC-12 (dichlorodifluoromethane), is contained within the sealed vapor-compression refrigeration system.

The refrigeration system uses the alternate compression and expansion of the coolant to remove heat from the air within the truck or trailer unit before it is re-introduced into the interior of the refrigerated unit. In the single-stage refrigeration process, the compressor compresses the low-pressure, low-temperature cold vapor from the evaporator to a high-pressure high-temperature gas. This gas is then fed into the condenser. Outside air passes through the condenser, cooling the high-pressure refrigerant vapor and causing it to condense into a high-pressure liquid. The liquid coolant then flows to an expansion valve where its pressure and temperature are reduced. In the evaporator, the low-pressure liquid refrigerant evaporates,thus removing heat from the surroundings and cooling the air blown through it by fans. At the same time, moisture in the air condenses on the outside surface of the evaporator core and is drained off as water. The cooled and dehumidified air then enters the refrigerated compartment, while the vaporized, low-pressure coolant returns to the compressor to start the cycle.

Mobile refrigeration systems are designed to operate continuously, constantly recycling coolant. Since a truck is subjected to constant vibration and movement while in operation, a mobile refrigeration system is much more likely to develop leaks than any type of stationary air conditioning or refrigeration system. Over time, leaks develop, resulting in CFC emissions and the introduction of moisture and other contaminants into the system. This results in a decrease in air conditioning efficiency and an increase in servicing and repairing the system.

Reason for considering the category

EPA may be required to implement CFC emissions reduction targets as a result of global warming and stratospheric ozone depletion concerns. If the use of greenhouse gas and ozone depletion chemicals is banned, some users may substitute CFCs for photochemically volatile organic compounds that participate in ozone formation. Potential CFC emissions per refrigerated trucks and trailers are small; cumulative emissions of ozone depletion chemicals are of interest.

Pollutants emitted

nonreactive VOC (CFCs)

Estimate of the pollutant levels

No estimate of pollutant level is currently available. Total U.S. CFC emissions from refrigerated trucks and trailers were calculated by estimating national values for refrigerated trucks and trailers from existing California data and applying emission factors obtained from a manufacturer of transport refrigeration equipment for trucks and trailers. Using this method, CFC-12 emissions for 1988 are 1,800 TPY, assuming each refrigerated unit is leaking 100 percent per year of its initial refrigerant charge of 17.94 pounds.[1]

Percent of Commercial Trucks in California
= Number of Commercial Trucks in California/Total Number of Trucks in California
= 2,688,392/3,771,658 = 71.3%

Percent of Refrigerated Trucks in California
(7,134/2,688,392) = 0.27%

Percent of Trailers in California
(897,974/2,688,392) = 33.4%

Percent of Refrigerated Trailers in California
(12,368/897,974) = 1.4%

Total Number of Trucks in the United States for 1985
39,196,161

Estimated Number of Commercial Trucks in the United States
39,196,161 x (2,688,392/3,771,658) = 27,938,547

Estimated Number of Refrigerated Trucks in the United States
27,938,547 x (7,134/2,688,392) = 74,139

Estimated Number of Trailers in the United States
27,938,547 x (897,974/2,688,392) = 9,332,005

Estimated Number of Refrigerated Trailers in the United States
9,332,005 x (12,368/897,974) = 128,532

Assume each refrigeration unit contains 17.94 pounds of CFC-12 and that 100 percent of the initial charge is leaked each year.

CFC-12 emissions = (74,139 + 128,532) x 17.94 x 1.00 = 3,635,918 pounds = 1,818 tons/year

A more accurate estimate by state could be developed using state Department of Motor Vehicle data.

Point/area source cutoff

Emissions from refrigeration units on trucks and trailers should be considered area sources.

Level of detail of information available

The number of refrigerated trucks and trailers can be obtained from state Departments of Motor Vehicles. The population of transport refrigeration units by county can be estimated by taking the total number of refrigeration trucks (nondetachable) and refrigeration trailers (detachable) in the state and disaggregating them by the percent regular commercial trucks and trailers in each county, respectively. Emission factors for leakage from refrigerated trucks and trailers have not yet been determined.

Level of detail required by users

Amount of coolant per refrigeration unit

Number of refrigerated trucks and trailers at a county or state level

Number of trucks and trailers at a county level

Emission factor requirements

Development of CFC emission factors by refrigeration unit type

Regional, seasonal or temporal characteristics

CFC emissions from leakage are uniform throughout the year. Transportation of perishable goods occurs seven days a week with slightly reduced activity on weekends. Transportation of fruit and vegetables occurs 24 hours per day with the majority of the activity occurring during the daylight hours. Emissions from refrigerated trucks and trailers may exhibit regional and seasonal differences.

Urban or rural characteristics

No urban or rural preference is expected.

Methodology

Emission factors for refrigerated trucks and trailers are not available. Emission factors for mobile refrigeration units should be developed. The state refrigerated truck and trailer population can be obtained from state Departments of Motor Vehicles. These values can be apportioned to the county level based on the number of regular commercial trucks and trailers at the county level. These county estimates can be multiplied by the emission factor to estimate county wide emissions from refrigerated trucks and trailers.

References

1. Telecon. Cawkwell, Roger, Alliance Technologies Corporation, with Patrick Martin, Jr., General Cryogenics Incorporated, Dallas, TX. Information about CFC usage per transport refrigeration unit. December 12, 1990.

2. *Methods For Assessing Area Source Emissions In California,* California Air Resources Board, Emission Inventory Branch, Stationary Source Control Division, Sacramento, CA, December 1982.

3. *An Evaluation of Programs for Reduction of Chlorofluorocarbon (CFC) Emissions from Motor Vehicle Air Conditioning Systems, Volume II Technical Analysis*, California Air Resources Board, Sacramento, CA, July 25, 1990.

4. *Highway Statistics*, U.S. Department of Transportation, Federal Highway Administration, Washington, DC. Annual publication.

5. Hammitt, James K., et al. *Product Uses and Market Trends for Potential Ozone-Depleting Substances, 1985-2000*, Rand Corporation, Santa Monica, CA, May 1986.

SYNTHETIC ORGANIC CHEMICAL STORAGE TANKS

Definition/description of category and activity

The synthetic organic chemical (SOC) industries manufacture organic chemicals for various uses in the industrial, commercial and other sectors. Synthetic organic chemical storage may be a source of VOC emissions.

Process breakdown

Manufacturer SOC storage

End-user SOC storage

Breathing losses (standing losses) are calculated separately from working losses (withdrawal losses). AIRS guidance gives emission factors for each loss type.[1]

Reason for considering the category

State air pollution control agency personnel have expressed concern that many individual SOC storage tanks are not being accounted for in the existing inventories.[2] Also, several major organic chemicals identified in Chemical & Engineering News (C&EN)[3] are not included in the NAPAP inventory.[4]

Pollutants emitted

VOC (including air toxics)

Estimate of the pollutant levels

The NAPAP inventory includes emissions estimates for many of the SOCs identified in C&EN. The SOC types included in the NAPAP inventory account for approximately 86 percent (by production) of the SOCs in the C&EN list. AIRS emission factors exist for six of the remaining 14 percent in the C&EN list. The AIRS emission factors and C&EN production data are used to generate a rough estimate of emissions from the sources comprising these six percent. This estimate assumes that SOCs are stored once at the manufacturer and once at the end-user. The estimate also assumes that SOC storage capacity is equal to one week's production or supply at the manufacturer or end-user. Combining this estimate with the NAPAP estimate generates an estimate for emissions from 92 percent of the SOCs identified in C&EN. The remaining eight percent are non-volatile organic compounds.

Note: NAPAP and AIRS classify chemicals by SCC. SCCs differentiate between fixed roof, floating roof and pressure storage vessels; therefore, a particular SOC may have more than one SCC (e.g., ethylene dichloride) if it is stored in more than one type of vessel.

Emissions Estimate:	1,492 TPY -	included in NAPAP (86 percent of C&EN production)
	1,125 TPY -	estimated from AIRS and C&EN data (an additional six percent of C&EN production)
	2,617 TPY -	total estimated emissions

Point/area source cutoff

Emissions from individual storage tanks will generally be less than ten TPY. However, individual storage tanks are often located at facilities which qualify as point sources, due to the many emissions sources located on the premises. Therefore, these tanks should be included in the point source inventory. Other tanks should be considered in the area source inventory.

Level of detail of information available

State-level production and consumption for each SOC may be available from various trade organizations.

Storage capacity data (at the national or state level) may be available through state agencies or trade organizations.

NEDS/AIRS guidance contains emission factors for all volatile SOCs in the C&EN list. The breathing loss emission factors are based on storage capacity and the working loss emission factors are based on throughput. These emission factors are derived from various sources, including SOC-specific EPA research and guidance such as *AP-42*.[5] *AP-42* contains detailed methods for calculating emission factors based on parameters such as tank size, tank color and tank location (underground or above ground), as well as storage capacity and throughput. The AIRS emission factors should be considered "typical" or "average" emission factors for use in estimating emissions from large numbers of tanks.

Level of detail required by users

County-level production, consumption and storage capacity for the relevant SOCs

Emission factor requirements

Since AIRS guidance contains emission factors for all volatile SOCs in the C&EN list, no additional emission factors are required (see **Level of detail of information available** section, above). However, EPA may wish to re-evaluate the current emission factors as more data become available.

Regional, seasonal or temporal characteristics

There may be some regional variation in VOC emissions from SOC manufacturers and end-users. Manufacturers may concentrate around particularly industrialized areas or where base chemicals are more readily available. SOC end-users may be more concentrated in industrialized and populated areas. It is not likely that there is any seasonal or temporal variation for manufacture of SOCs, but there may be some variation for some end-users. VOC emissions may vary due to seasonal and temporal temperature variations.

Urban or rural characteristics

VOC emissions from SOC storage are presumably more urban than rural.

Methodology

There are numerous areas for improvement in estimating VOC emissions from SOC storage. The following list summarizes some of the major concerns:

- The magnitude of emissions from SCCs included in NAPAP is comparable to the rough estimate of emissions from SCCs not included in NAPAP; however, the production of SCCs included in NAPAP is approximately 17 times greater (by gallon) than production of SCCs not included in NAPAP. This discrepancy may indicate that SOC storage may be significantly undercounted in the current NAPAP inventory. Lack of reporting for many smaller SOC users may be one cause of undercounting. Comparison of NAPAP activity data and other known data (obtained from C&EN or other chemical trade groups) may be used to estimate the size of this discrepancy. More extensive activity data need to be obtained for these undercounted sources.

- Emission factors exist for several SOCs which do not appear in the NAPAP inventory. Activity data and emission estimates should be obtained for these SOCs. The emissions estimate generated above is extremely rough and is not a reasonable substitute for a more fully developed estimate.

- Current AIRS methodologies (emission factors and activity data) do not differentiate storage tanks by size, above ground/underground or various other parameters which may affect emission rates. More specific emission factors (developed from methods in *AP-42*) and more detailed activity data are necessary for improved emission estimates.

References

1. *AIRS Facility Subsystem: Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants*, EPA-450/4-90-003 (NTIS PB90-207242), U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1990.

2. Telecon. Zimmerman, David, Alliance Technologies Corporation, with Richard Dalebout, Michigan Department of Natural Resources. Possible missing emission sources. June 1990.

3. "Facts and Figures for the Chemical Industry," *Chemical & Engineering News*, Volume 63, No. 25, June 18, 1990.

4. Saeger, M., et al. *The 1985 NAPAP Emissions Inventory (Version 2): Development of the Annual Data and Modelers' Tapes,* EPA-600/7-89-012a (NTIS PB91-119669), U.S. Environmental Protection Agency, Research Triangle Park, NC, November 1989.

5. *Compilation of Air Pollutant Emission Factors,* Fourth Edition and Supplements, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1985 through September 1991.

FARMING OPERATIONS

Definition/description of category and activity

Farming operations, including tilling, cultivating and harvesting, can result in emissions of particulate matter (PM) from the dust that is loosened from soil. Some PM emissions may include PM_{10}. In addition to the soil components that comprise the PM, residue from fertilizer, defoliant and pesticide applications can be found in the PM emissions released during agricultural activities.

Process breakdown

Farming operations, including tilling, cultivating and harvesting, are included in SICs 01 and 02. Each activity may be broken down by crop (e.g., sugar cane, cotton, wheat, etc.), major soil type (e.g., clay, silt, loam, etc.) and activity type (e.g., manual harvesting versus machine harvesting).

Reason for considering the category

The national ambient air quality standard (NAAQS) for particulate matter was revised to include PM_{10}. Farming operations may be a significant source of PM_{10}.

Pollutants emitted

Particulate matter of all sizes, including PM_{10}. Residual matter from pesticides, defoliants and fertilizers, as well as silica, may also be emitted.

Estimate of the pollutant levels

The exact level of emissions from farming operations will depend on the size of the farm, the crops grown and the agricultural practices used. Factors such as soil type and climate can also affect the level of emissions. Some large farms may have emissions greater than 100 TPY.

Point/area source cutoff

Farms having emissions greater than ten TPY should be included in the point source inventory. Emissions from smaller farms may need to be aggregated in an area source inventory.

Level of detail of information available

AP-42 contains PM emission factors for tilling of soil and harvesting of cotton and grain.[1] A 1988 EPA study, *Gap Filling PM_{10} Emission Factors for Selected Open Area Dust Sources*, adjusts these factors to make them specific to PM_{10}.[2]

(1) The PM emission factor from agricultural tilling can be described by the following empirical equation:[2]

$$E = k(5.38)(s)^{0.6} \quad \text{(kg/hectare)} \qquad (1)$$

where k = particle size multiplier
s = percent silt content of the surface soil

The k value for PM_{10} is 0.21, which reduces the equation to:

$$E = 1.13(s)^{0.6} \quad (2)$$

A k value of 0.21 indicates that 21 percent of the total particulate matter emitted is less than 10 μm in aerodynamic diameter. Approximately 15 percent of the total particulate matter emitted is less than 5 μm in diameter and approximately ten percent is less than 2.5 μm in diameter.

A methodology for determining silt content of soil, based on soil classification units, is described in *Emissions Inventory of Agricultural Tilling, Unpaved Roads and Airstrips, and Construction Sites*.[3] The methodology outlined in this document was used, along with detailed soil maps of the Great Plains and North Central States and a more general soils map of the United States, to determine silt content values for each county in the United States.

The PM emission factor derived above represents the emissions per hectare tilled as a function of the silt content of the surface soil. The number of hectares tilled depends on the amount of land devoted to agricultural production and the number of times per season that the land is tilled. Number of annual tillings varies by crop; estimates of annual tillings for different crops are listed below.[3]

Crop	Number of tillings per year
Barley	3
Corn	3
Cotton	4,3 (East, West)
Oats	3
Sorghum	2,3 (East, West)
Soybeans	3
Wheat	3,2 (East, West)

If a county-specific silt content value cannot be determined, the default value is 18 percent. When an actual silt value is used in Equation 2, the emission factor rating is B. If the default value is used, the emission factor has an EPA rating of C.

(2) *AP-42* lists PM_7 emission factors associated with different processes involved in the harvesting of cotton. A 1988 study determined that PM_{10} emissions are closely represented by the PM_7 factors in *AP-42*. The PM_{10} emission factors that are presented here are the *AP-42* factors for PM_7.

The mechanical harvesting of cotton involves three operations: harvesting of the cotton, loading the cotton into trailers and transporting the cotton on the trailers from the field. Emission factors

have been developed for each of these operations for two types of harvesters, pickers and strippers. The stripper factors are based on estimates that two percent of strippers are four-row models with baskets, 39 percent are two-row models with pulling trailers and 59 percent are two-row models with mounted baskets. The picker emission factor represents a two-rowed picker with basket. The following assumptions are used: average machine speed of 1.34 meters per second for pickers and 2.25 meters per second for strippers; a basket capacity of 109 kilograms, with six baskets per trailer; lint cotton yield of 63 metric tons per square kilometer for pickers and 41.2 for strippers; and a transport speed of 4.47 meters per second.[3]

Harvester Type	Harvesting (kg/km^2)	Trailer Loading (kg/km2)	Transport (kg/km^2)
Picker	0.46	0.07	0.43
Stripper	4.30	0.06	0.28

The free silica content of the particulate matter is 7.9 percent from pickers and 2.3 percent from strippers. The maximum content of pesticides and defoliants is 0.02 percent from pickers and 0.2 percent from strippers. The EPA emission factor rating for this source is C.

(3) PM_7 emission factors for grain harvesting, specifically wheat and sorghum, are available from *AP-42*. A 1988 EPA study reported that these factors are representative of PM_{10} emissions.[3]

Grain harvesting involves three operations: crop handling by the harvest machine, loading the grain into trucks and transporting the grain from the field. Emission factors have been developed for each of these operations for two different types of grains, wheat and sorghum. The following assumptions are used: average combine speed of 3.36 meters per second; combine swath width of 6.07 meters; field transport speed of 4.48 meters per second; truck loading time of six minutes; truck capacity of 0.52 km^2 for wheat and 0.29 km^2 for sorghum; and a filled truck travel time of 125 seconds per load.

	Emission Factors	
Operation	Wheat (g/km^2)	Sorghum (g/km^2)
Harvest machine	170	1,100
Truck loading	12	22
Field transport	110	200

The EPA emission factor rating for this source is D.

Level of detail required by users

Acreage of land used for agricultural purposes

Use of agricultural land by crop type and area

Number of tillings per year for each crop type

Silt content of the surface soil

Agricultural methods employed, including type of harvesting equipment

Emission factor requirements

AP-42 has emission factors for PM_{10} from tilling and from harvesting of cotton, wheat and sorghum. Emission factors for harvesting of other crops grown in the United States must be developed to get a complete inventory of PM_{10} emissions from agricultural harvesting.

Regional, seasonal or temporal characteristics

Emissions from this source will be higher in the agricultural regions of the United States, specifically the North Central States and the Great Plains. Emissions vary seasonally and regionally by type of crops planted (harvested) and silt content of soil.

Urban or rural characteristics

PM_{10} emissions from agricultural activity are a rural source.

Methodology

Agricultural acreage and crop data can be obtained from the U.S. Department of Agriculture.[4] Maps by soil types in regions can be obtained from Soil Conservation Service of the U.S. Department of Agriculture. The data from these maps can be used to apply the methodology outlined in Reference 2 to estimate values for silt content of soil. If the data for acreage tilled are on a county-specific level, the values of silt content can be applied to the *AP-42* equations to determine PM_{10} emissions from tillage for each county in the United States.

To determine emissions from harvesting operations, data on acreage and harvesting process can be applied to the *AP-42* equations. Emission factors for harvesting of other crops must be determined or estimated to compile a complete inventory of PM_{10} emissions from harvesting. Data on harvesting methods must be determined to ensure that the correct emission factors are applied. An important parameter for applying these emission factors is the number of tillings per year per crop. Although there are crop-specific estimates for annual tillings, areas experiencing moderate or high soil erosion may be experimenting with low or no-till farming methods. These minimum tillage approaches would greatly reduce PM emissions. It is estimated that over 20 percent of U.S. farmland is moderately or highly erosive; this land is concentrated in the Corn Belt, the Southeast, the Northeast, the Delta States, and Appalachia. Given the importance of tilling practices on overall emissions, it may be necessary to obtain county-specific estimates of annual tillings to develop more accurate emissions estimates.

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LANDFILL ACTIVITIES - TSP

Definition/description of category and activity

Municipal solid waste (MSW) landfills emit particulate matter due to traffic, materials handling and temporary/permanent covering operations. These operations are generically covered in *AP-42* (Section 11.2) under fugitive dust sources.[1] VOC emissions are covered in current SIP categories and methods. Although methane emissions are not considered by current SIP methodologies, review of landfills as methane sources will be discussed separately because of the distinct difference in emissions sources between particulate matter and methane.[2]

Process breakdown

Fugitive dust from unpaved road travel

Fugitive dust from earth moving, including excavation, waste debris, fill, compaction and daily cover activities

Reason for considering the category

The number of MSW landfills and volume of waste in the United States represents a large potential for emissions, even if emissions per landfill or unit waste are modest. One study on two Chicago area landfills indicated that unpaved road travel contributed the major portion of PM_{10} emissions (82 to 84 percent), based on the fugitive dust emission factors currently in *AP-42* and including cover and fill handling and dozer activities.[3] MSW handling and compaction activities and wind erosion were found to be insignificant sources of PM_{10}.

Pollutants emitted

TSP, PM_{10}

Estimate of the pollutant levels

Based on a rough calculation using 1.8 kg/capita/day, one mile distance traveled from the landfill gate to the fill site and a U.S. population of 236 million, potential PM_{10} emissions are 170,000 TPY.

Point/area source cutoff

Landfills are currently considered point sources.

Level of detail of information available

Average per capita waste generation rate: 1.8 kg/day

State and county population figures

Emission factor: 1 lb PM_{10}/cubic yard of waste/mile

Level of detail required by users

Emissions by county

Waste disposal rates by county

Distance from landfill gate to disposal site

Emission factor requirements

The available emission factor uses both waste disposed (cubic yards) and distance traveled to waste disposal cell from site entrance.

Regional, seasonal or temporal characteristics

None

Urban or rural characteristics

Waste generation is principally associated with urban areas and landfills are in proximity to urban sources.

Methodology

The existing PM_{10} emission factor would have to be adapted to TSP and is subject to considerable uncertainty. First, surface, soil and environmental conditions vary greatly between sites and may be significantly different from the two Chicago area landfills on which the emission factor is based. Second, dust control measures (such as water application) may vary from site to site. The two sites studied regularly applied water for dust suppression. Third, the distance traveled is a parameter that will change over time for each landfill and is, in any case, difficult to estimate.

References

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ROAD CONSTRUCTION

Definition/description of category and activities

Emissions from road construction primarily include fugitive dust emissions from unpaved roads. Secondary concerns are associated with volatile organic compounds released from paving operations, road striping and chemical dust suppressants. Cutback asphalt paving, once a major source of VOC emissions associated with naphtha and kerosene, has largely been replaced by water-emulsified products. According to the Asphalt Institute, only three percent of asphalt sold in the United States in 1989 was cutback asphalt.[1] VOC emissions from cutback and emulsified paving operations are currently included in SIP inventories. OAQPS is exploring the possibility of using water-based paints in road striping operations.[2] (Road striping or traffic painting is discussed in another characterization.) Dust is primarily controlled by spraying water, rather than chemical dust suppressants or waste oil which would release volatile organic compounds.

Process breakdown

Road construction can be broken down into several activities: clearing activities, such as dynamiting, burning and bulldozing; roadbed preparation, including landform reshaping, spraying chemical dust suppressants and resurfacing unpaved roads; paving, including both cutback and non-cutback asphalt paving; and road striping. Most road construction activity involves resurfacing paved roads, rather than building new roads. Therefore, impacts associated with clearing and landform reshaping are nominal. Likewise, because cutback asphalt and chemical dust suppressants have largely been replaced by water-based products, their current contributions to VOC emissions are limited.[1-11]

Reason for considering the category

Road construction activities release PM_{10} and VOC and have the potential to affect an area's attainment of NAAQS.

Pollutants emitted

TSP, PM_{10}, VOC

Estimate of pollutant levels

The national total emissions of pollutants per year released due to road construction are difficult to estimate and highly variable from year to year. Construction activity is short-term and directly dependent on the fluctuations of federal and state economies, as well as the weather. A further restriction on estimating emissions is the fact that the Federal Highway Administration does not keep records on total acres or miles under construction at any given time. For these reasons, only emission factors are presented below.[7,8]

Pollutant	Level	Source
Fugitive Dust	4.939 lbs/vehicle-mile	unpaved roads/trucks
Fugitive Dust	1.2 tons/acre/month	construction activities
TSP	1,737.57 tons/year	unpaved roads at steel plant

Point/area source cutoff

Large long-term industrial projects likely result in greater than ten TPY fugitive dust emissions and should be addressed as point sources. More typical operations on public roadways should be considered area sources, since the amount of time that the surface remains unpaved and that paving operations take place is limited to days or weeks.

Level of detail of information available

For TSP/PM_{10} associated with unpaved roads, traffic and road construction data are available from state Departments of Transportation, usually by county. Mean vehicle speed and weight will vary substantially depending on the nature of construction, and therefore should probably be estimated. Silt content may be available from the Soil Conservation Service or may require field sampling. Precipitation data are available from the National Weather Service.

Level of detail required by users

Emissions by county

Average miles under construction by county

Emission factor requirements

Total TSP/PM_{10} emission factors per mile of road construction

Regional, seasonal or temporal characteristics

Greater emissions occur in summer due to drier weather and higher amount of construction activity. For the same reasons, greater emissions occur during daytime operations.

Urban or rural characteristics

Construction activity may occur in urban, suburban or rural areas.

Methodology

(1) *AP-42* emission factors for fugitive dust on unpaved roads

$$E = k(5.9)\ (s/12)\ (S/30)\ (W/3)^{0.7}\ (w/4)^{0.5}\ (365\text{-}p/365), \text{ in pounds per VMT}$$

where E = emission factor
k = particle size multiplier (dimensionless)
s = silt content of road surface material (percent)
S = mean vehicle speed (mph)
W = mean vehicle weight (ton)
w = mean number of wheels
p = number of days with at least 0.01 inch of precipitation per year

This algorithm should be adjusted to account for the temporary and seasonal nature of road construction activities.

(3) VOC emissions from road striping paint are addressed in the Traffic Painting characterization.

(4) Emissions of VOC from dust suppression chemicals are assumed minimal since their use is rare in road construction operations. Presumably, waste oil has not been used as a dust suppressant since such activities were banned by the Resource Conservation and Recovery Act (RCRA), 3004(1) in 1980. Therefore, VOC emissions from waste oil need not be considered.

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9. Cowherd, C., C. Guenther, and D. Wallace. *Emissions Inventory of Agricultural Filling, Unpaved Roads and Airstrips, and Construction Sites*, EPA 450/3-74-085 (NTIS PB238-919), U.S. Environmental Protection Agency, Research Triangle Park, NC, 1974.

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GRAIN GRINDING AND FEED PREPARATION

Definition/description of category and activity

Many grain grinding and feed preparation activities, including handling, mixing and milling of grains, are sources of fugitive dust emissions. PM emissions result from loading, unloading and cleaning of feed in grain elevators; receiving, handling, cleaning and drying of grains in the milling process; and receiving, handling, grinding and cooling in the feed manufacturing process. Grain elevator facilities are used to condition, handle and store grain as it moves from the farms to the markets. At country elevators, grain is unloaded, weighed, stored and sometimes dried and cleaned before being shipped to a terminal elevator or processor. Terminal elevators are used to furnish official weights of grain shipments; they are generally located in the principal grain-marketing and shipping centers in metropolitan areas.[1,2,3]

Process breakdown

There are SCC groups for four phases of feed preparation: terminal grain elevators are covered by SCCs 3-02-005-xx; country elevators by SCCs 3-02-006-xx; milling by SCCs 3-01-007-xx; and feed manufacture by 3-02-008-xx.[4]

Reason for considering the category

The NAAQS for particulate matter was revised to include only particulate matter of less than 10 μm in diameter (PM_{10}).

Pollutants emitted

Pollutants emitted from these activities include particulate matter of all sizes, including PM_{10}. PM is the only air pollutant emitted from these activities, with the exception of very small amounts of combustion products emitted from grain dryers. These grain dryers usually operate less than three months per year and burn natural or propane gas.

Estimate of the pollutant levels

Emissions from elevators, milling and feed preparation depend on the size of the operation, the type(s) of grain(s) handled and the control technologies in place. Large grain elevators may be sources of over 100 tons per year of PM emissions. PM_{10} emission factors need to be developed for each emissions source associated with elevators. PM emissions from large grain milling establishments may exceed ten TPY. There is not enough information for each grain type to determine how many mills would exceed ten TPY of PM_{10}. Feed manufacturing establishments with over 50,000 tons of production per year probably emit greater than ten TPY of PM_{10}. In 1969, approximately 3.6 percent of feed manufacturing establishments were of such capacity. These establishments produced over 47 percent of the feed.[1,2,3]

Point/area source cutoff

Feed manufacturing establishments which process over 50,000 tons of grain per year may emit greater than ten TPY of PM_{10}. Establishments which process less than 50,000 tons per year of grain accounted

for over 95 percent of the feed manufacturing establishments. These smaller establishments probably emit less than ten TPY and may be included as an area source.

To determine if any grain milling establishments emit greater than ten TPY of PM_{10}, information on the types of grains milled at each establishment must be gathered.

Some large grain elevators can emit 100 TPY or more of PM. To determine if PM_{10} emissions from these elevators exceed ten TPY, emission factors need to be developed for each emissions source associated with these elevators.

Level of detail of information available

AP-42[1] and *NEDS Source Classification Codes and Emission Factor Listing*[4] present PM emission factors for grain elevators, grain mills and feed manufacturing facilities which are based on information found in *Emissions Control in the Grain and Feed Industry*.[2] This document also provides estimates of the particle size distribution of PM (and thus PM_{10}) emissions estimates for some of the sources. In addition, SCAQMD has compiled an inventory of emissions, by SCC category, for pollutants including PM and PM_{10}.[5] This inventory was the basis of some of the estimates of the ratio of PM_{10} to PM emissions listed in Tables 1 and 2 (PM emission factors for grain elevators and PM emission factors for grain processing operations, respectively). Table 3 gives PM emission factors for feed manufacturing. The PM_{10}/PM ratios developed from the SCAQMD document are based on controlled emissions. This must be taken into account if these estimates are to be applied to non-California sources.

Level of detail required by users

Amount and type of grain processed by country, terminal and export elevators

Amount and type of grain passing through each function of an elevator (receiving, handling, cleaning, drying and shipping)

Amount and type of grain processed by grain milling facilities and the amount of grain affected by each function of a mill (receiving, handling, cleaning, degerming and milling)

Amount and type of grain manufactured into feed and the amount of grain passing through each process in feed manufacturing (receiving, shipping, handling, grinding and cooling pellets)

Emission factor requirements

Although several sources provide PM emission factors from grain grinding and feed manufacture, there are not enough factors specific to PM_{10} to allow the user to estimate emissions from these sources. PM_{10} emission factors must be developed for grain elevator activities, grain grinding and feed preparation activities.

Development of emission factors for PM_{10} must include better crop-specific factors for elevators.

Control equipment in place in elevators and granaries that is not subject to the New Source Performance Standards (NSPS) must be detailed.

TABLE 1. PM EMISSION FACTORS FOR GRAIN ELEVATORS

Process	SCC	lbs PM/ton of grain processed	lbs PM/ton shipped or received	PM size
Feed and Grain Terminal Elevators	3-02-005-xx			
Cleaning	3-02-005-03	3.0[e]	0.6	
Drying	3-02-005-04	1.2[c]	0.1	95% > 50um[d]
Unloading (receiving)	3-02-005-05	1.0	1.0	most > 100um[a]
Loading (shipping)	3-02-005-06	0.4	0.4	
Removal from bins	3-02-005-07	1.4	2.8	most < 5um[b]
Elevator legs	3-02-005-08	1.6	4.8	
Tripper (gallery belt)	3-02-005-09	1.0	1.7	
Feed and Grain Country Elevators	3-02-006-xx			
Cleaning	3-02-006-03	3.0[e]	0.3	
Drying	3-02-006-04	0.8[c]	0.2	
Unloading	3-02-006-05	0.6	0.6	
Loading	3-02-006-06	0.4	0.4	
Removal from bins	3-02-006-07	1.0	2.1	
Elevator legs	3-02-006-10	1.6	5.0	
Export Elevators	NA			
Unloading		1.0	1.0	
Loading		1.0	1.0	
Removal from bins		1.4	1.7	
Drying		1.0[c]	0.01	
Cleaning		3.0[e]	0.6	
Elevator legs		1.6	3.5	
Tripper (gallery belt)		1.0	1.1	

[a]Emissions are based on a cyclone system serving a dump truck unloading grain.[2]

[b]Approximately 70 percent of the grain dust emitted is composed of organic material and about 17 percent is silicon dioxide. Other materials in the dust include particles of grain kernels, spores of smuts and molds, insect debris, pollens, herbicides and field dust.[2] The dust emitted to the interior of the elevator creates problems that are not necessarily related to air pollution, i.e., dust which is not emitted externally poses more of a safety and housekeeping problem than a non-safety health problem.

[c]Emission factors for drying are based on 1.8 pounds per ton for rack dryers and 0.3 pounds per ton for column dryers, weighted by the distribution of these two types of dryers in each elevator category.

[d]Estimate from Reference 2.

[e]The emission factor of 3.0 pounds per ton for cleaning is an average value which may range from less than 0.5 pounds per ton for wheat up to 6.0 pounds per ton for corn.

TABLE 2. PM EMISSION FACTORS FOR GRAIN-PROCESSING OPERATIONS

Process	SCC	lbs/ton of grain received
Barley Milling	3-02-007-0x	
Barley Cleaning	3-02-007-03	0.2
Barley Flour Mill	3-02-007-05	3.0
Milo Milling	3-02-007-04	
Milo Cleaning	3-02-007-04	0.4
Durum Milling	3-02-007-1x	
Grain Receiving	3-02-007-11	1.0
Precleaning/Handling	3-02-007-12	5.0
Cleaning House	3-02-007-13	-
Millhouse	3-02-007-14	-
Rye Milling	3-02-007-2x	
Grain Receiving	3-02-007-21	1.0
Precleaning/Handling	3-02-007-22	5.0
Cleaning House	3-02-007-23	-
Millhouse	3-02-007-24	70.0
Wheat Milling	3-02-007-3x	
Grain Receiving	3-02-007-31	1.0
Precleaning/Handling	3-02-007-32	5.0
Cleaning House	3-02-007-33	-
Millhouse	3-02-007-34	70.0
Dry Corn Milling	3-02-007-4x	
Grain Receiving	3-02-007-41	1.0
Grain Drying	3-02-007-42	0.5
Precleaning/Handling	3-02-007-43	5.0
Cleaning House	3-02-007-44	6.0
Degerming and Milling	3-02-007-45	-
Wet Corn Milling	3-02-007-5x	
Grain Receiving	3-02-007-51	1.0
Grain Handling	3-02-007-52	5.0
Grain Cleaning	3-02-007-53	6.0
Dryers	3-02-007-54	0.48
Bulk Loading	3-02-007-55	-
Milling	3-02-007-56	-

(continued)

TABLE 2. PM EMISSION FACTORS FOR GRAIN-PROCESSING OPERATIONS (continued)

Process	SCC	lbs/ton of grain received
Oat Milling	3-02-007-60	
Total	3-02-007-60	2.5
Rice Milling	3-02-007-7x	
Grain Receiving	3-02-007-71	0.64
Precleaning/Handling	3-02-007-72	5.0
Drying	3-02-007-73	0.30
Cleaning and Millhouse	3-02-007-74	-
Soybean Mills	3-02-007-8x	
Grain Receiving	3-02-007-81	1.6
Grain Handling	3-02-007-82	5.0
Grain Cleaning	3-02-007-83	-
Drying	3-02-007-84	7.2
Cracking and Dehulling	3-02-007-85	3.3
Hull Grinding	3-02-007-86	2.0
Bean Conditioning	3-02-007-87	0.1
Flaking	3-02-007-88	0.57
Meal Dryer	3-03-007-89	1.5
Meal Cooler	3-03-007-90	1.8
Bulk Loading	3-03-007-91	0.27

TABLE 3. PM AND PM_{10} EMISSION FACTORS FOR FEED MANUFACTURING

Process	SCC	PM (lb/ton)	PM_{10} (lb/ton)
Feed Manufacture	3-02-008-0x		
Grain Receiving	3-02-008-02	2.5	0[a]
Shipping	3-02-008-03	1.0	0.66[a]
Handling	3-02-008-04	5.5	0.50[a]
Grinding	3-02-008-05	0.2[a]	-
Pellet Coolers	3-02-008-06	0.4[a]	1.0[a]

[a] These estimates are based on controlled emissions in California and, therefore, are based on control technologies in place in California.

Regional, seasonal or temporal characteristics

Country elevators, which generally receive grains harvested within ten to twenty miles, are concentrated in the grain-producing states in the Mid-Plains, South Plains and Great Lakes regions. Therefore, emissions from this source will be higher in the grain-producing states. While country elevators are found in rural areas, terminal and export elevators are concentrated in urban areas, particularly in the principal grain-marketing and shipping centers. Grain-processing facilities are located in both rural and urban areas. Feed manufacturing plants are located throughout the United States, with concentrations in the Corn Belt and Texas. Emissions will be highest during the harvesting season.

Urban or rural characteristics

PM_{10} emissions from grain grinding and feed preparation can be a rural or urban source.

Methodology

Although there are some data available for estimating PM_{10} emissions from grain grinding and feed preparation, these data do not provide enough information to develop county-level emissions estimates. PM_{10} emission factors for these activities must be identified or developed. Once emission factors are available, information on elevator types and locations, as well as locations of granaries and feed manufacturers must be developed. The Department of Agriculture will probably have many of these data. Data on grain-handling facilities, including any dust control technologies in place, must also be gathered. Newer grain-handling facilities will often have lower emissions due to advanced design and control technologies. For example, if grain is handled in an area closed off from the wind, as is the case in some of the newer facilities, emissions will be lower and easier to contain and capture.[3] With PM_{10} emission factors and data on amount and type of grain handled, uncontrolled emissions can be estimated; data on design and controls of the facilities in the grain and feed industry can be used to develop estimates of controlled emissions.

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ROAD SALTING AND SANDING

Definition/description of category and activity

Salt and sand are applied to road surfaces to increase traction and lower the freezing point of the water in snow and icy conditions. Vehicular traffic entrains the particulate, principally the silt fraction, deposited in the active lanes into the atmosphere. Additional silt is created due to the grinding action of vehicle tires. Sand is generally applied in an abrasive mixture with salt. The ratio may range from 1:3 to 1:20 sand to salt. Other abrasives besides sand (such as very small pea gravel) can represent a minor component of the abrasive mixture. Sodium chloride is the principal salt used; small amounts of calcium chloride are used in certain special situations involving low temperatures and wet roadways.[1,2,3]

Process breakdown

Emissions of PM_{10} are caused by the entrainment of the silt fraction from deposited particulates and of the silt fraction created by the grinding action of vehicle tires. Emissions of particulates from both salt and sand are associated with snow, sleet, freezing rain and ice on interstates and tollways, primary roads, secondary roads and city streets. The amount of salt or abrasive mixture used, as well as the composition of the mixture, is dependent on weather conditions, local availability and local regulations concerning the composition of abrasive mixtures.

Reason for considering the category

Sand and salt represent a primary source of particulate matter available for entrainment from paved roads by vehicles. PM_{10} generated in this manner occurs at the time of year that emissions are of particular concern.

Pollutants emitted

PM_{10}. Other particulate fractions are generated and emitted, but the amounts of these fractions are known.

Estimate of the pollutant levels

An estimate of pollutant levels was made on three bases. First, salt consumption data from the State of North Carolina were obtained. Second, these North Carolina data were used with EPA guidance to derive a rough national estimate.[4] Finally, data from the Salt Institute were used as the basis for a national estimate.

Based on data supplied by the North Carolina Department of Transportation (DOT), state-maintained roads use 40,000 TPY of salt over 24,000 lane-miles of roadway. Sand use is not monitored on a total basis, but is used normally in a 20:1 mix of salt and sand.[5] Based on EPA emission factors discussed below, North Carolina emissions are calculated to be 200 tons PM_{10} as salt and 25 tons PM_{10} as sand in a typical year.

Based on a rough evaluation of the number of road miles and inclement (snow) days in other states, northeastern, upper midwestern and northwestern states may use (and emit) more than ten times the salt

and sand. A rough national estimate of 50,000 TPY assumes 2,000 TPY emitted per state and 25 states receiving significant snowfall (ten or more days per year).

In fact, 1989 data from the Salt Institute indicate 1989 sales of 10,181,000 tons of salt for highway use (the Salt Institute does not compile these data by state).[6] Using the emission factor of ten pounds PM_{10} per ton salt, the 1989 national estimate based on salt sales is 50,905 tons PM_{10}. No parallel data for sand have been located, but based on the North Carolina example above, salt is expected to be the major contributor.

Point/area source cutoff

Due to the nature of the activity, this category is considered an area source.

Level of detail of information available

States track salt usage through state DOTs and may have sand estimates as well. Typical abrasive mixtures applied are likely to be documented as well. Application rates (per lane-mile) are available or can be estimated from available data. Municipalities also keep these data for city streets and city/county-maintained roads.

Emission factors are available as PM_{10} per ton salt or sand applied, or can be related to application rate (mass/lane-mile), snow days and maintained lane-miles. Percentage of PM_{10} in the silt and fraction of silt in the salt and sand are necessary, but default values are available. Snow days are available from the National Weather Service or can be estimated from state/local records. Lane-miles are also available from state DOTs and local street maintenance departments in most cases.

The National Industrial Sand Association was also contacted for sales or tonnage data on salt and sand for road application. Neither sales nor tonnage data sand used for road application are available.

Level of detail required by users

PM_{10} emissions per county. Therefore, salt and sand quantities per county, or application rate, maintained miles and snow days per county are needed. Apportionment from the state level is possible based on percentage of county roadway to state roadway (lane-miles) or a combination of roadway and snow day information.

Emission factor requirements

Emissions per ton salt and sand applied, or emissions per lane-mile per snow day per application rate:

<u>SAND</u>

PM_{10} (lb/ton) = 2,000 x f x (s/100)

where: f = proportion of PM_{10} in the silt fraction (default = 0.0026)
s = percent silt content of the sand (default 0.35)

SALT

PM_{10} (lb/ton) = 10

Regional, seasonal or temporal characteristics

Emissions occur primarily in winter, although some fall and spring use of salt and sand occurs along the northern tier of states. Amount of salt and sand used directly correlates with the number of snow and ice days.

Urban or rural characteristics

Application and emission rates are related to maintained road miles. Emissions are directly related to roadway density and would be higher in urban areas.

Methodology

EPA has proposed an emission factor (discussed above).[4] Salt and sand usage from state DOTs and municipalities would be required and are available from the individual states. The Federal Highway Administration does not compile data on salt and sanding. A moderate effort would be required to contact state DOTs, but collection of municipal data would entail identification of relevant municipalities and collection of information from each locality. Using roadway mileage is a more appealing alternative, but requires assumptions regarding application rates and occurrences. From a SIP viewpoint, contact with state DOT and municipal street maintenance officials is a credible approach. National estimates would be far easier to obtain using the roadway mileage/application rate approach or by apportioning salt usage by state according to road mileage and snow days.

References

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SANDBLASTING

Definition/description of category and activity

Abrasive cleaning is the use of natural or synthetic fine particulate to clean concrete or metal surfaces. Sandblasting is the most recognizable type of abrasive cleaning. Other substances, including pulverized coal slag and plastic pellets, are also used. Processes include architectural cleaning of concrete, brick and metal surfaces; metallic cleaning, including shot blasting and peening, deburring, grinding and polishing of large and small metal parts; and large-scale blasting of ships, bridges, etc., prior to repainting.

Process breakdown

Emissions are fugitive in nature. Emissions occur outdoors during architectural and large-scale metal cleaning and indoors in industrial and commercial settings during metal parts cleaning.

Reason for considering the category

Abrasive cleaning is a noticeable, but sporadic, source of particulates in urban atmospheres. Occupational standards exist due to the health hazards of crystalline silica (i.e., sand) inhalation.[1] However, ambient emissions and effects have not been studied.

Pollutants emitted

Particulate matter

Toxic components of paints and coatings cleaned from metal or brick surfaces

Estimate of the pollutant levels

No emission factors or activity data are currently available. Emissions depend on type of cleaning agent, type of surface cleaned, environmental conditions, etc. Based on anecdotal evidence, the potential for particulate emissions are high during outdoor cleaning of architectural surfaces or large-scale metal cleaning.[2]

Point/area source cutoff

Abrasive cleaning is not currently inventoried. Existing point/area distinctions are appropriate to the category and would likely result in point source listings for large, fixed operations such as ship drydocks. Construction-related cleaning is likely to be smaller in magnitude for any single site and may be placed in the area source inventory. Metal parts cleaning may be large or small scale and would probably need to be addressed in both point and area source inventories.

Level of detail of information available

No emissions or activity data are available. EPA and NTIS databases were searched for relevant documentation and only bibliographic reports on abrasive processes were located. Occupational

exposure and epidemiological data are available for abrasive-blasting operations. Construction employment data are available. The National Industrial Sand Association does not separate sand used for abrasive cleaning from other types of sand.[3]

Level of detail required by users

Emissions per process throughput or per county are required. Emissions estimation requires emission factors and throughputs for point sources. Activity data, such as construction activity or SIC employment, and emission factors are required for area sources.

Emission factor requirements

Emissions per ton abrasive cleaner or unit cleaned (e.g., ships)

Emissions per construction unit and/or per SIC employee in the construction sector

Regional, seasonal or temporal characteristics

Overall, abrasive cleaning should show trends similar to activity in the construction industry. However, large-scale abrasive cleaners like shipyards and metal part cleaning probably do not exhibit regional or seasonal characteristics.

Urban or rural characteristics

Primarily urban

Methodology

Point source emissions estimation requires identification of relevant industrial and commercial processes and emission factor development for those processes. Area source methodologies can be based on construction activity and SIC employment data, but they also require development of emission factors. Currently, there are no test data on which to base emission factors.

References

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STREET SWEEPING AND CLEANING

Definition/description of category and activity

Street sweeping and cleaning is the mechanical removal of dust from paved roads. Dust is deposited from emissions sources, local erosion, wear of vehicle components and carry-out from vehicles working in or hauling dirt or loose materials. Dirt removal is primarily accomplished by sweeping or vacuuming and water flushing. Mechanical broom sweepers use large, rotating brooms to lift material from the street and direct it to a hopper. Vacuum sweepers use a broom to loosen road dirt or a strong vacuum to pick up dirt and a vacuum system to direct dirt to the hopper. Blasts of air may be used in conjunction with the vacuum to dislodge dirt particles. Water flushing washes dust directly to storm drains and generally is not used because of the washoff of toxic pollutants and the demand for water. Typically, residential and some commercial areas are swept, but rarely highways and primary roads.[1,2,3]

Process breakdown

Emissions of TSP are caused by the dislodging of dirt from the road surface into the ambient air and exhausted air from the hopper.

Reason for considering the category

Vehicular entrainment of paved road dust is considered a significant source of TSP and PM_{10}. Sweeping is a common control strategy to reduce the pool of road particulates subject to reentrainment, but may be a major cause of reentrainment due to the blasting action and exhaust of particulates.

Pollutants emitted

TSP, including PM_{10}

Estimate of the pollutant levels

No information was located that indicated that sweeping is a source of TSP due to reentrainment. Studies in Chicago measured the effect of sweeping on ambient suspended particulate levels and found no statistical differences between swept and unswept areas on an averaged basis. During the sweeping activity, particulates are raised into the ambient atmosphere, but the Chicago study and other literature show that the net effect is either a reduction in overall emissions from paved roads or no measurable effect, depending on the sweeper type, location, cleaning program and other individual variables. No quantitative emissions estimates from sweeper action or exhaust were found.[1,2,3,4]

Point/area source cutoff

The nature of this source makes it an area source.

Level of detail of information available

No data on emissions from street sweepers are available.

Level of detail required by users

Activity data such as frequency, efficiency, equipment type, etc., are required. Emission factors are specific to each equipment type.

Emission factor requirements

Emissions per curb-mile swept (if this source is determined to be a net emissions source)

Regional, seasonal or temporal characteristics

Frequency of street sweeping is weather related. Colder, wetter meteorological conditions require less sweeping due to snow or frequent washing from rain.

Urban or rural characteristics

Urban and suburban areas

Methodology

At this time, street sweeping is not considered a net source of particulates (TSP or PM_{10}) to the urban ambient atmosphere.[1,2,3,4] Rather, it is used as a control strategy to reduce particulate reentrainment from paved roads and to reduce potential urban stormwater contaminants/sediment loadings.

References

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INFLIGHT AIRCRAFT

Definition/description of category and activity

Current aircraft emissions estimation methods base emissions on landing/take-off (LTO) cycles for three categories: civil, commercial and military aircraft. Emission factors are further defined by aircraft type within each category (e.g., jet, turboprop, piston, helicopter, etc.). The *AP-42* mobile source emissions estimation methods for the category make it possible to estimate emissions based on engine manufacturer.[1] Emissions are estimated for the following modes: approach, taxi/idle in, taxi/idle out, take-off and climb-out. Only emissions produced below 915 meters (m) altitude are considered, although emissions at any altitude can be computed if the depth of the inversion layer is known. Inflight emissions occur above the 915 m level. Emissions of greatest interest occur between 915 m (current *AP-42* assumption) and the top of the actual inversion layer.

Process breakdown

Jet Engine Inflight
Turboprop Inflight
Piston Engine Inflight
Helicopter Inflight
Small Piston Engine Inflight

Reason for considering the category

Environment Canada does compute inflight emissions for their inventory.[2,3] Emissions potential in the United States is unknown, but some major urban centers could be affected under some meteorological conditions.

Pollutants emitted

SO_2, NO_x, VOC, TSP and CO

Estimate of the pollutant levels

Canadian estimates have been requested from Environment Canada. Based on Environment Canada emission factors and an assumption of a one-hour flight, inflight emissions would be about ten percent of LTO emissions for jets, five percent for turboprops, and equal to or slightly more for other aircraft types. Based on 1985 NAPAP data, national emissions may be 10,000 to 20,000 TPY NO_x and VOC (each).[4]

Point/area source cutoff

Not applicable, as aircraft are considered an off-highway mobile source.

Level of detail of information available

FAA records and county airport and aircraft registration data are used to estimate LTO cycles. Time in mode can be estimated along with aircraft type to compute weighted average emission factors. Aircraft

routes and flight frequencies are available from the FAA and most airports. Meteorologic data are available in *Local Climatological Data*.[5]

Level of detail required by users

Height of the inversion layer on a daily and/or average basis by airport. Because mixing height shows diurnal variation, morning and afternoon traffic could be considered separately.

Aircraft route and frequency data

Aircraft type (including engine manufacturer)

Time in mode

Emission factor requirements

Existing *AP-42* factors are adequate, providing these factors are updated as engine designs change. To consider altitudes above (or below) the 915 m level, time-in-mode for approach and climb-out are extended or shortened. Canada considers total inflight emissions and has used *AP-42* emission factors to develop inflight emission factors for all altitudes above 915 m.[6]

Regional, seasonal or temporal characteristics

Air traffic dependent - large urban centers and military bases would be major contributors and have peak hours during daylight hours.

Urban or rural characteristics

Principally an urban source. If all inflight emissions are considered, rather than only those below the inversion layer, the area of impact would be greater. Aircraft that typically fly at lower altitudes (including civil aviation and helicopters) will contribute little to inflight emissions.

Methodology

Total inflight emissions could be computed with existing emission factors (*AP-42*) and FAA and military data on air traffic activity and aircraft censuses. Inclusion of only emissions below the inversion layer requires specific meteorological data. The method envisioned would then require extending existing 'climbout' emissions estimation to another altitude. This, in turn, requires assumptions about flight time to that altitude. Current *AP-42* methods allow for this kind of computation to be made.

Conversations with Environment Canada staff indicated the mapping of flight paths and frequencies was a long and tedious process they would not repeat. It appears the estimated emissions potential does not justify this level of effort.[6]

References

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3. *Methods Manual for Estimating Emissions of Common Air Contaminants from Canadian Sources*, ORTECH International (in development).

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COMPRESSED NATURAL GAS VEHICLES

Definition/description of category and activity

Since the 1960s, many fleet vehicles have been converted (retrofitted) to compressed natural gas (CNG) as an alternative energy source to gasoline and diesel fuels. Most vehicles operating on CNG are modified versions of vehicles designed for operation on liquid fuels. Some conversions allow the alternate use of either CNG or gasoline and are known as dual-fuel vehicles. Currently, there are no vehicles produced specifically for operation with CNG. These production CNG vehicles would operate on CNG as a sole source of fuel, with design specifications optimizing the use of CNG as fuel. The discussion of emission rates in this report is based on the rates from conversions. These emission rates are expected to vary appreciably for production CNG vehicles.[1-7]

Process breakdown

Two basic vehicles categories can use CNG as a fuel:

- retrofit vehicles, originally designed for gasoline or diesel fuel use
- production CNG fueled vehicles, specifically designed for CNG use

Within each of these categories are two types of vehicles: those using CNG as the sole fuel and dual-fuel vehicles that can operate on either gasoline or diesel in addition to CNG. Most information available on CNG emissions is based on tests with retrofit vehicles. However, there are wide differences in emissions estimates from different agencies/research groups, even for the same model vehicle. Emissions estimates are affected by the type of pollution control equipment installed on the vehicle; the manufacturer of the retrofit conversion kit; the adjustment of the timing and tuning of the converted vehicle; whether the vehicle is a dual-fuel vehicle; and the changing technologies being considered for use in converting vehicles to CNG. Production CNG vehicles are not currently available; therefore, the discussion of emissions includes only retrofit vehicles.

Reason for considering the category

Emissions from CNG-fueled vehicles and dual-fueled vehicles have not been addressed previously in emissions inventories. Nationally, there are an estimated 30,000 vehicles currently operating on CNG. As the economic and technological barriers disappear, the use of CNG as a vehicle fuel will most likely increase. Emissions from this source category may increase in importance if SIP and FIP plans in ozone and/or CO nonattainment areas require using CNG vehicles as a control strategy.

Pollutants emitted

CO, NO_x and hydrocarbons (mostly methane) are emitted from CNG-fueled vehicles. The percent difference in pollutant emissions from CNG- versus gasoline-fueled vehicles is presented in Table 1. The relatively lower amounts of reactive hydrocarbons and CO from CNG make this fuel especially attractive for CO and ozone nonattainment areas.

TABLE 1. CHANGE IN EMISSIONS IN A VEHICLE CONVERTED FROM GASOLINE TO CNG FUEL

Pollutant	Change in Emissions	Comments
Reactive Hydrocarbons	-40%	Includes effect of reduced reactivity due to high methane fraction.
CO	-50%	
NO_x	+40%	NO_x emissions generally increase with CNG due to its high flame temperature. This reflects an average of the data range.
Evaporative Hydrocarbons	-100%	Assumes no evaporative emissions. However, there may be some leakage of methane upon refueling.

Estimate of pollutant levels -- general considerations

Emissions estimates exist for some individual retrofit vehicles. However, the emissions estimates vary widely, based on several considerations. The primary consideration is whether the vehicle operates on CNG as the sole fuel or operates as a dual-fuel vehicle. A vehicle operating on two fuel types is not as efficient in either fuel as a vehicle running exclusively on one fuel. Even with dedicated CNG service, a deterioration of driveability and power loss may be experienced and readjustments for better operation would affect emissions. Furthermore, there are several different conversion kits available. Each one can have a wide variation in emissions, depending on proper installation and changes made to the vehicle's operating parameters (i.e., timing, fuel mix, etc.). In addition, each model vehicle may have different emission characteristics, even when the same conversion kit is properly installed.

A critical assessment of the contribution of this category to area-wide emissions was not undertaken in this effort and none of the references cited gave any estimate on the overall emissions from this source category. Additional effort is warranted to adequately assess the population of vehicles using CNG as a fuel and to develop the appropriate emissions estimates based on specific factors for each population subgroup.

Estimate of pollutants levels -- gasoline engines

A vehicle operating on CNG (either a dual fuel vehicle or a dedicated CNG vehicle) will generally show a reduction in CO emissions. CNG vehicles operate more efficiently when the engine timing is advanced and the compression ratio is higher. However, CNG use is often incompatible with current emissions control hardware. Conversion kits have little interaction with control hardware or computers. NO_x emissions may then increase due to a lack of control of the stoichiometric mix with CO and hydrocarbons. Stopping gasoline flow when CNG is used may cause gumming and corrosion in fuel lines and injectors, causing error codes to be stored in the onboard computers designed to operate emission control equipment and system failure. Development of appropriate fuel metering systems will allow proper performance in engine and emission controls.

Total hydrocarbon emissions (mostly methane) are greater in CNG vehicles when operating on CNG, but there is a 40 percent reduction (approximately) in reactive hydrocarbons. CO emissions are 25 percent

less in CNG vehicles; other research has indicated a 19 percent reduction in the total of greenhouse gases produced when compared to operation of the same engine on gasoline.

No data are available on aldehyde emissions or other toxic air pollutants from late model vehicles. One test with earlier models showed a decrease in aldehyde emissions.

Estimate of pollutants levels -- diesel engines

All tests performed with compression ignition (diesel) engines were performed without a changeover to spark ignition when in the CNG operational mode. CO and hydrocarbons emissions were higher when the vehicle was operated with CNG; PM emissions were substantially lower. Aldehyde emissions were also higher when the method of fuel addition was direct injection instead of fumigation or a mixing of fuel and air before entering the ignition chamber. Aldehyde emissions may be lower when CNG is added by fumigation.

It is estimated that NO_x and PM emissions may be reduced by conversion of diesel engines to CNG, but at an unknown power/performance trade-off.

Point/area source cutoff

Emissions from this category should be included in the area or mobile source portion of the emissions inventory.

Level of detail of information available

The information currently available for CNG vehicles is based on a limited number of tests with only a few vehicle model/conversion kit combinations. Information on VMT, consumption of CNG for vehicular use and types of vehicles using CNG are currently not available.

Level of detail required by users

The least amount of information necessary to determine the contribution of CNG vehicles to mobile source emissions would be an inventory of the types and sizes of vehicles using CNG, how many of each type/size are dual-fuel vehicles, and VMT and fuel consumption for each combination of characteristics.

Emission factor requirements

The specific emission factors for the vehicle type, conversion type (dedicated CNG versus dual-fuel) and control equipment need to be established.

Regional, seasonal or temporal characteristics

No regional, seasonal or temporal characteristics are expected in the use of CNG as a vehicle fuel. However, CNG has superior cold start characteristics, making this fuel more efficient than gasoline at low ambient temperatures.

Urban or rural characteristics

CNG use is dependent on fuel availability and access to refueling stations. The driving forces in CNG use include the economies of scale (i.e., the cost of construction and operation of refueling stations require a large number of vehicles using the facility to make it feasible) and emissions reductions in nonattainment areas. Therefore, urban areas will most likely be more heavily involved in using CNG vehicles.

Methodology

The methodological guidelines used to develop emission factors (the Federal Test Procedures, or FTP) are the same as those used for gasoline-fueled vehicles. Estimates of fuel usage will most likely be available through distributors. Information on type of conversion (dedicated or dual-fuel), the vehicle converted, the conversion kit used and driving conditions will need to be obtained before an accurate emissions estimate can be made.

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MOBILE SOURCE EVAPORATIVE AND RUNNING LOSSES

Definition/description of category and activity

Mobile source emission factors (i.e., grams of non-methane hydrocarbons (NMHC) per mile) are currently estimated using the MOBILE4 emission factor model.[1] MOBILE4 model calculates emission factors for eight individual motor vehicle types. NMHC emission factors are separated into four categories: exhaust, evaporative, refueling losses and running losses. Running losses are not included in MOBILE3, the previous motor vehicle emission factor model. In addition, evaporative emissions are now based on the user input minimum and maximum daily temperatures, fuel Reid vapor pressure (RVP) and the fractions of vehicles assumed to experience hot soaks and diurnal emission generation cycles.

Process breakdown

The most significant change to MOBILE4 is the addition of running loss emission factors. Running loss emissions are defined as evaporative emissions occurring while the vehicle is in operation. Running losses are in part the result of insufficient evaporative canister purging during vehicle operation, i.e., the canister reaches saturation and evaporative emissions continue to be generated. As a result of fuel tank temperature increases, these emissions are released from the vehicle into the atmosphere. Vehicle fuel system leaks may also contribute to running loss emissions. Running losses are a function of temperature and fuel volatility and depend on average vehicle speed, vehicle type, vehicle age and the evaporative control system.

Evaporative emissions occur while the vehicle is standing. Evaporative emissions are caused by the inability of existing carbon adsorption fuel vapor control systems to handle evaporative emissions as a result of fuel tank temperature increases. Evaporative emissions are also generated through leaks in hosing and connections in the evaporative systems. Evaporative emission factors have been modified since the introduction of the MOBILE3 model. In the MOBILE4 model, there are three major differences in the calculation of evaporative emission rates: diurnal and hot soak rates are now based on the user input minimum and maximum daily temperatures; diurnal and hot soak rates are dependent on the user input fuel RVP; and the fractions of vehicles assumed to experience hot soaks and diurnal emission generation cycles are based on analysis of a large amount of detailed trip information. Hot-soak emissions from the carburetor system occur after the engine is shut down at the end of a trip. Diurnal emissions are caused by diurnal changes in ambient temperature resulting in the expansion of the air-fuel mixture in a partially-filled fuel tank. As a result, gasoline vapor is expelled to the atmosphere. Each of these changes results in more accurate and realistic evaporative emission factors.[2]

Reason for considering the category

The previous mobile source emission factor model, MOBILE3, did not consider running losses. Evaporative emission rates did not vary on the basis of temperature information input by the user or on the basis of fuel volatility. These changes cause a significant increase in the mobile emission factors. On-road mobile sources account for 37 percent of the total VOC emissions nationally.

Pollutants emitted

VOC

Estimate of the pollutant levels

Total on-road mobile source emissions from the 1985 NAPAP Inventory are estimated to be 7,363 thousand tons of VOC.[3] National mobile source VOC emissions for 1985 have increased from 24.7 to 29.0 percent of the total to adjust for running losses and evaporative emissions that MOBILE3 does not include. Table 1 lists the percent increase in emission factors using MOBILE4 instead of MOBILE3 for each state.

TABLE 1. MOBILE SOURCE EMISSION FACTOR INCREASES RESULTING FROM THE SUBSTITUTION OF MOBILE4 FOR MOBILE3

		EMISSION FACTOR INCREASE IN PERCENT FROM MOBILE3 TO MOBILE4		
STATE	ANNUAL AVERAGE TEMPERATURE (°F)	EXCESS EVAPORATIVE LOSS	RUNNING LOSS	TOTAL ADJUSTMENT
Alabama	62.5	24.7	1.4	26.1
Arizona	67.5	24.7	4.3	29.0
California	65.1	24.7	2.9	27.6
Florida	67.3	24.7	4.2	28.9
Georgia	60.7	24.7	0.4	25.1
Louisiana	65.4	24.7	3.1	27.8
Mississippi	63.2	24.7	1.8	26.5
Nevada	67.5	24.7	4.3	29.0
North Carolina	60.1	24.7	0.1	24.8
South Carolina	62.7	24.7	1.5	26.2
Texas	65.7	24.7	3.2	27.9

Note: All remaining states and the District of Columbia were based on average temperatures below 60 degrees Fahrenheit. VOC emissions were adjusted by the factor 24.7 percent for excess evaporative loss and zero percent for running losses.

Point/area source cutoff

Not applicable, as running and evaporative losses from mobile sources are considered in the mobile source inventory.

Level of detail of information available

Climatological data are available from the National Climatic Data Center in Asheville, North Carolina. State- level VMT data are available from *Highway Statistics*.[4]

Level of detail required by users

VMT by county

Minimum and maximum ambient temperatures

Fraction of vehicles experiencing hot soaks and diurnal emissions (fraction of vehicles operating in a cold start condition, hot start-up condition and hot stabilized condition)

RVP of gasoline used

Vehicle speeds

Emission factor requirements

NMHC emissions per VMT

Regional, seasonal or temporal characteristics

Greater emissions occur in summer due to higher temperatures and higher VMT. Running losses occur mainly during daytime operations. Evaporative emissions, diurnal and hot-soak, vary throughout the day.

Urban or rural characteristics

An urban and rural source

Methodology

A methodology for estimating VOC running and evaporative emissions is described in *Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources*.[5] This document provides guidance for selecting inputs for the MOBILE4 emission factors model. VOC emission factors from MOBILE4 are multiplied by county VMT data to obtain county level VOC emissions. There are several methods for allocating state VMT data. These methods involve apportioning state VMT by county gasoline sales, total roadway inventory data, county vehicle registration data or county population.

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MOTOR VEHICLE RACING

Definition/description of category and activity

Air emissions from motor vehicle racing result from combustion of fuels and disturbance of dust on dirt tracks. While *AP-42*[1] lists emission factors for sources very similar to these two activities, these emission factors require some adjustment for application to motor vehicle racing and substantial amounts of data must be collected.

Calculating motor vehicle racing emissions is complicated by several factors. First, emissions from automobiles are not calculated uniformly for all inventories and for all states within a given inventory. An example of the various sources of VMT data for the 1986 NEDS inventory is included in Table 1. In cases where emissions are based on gasoline sales taxes, motor vehicle racing may already be accounted for in those states which tax off-highway use of gasoline and for those race classes which use gasoline.[2]

A second complicating factor is the paucity amateur racing statistics, non-racing miles and non-car races. Finally, professional car races are administered by five different organizations. Data available from the National Association for Stock Car Racing (NASCAR), Championship Auto Racing Teams (CART), Sports Car Club of America (SCCA), American Race Car Association (ARCA) and the National Hot Rod Association (NHRA) vary widely in accessibility, detail and quality. Comparisons among the different classes of races are difficult due to variations in fuel type (methanol, nitrous oxide and gasoline), fuel efficiency (which varies from 1.8 to 15 mpg) and percent of participating cars completing each race.

Process breakdown

Air emissions from motor vehicle racing results from fuel combustion and disturbance of dirt on unpaved tracks. While the dust disturbance can not practically be further subdivided, fuel combustion can be addressed in great detail. A variety of classes of motor vehicle races are held in the United States, as listed below:

- I. Motorcycles
  - A. Off Road
    - 1. Ice racing
    - 2. Outdoor motocross
    - 3. Supercross
    - 4. Enduroracing
    - 5. Trials (obstacle course)
    - 6. Hill climbing
    - 7. Flat track
  - B. Road Racing
    - 1. Club racing (amateur)
    - 2. Grand prix
    - 3. V-twin
    - 4. Superbikes
  - C. Schools
- II. Cars
  - A. National Hot Rods Association
  - B. Sports Car Club of America
    - 1. Proracing
      - a. TransAm

TABLE 1. SUMMARY OF 1986 NEDS VMT DERIVATION

State	Total VMT[3] (Thousands)	State[4] Reported	EPA[4] Calculated
Alabama	33,241,875		X
Arizona	26,473,579		X
Arkansas	19,603,671		X
California	202,312,067	X	
Colorado	25,039,081		X
Connecticut	23,367,776		X
Delaware	6,019,228	X	
District of Columbia	3,287,389		X
Florida	92,363,721		X
Georgia	60,270,210	X	
Idaho	7,139,806		X
Illinois	76,708,774	X	
Indiana	43,586,456		X
Iowa	21,820,696	X	
Kansas	21,164,321	X	
Kentucky	30,003,628		X
Louisiana	33,827,725		X
Maine	9,222,839		X
Maryland	36,733,245	X	
Massachusetts	31,887,274	X	
Michigan	74,273,888	X	
Minnesota	35,327,926	X	
Mississippi	20,521,124	X	
Missouri	44,643,996		X
Montana	6,559,189		X
Nebraska	3,665,884	X	
Nevada	8,395,582	X	
New Hampshire	7,738,618		X
New Jersey	59,140,388		X
New Mexico	14,089,772	X	
New York	98,520,232		X
North Carolina	51,892,668		X
North Dakota	6,102,354	X	
Ohio	79,967,791		X
Oklahoma	27,736,640		X
Oregon	24,076,063	X	
Pennsylvania	75,108,939		X
Rhode Island	6,491,566		X
South Carolina	7,784,880		X
South Dakota	6,715,422	X	
Tennessee	42,950,680		X
Texas	156,448,887	X	
Utah	12,774,697	X	

(continued)

TABLE 1. SUMMARY OF 1986 NEDS VMT DERIVATION (continued)

State	Total VMT[3] (Thousands)	State[4] Reported	EPA[4] Calculated
Vermont	4,980,745	X	
Virginia	46,434,434		X
Washington	32,926,795		X
West Virginia	13,781,168	X	
Wisconsin	33,170,412		X
Wyoming	6,006,467	X	
TOTAL	1,842,300,568	854,075,794	988,224,774

b. World Challenge
c. Race Trucks (light duty pick up trucks)
d. Formula type
2. Club racing and Amateur
C. Championship Auto Racing Teams
1. Indy Cars
D. Auto Racing Club of America
1. Stock cars
2. Pro-fours
3. Midgets
4. Figure-eights
E. National Association for Stock Car Auto Racing
1. Senior circuit
2. Weekly circuit
F. Schools

III. Other
A. Monster Trucks
B. Demolition Derby
C. Tractor pulls
D. All Terrain Vehicles
E. Non-racing miles for all of the above
1. Time trials
2. Practice laps
3. Victory laps
F. Amateur races for all of the above

Reason for considering the category

Because motor vehicles contribute the majority of CO, VOC and NO_x emissions as well as a substantial proportion of PM_{10} emissions. All types of motor vehicle use should be inventoried. Emissions from motor vehicle racing, although likely to be negligible on a national aggregate basis, may be large enough to affect compliance status at a local level. Furthermore, each of these pollutants can cause significant health effects, visibility impairment and ecological damage.

Pollutants emitted

CO, NO_x, VOC and PM_{10}

Estimate of the pollutant levels

Due to the variability of race characteristics and the paucity of recorded data, it is beyond the scope of this characterization to estimate national levels of pollutant emissions from motor vehicle racing.

Point/area source cutoff

Racing vehicles, like other motorized vehicles, may be addressed as area sources. Individual race courses may be inventoried as point sources.

Level of detail of information available

As stated above, the level of information available varies enormously between classes of vehicles. Virtually no data are maintained on racing schools, motorcycle events or the categories labeled "Other" in the process breakdown. Since most unpaved tracks are amateur circuits, information on PM_{10} emissions from dirt disturbance during racing will be extremely difficult to evaluate. Data on professional car racing were provided by NHRA, SCCA, CART, ARCA and NASCAR. Approximately 90 percent of United States professional car races are administered by these five organizations.[5]

NHRA has collected much of the data necessary for emissions calculations, which will be forthcoming. NHRA administers approximately 3,000 events annually, all of which are 0.25 mile races in which five to 1,000 cars participate.[6]

Mr. Lars Hanson of SCCA provided sports car race statistics. Fuel efficiency for TransAm race cars is five to six miles per gallon. Mr. Hanson did not identify the types of fuels used by TransAm racers. SCCA sponsors 15 TransAm races per year, all of which are 100 miles in length. Thirty-five cars typically race in each TransAm event. Fuel efficiency for World Challenge race cars is ten to 12 miles per gallon of gasoline. Eight World Challenge events are held per year, five of which are 40 miles in length and three of which are 150 miles in length. Typically, 35 vehicles race in each World Challenge event. Fuel efficiency for SCCA's race trucks is approximately 15 miles per gallon of gasoline. SCCA sponsors eight road races for trucks: two races are 20 miles long, four races are 40 miles long and two races are 150 miles long. Usually, 12 trucks participate in each event.[7]

CART administers a single class of car races: eight-cylinder, rear engine, purpose-built, single seat, open cockpit, open wheel vehicles known as Indy cars. CART requires these cars to get at least 1.8 miles per gallon of pure methanol. The maximum VMT per car per season in this circuit is 3,567.3, while the average is 3,000. Sixteen races are sponsored annually, with 26 cars participating in each event. Total annual VMT in CART events is 78,000.[5]

ARCA administers four classes of race cars, including stock cars, midgets, figure-eights and pro-fours. With the exception of midgets, which use methanol, all of the race car classes burn gasoline. Seventy to 80 races are held by ARCA annually, ranging in length from one-quarter mile to 500 km. Between 18 and 42 racers participate in each event.[8]

NASCAR administers a senior racing circuit as well as 85 weekly tracks in 37 states. The senior circuit has 16 paved tracks which run a total of 29 races each season. In addition, the senior circuit includes

three races on road courses, which are 150, 219 and 187 miles in length. Each of the weekly tracks hold approximately 20 races annually.[9]

Level of detail required by users

Emission factors by vehicle type or fuel type

VMT by vehicle type or fuel type

Fuel efficiency by vehicle type

Emission factor requirements

CO, NO_x, VOC, PM_{10} emissions per county, by vehicle class

Regional, seasonal or temporal characteristics

Motor vehicle races are held in most states, although the activity is concentrated in the South, Midwest and California, New York, Florida and New Jersey. Racing is less common in the Northwest, Alaska, Hawaii, New Mexico, Texas, North Dakota and South Dakota. Professional events are held during a specific season, usually running from February to November. Most events are held in the afternoon and evening.

Urban or rural characteristics

Most racing events are very localized, in that they are restricted to oval tracks. These races are largely held in rural areas. Grand Prix events and other major races are held exclusively in cities.

Methodology

- Determine which states base their VMT estimates on fuel taxes. Determine which of those states tax off-highway gasoline use. Assume that those states have already accounted for the majority of motor vehicle races in their inventory.
- Calculate VMT attributable to motor vehicle racing for the remaining states. Allocate VMT to counties based on locations of race tracks.
- Determine which emission factors are most applicable to the various classes of race cars; if none are, develop new emission factors through field studies.
- Compute pollutant emissions attributable to fuel combustion by motor vehicle racing, by vehicle class and county.
- Survey racing agencies and clubs to inventory unpaved tracks by state or county.
- From previous calculations, apportion VMT on unpaved tracks by county.

- Adjust existing emission factors for unpaved roads to address racing activity or develop new emission factors through field studies.

- Compute PM_{10} emissions attributable to dirt disruption on unpaved race tracks, by county.

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PETROLEUM VESSEL LOADING AND UNLOADING LOSSES

Definition/description of category and activity

Evaporative VOC emissions from ocean-going ships and barges carrying petroleum liquids result from loading losses, ballasting losses and transit losses. Loading losses are the primary source of evaporative emissions from marine vessel operations.[1] Ballasting losses are a major source of evaporative VOC emissions associated with unloading petroleum liquids at marine terminals. In addition to the losses associated with loading and unloading, evaporative VOC emissions also occur while the cargo is in transit. These transit losses are similar in many ways to breathing losses associated with petroleum storage. Marine vessels transport both crude oil and refined petroleum products. About 46 percent of the crude and refined petroleum is transported by water.[2] In 1988, approximately 590,000,000 gallons of petroleum were transported between Petroleum Administration for Defense (PAD) districts by barge and tanker ships.[3] This figure does not appear to take into account the volume of petroleum imported into the United States, almost all of which is brought into the country on tanker ships.

Process breakdown

VOC emissions result from three processes: loading, ballasting and transit.

Loading Losses

Loading losses occur as organic vapors are displaced from the cargo tanks to the atmosphere as the liquid is loaded into the tanks. These vapors are formed by three processes: (1) formation of vapors in the empty tank by evaporation of the residuals from the previous cargo; (2) vapors transferred to the tank in vapor balance systems as product is being unloaded; and (3) vapors generated in the tank as the product is being loaded. The quantities of vapor generated and eventually emitted depend on several factors, including the physical and chemical characteristics of the cargo and the method of loading the cargo. Emission factors for loading loss emissions are given in *AP-42*.[1]

Ballasting Losses

It is common practice for marine vessels to load several cargo tanks with sea water after the petroleum is unloaded. This water, or "ballast," acts to improve the stability of the empty vessel. Ballasting techniques vary with the port and size of ship. However, VOC emissions occur from the empty cargo tanks when the vapors are displaced to the atmosphere as the cargo tank is loaded with sea water. VOC emission factors for various ballasting conditions are given in *AP-42*.

Transit Losses

Additional evaporative losses occur while the petroleum cargo is in transit. Transit losses are similar in many ways to the breathing losses associated with petroleum storage tanks in bulk terminals. Emissions are dependent on the pressure in the tank at the start of the trip, vapor pressure of the transported fuel, pressure relief valve settings, vapor tightness of the tank and degree of fuel vapor saturation of the space in the tank during transportation. Emissions factors due to transit losses are given in *AP-42*.

Reasons for considering the category

As mentioned above, waterborne transport of petroleum represents a significant percentage of the total petroleum transported in the United States. In 1987, the United States imported about 2,004,000 barrels

of petroleum products per day and 4,674,000 barrels of crude oil per day, almost all of which was brought to the country aboard maritime tankers.[4] Also in 1987, approximately 676,000 barrels of petroleum products per day and 599,000 barrels of crude oil per day were transported by water between PAD districts. The 1985 NAPAP Emissions Inventory estimated that approximately 21,315 tons of VOC were emitted from loading and unloading crude oil onto waterborne tankers.[5] An additional 27,248 tons of VOC were emitted from loading and unloading petroleum products onto waterborne tankers. These emissions do not seem to be consistent with the activity data for waterborne commerce published by the U.S. Army, Corps of Engineers. For instance, the *Waterborne Commerce of the United States* statistics show that Mobile harbor in Alabama handled approximately 161,000 short tons of jet fuel in 1987.[6] The NAPAP inventory for emissions from marine vessel loading shows no throughput of jet fuel for Mobile County, Alabama.[5] Such inconsistencies between activity data and emissions need to be addressed.

Pollutants emitted

Mostly VOC, but can include some small quantities of other hydrocarbons such as methane and ethane

Estimate of the pollutant levels

The 1985 NAPAP Inventory estimated that 48,564 TPY of VOC were emitted from marine vessels handling petroleum products and crude oil as cargo.[5] This estimate is probably somewhat lower than the actual emissions from this source category.

Point/area source cutoff

Although there may be certain ports where loading large marine tankers results in emissions greater than 100 TPY, VOC emissions in most ports do not exceed 100 TPY. Marine vessels should be considered area sources and thus better account for VOC emissions from transit losses.

Level of detail of information available

Tables 4.4-2, 4.4-4 and 4.4-6 in *AP-42* give emission factors for various marine vessel sources such as loading operations on ocean tankers and barges, tanker ballasting and transit losses of VOC for the following fuels: gasoline; crude oil; jet naphtha; jet kerosene; distillate oil No. 2; and residual oil No. 6.

The throughput of petroleum through each port in the United States is published by the U.S. Army Corps of Engineers in *Waterborne Commerce of the United States*.

Waterborne Commerce of the United States also contains information on the number of vessels passing through each port.

Level of detail required by users

VOC emissions from petroleum marine vessel sources in each county

Amount of fuel, by type, passing through port

Number of vessels, by type, passing through port

Properties of fuel transported such as the vapor pressure, temperature, molecular weight and density

Emission factor requirements

The following emission factors are not given in *AP-42* and should be developed:

- emission factors for tanker ballasting petroleum products such as jet naphtha, jet kerosene, distillate oil No. 2 and residual oil No. 6
- emission factors for tanker lightering (Tanker lightering is a process by which some very large supertankers unload petroleum to smaller barges, since when fully laden these tankers are unable to enter a harbor.[7])

Regional, seasonal or temporal characteristics

The emissions from this source are likely to be concentrated in urban coastal areas and ports on inland waterways. There are unlikely to be any seasonal or temporal differences, unless a port freezes over in winter and is inaccessible.

Urban or rural characteristics

Principally an urban source

Methodology

The weight of various petroleum cargo shipments in short tons received and shipped through each port (inland and coastal) in the United States is given in *Waterborne Commerce of the United States*. This document also provides statistics on the number of tankers and barges, vessel draft in the water and the direction of travel, i.e., if they are inbound or outbound into a coastal port or upbound or downbound at an inland port. Once the draft and number of vessels are known at each port, an estimate can be made for the amount of petroleum shipped in tankers versus barges. VOC emissions at each port can be estimated by converting the short tons of petroleum into 1,000 gallons and multiplying this by appropriate multipliers and emission factors for tankers or barges available in *AP-42*.

References

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DRINKING WATER TREATMENT WITH OZONE

Definition/description of category and activity

Ozone is used in the treatment of potable water primarily as a disinfectant agent. Since 1906, Europeans have been treating water with ozone and more than 200 plants currently use this technique.[1] There are 40 water treatment facilities using ozone in the United States and many more installations are planned.[1] Ozone has also been found effective in various stages of water treatment including the control of taste and odors; the reduction of color, turbidity, and trihalomethane precursors; the oxidation of reduced inorganic chemicals such as iron and manganese; and the control of algae and aquatic growths. Ozonation is most effective when employed in a number of stages or as a single step near the end of treatment after other processes have reduced the ozone demand. In a 1989 survey of the 40 U.S. plants equipped with ozonation technologies, half had single stage contractors. The survey noted that the increased use of multiple stage reactors with longer contact times may be necessary to meet new bacterial and virus inactivation regulations.[2]

Process breakdown

The unit treatment operation consists of ozone generation, ozone contact with treated water, and the treatment of offgases. All gaseous ozone used in the operation is prepared onsite using ambient air or liquid oxygen as raw feed-gas for electric discharge ozone generators. These generators range in size from two pounds per day to nearly one ton per day. Contact between target pollutants in the water influent and ozone is then achieved by dispersing ozone gas bubbles at a concentration level ranging from two to ten mg per liter into covered columns or mechanically agitated vessels via fine-bubble diffusers and aspirating turbines.

Typical water depth of fine-bubble contactors in the 1989 survey ranged from ten to 25 feet, most in excess of 15 feet.[2] Offgases from the contactor units are captured and concentrations of contaminants are reduced to an acceptable level using heated catalytic ozone-destruction units, thermal destruction, dilution, and recycling to the liquid stream.

No emission factors have been developed for this process. Potential sources of ozone emissions are fugitive losses from the ozone generator and the ozone contactor and residual ozone in the treated offgas (Figure 1). Open systems using diffuse ozone aeration of treatment basins may result in fugitive losses from the basin.

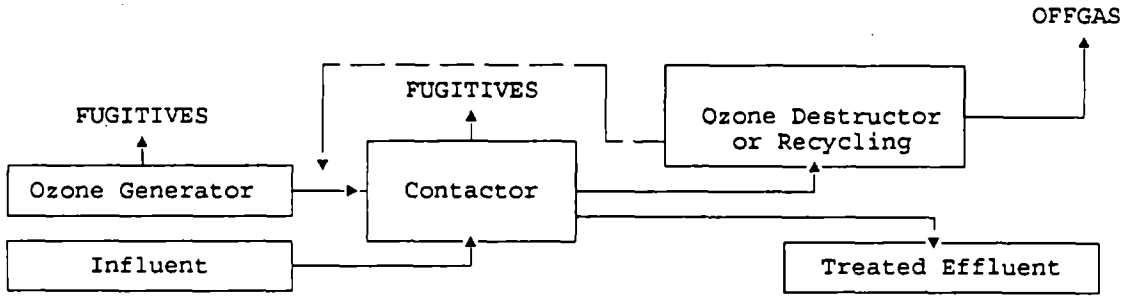

Figure 1. Schematic representation of closed loop water ozonation.

Reason for considering the category

The use of ozone in water treatment has been steadily rising due to significant improvements in ozone technology and the concern over the use of chlorine disinfection as a source of toxic chloroorganics.

Pollutants emitted

Ozone (potential)

Estimate of the pollutant levels

For an average contacting system with a practical yield of 90 percent (i.e., 90 percent of the ozone added to the contactor reacts with the aqueous phase) and an initial concentration of the process gas around ten ppm, the approximate concentration of ozone in the untreated offgas may approach one ppm. Heated catalytic and thermal ozone destruction units with ozone removal rates of 99 and 100 percent, respectively, are utilized by many larger capacity plants. In other processes which include repeated injection, preozonation, dilution and recycling, the final concentration of ozone in the offgas is reduced to 0.1 to 0.25 ppm. Emissions concentrations resulting from these processes may be vented directly up to the threshold limit value (TLV) of 0.1 ppm ozone.[3,4]

Assuming a typical system generating 100 pounds of ozone per day, approximately ten pounds of ozone per day would not react in the water stream and would be present in the untreated offgas. Based on a 99 percent removal rate, treated and released offgas may contain only 0.1 pounds of ozone per day (about four pounds per year) barring upsets. Additional ozone may be emitted due to fugitive leaks at the generator and contactor. Large treatment systems may approach 100 pounds of ozone emitted per year, but total U.S. emissions of ozone from water treatment may be only a few tons or less at this time. However, no emissions studies are available to confirm this assumption.

Point/area source cutoff

The size of treatment plants using this process ranges from small to large. A major limitation to selection of ozone disinfection is the large capital outlay and operational costs. Emissions of ozone are likely to be small at all plants due to the operation of ozone destructors prior to release of the process gases. Apparently, small point-of-use units are also available to domestic users, though no information on the potential market penetration of these systems or potential emissions is available.

Level of detail of information available

No studies on atmospheric ozone emissions from ozonation of water treatment have been documented. Location of treatment works employing ozone and their capacities are available from the American Water Works Association (AWWA) Research Foundation and from state permitting systems.

Level of detail required by users

Location of relevant water treatment plants

Emissions rate by plant and process (fugitives and offgas)

Million gallons of water treated by plant

Emission factor requirements

Ozone emitted per million gallons per day water treated

Regional, seasonal or temporal characteristics

None

Urban or rural characteristics

Although associated with urban areas, treatment plants may be in or outside the urban area.

Methodology

Because only 40 plants using ozonation are currently online, these plants represent only a small fraction of the total water treated for disinfection in the United States. It is likely that potential emissions of ozone during normal operating conditions are very small due to the ozone destruction technologies employed prior to offgassing. The category should therefore be treated as an area source for emissions estimation purposes. However, these plants can be identified through the AWWA or state permits and included either as point sources in an inventory or individually evaluated prior to inclusion in an area source category. Development of any methodology is predicated on the determination of an emissions factor based on source testing and related to the flow of treated water in a plant.

The AWWA Research Foundation is currently publishing a new reference, *Ozone in Water Treatment: Applications and Engineering* (Lewis Publishers). This text should be available in early 1991 and the AWWA will notify Alliance Technologies upon its release. A review of current research and information on existing systems, planned installations, and current and anticipated technologies will be included.

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EXTRA HIGH VOLTAGE (EHV) TRANSMISSION LINES

Definition/description of category and activity

EHV transmission lines transport electrical power at 765 kilovolts (kV). Ozone emissions occur when corona is discharged in the air from electrical apparatus (transmission lines). Corona is generated when an electrodeless discharge is induced in air passing through an alternating electric field. Corona starts at points along the transmission line where, due to scratches, solid particles or water droplets, the local voltage gradient is high.[1-7]

Process breakdown

Ozone production is associated with the ionization of the molecular constituents of air, oxygen and nitrogen in the vicinity of transmission-line conductors. 59 kcal of energy is required to produce a mole of ozone from oxygen by electric discharge. With the ionization of the oxygen molecule the following reactions are possible:

$$O_2 \rightarrow O + O \quad \text{and} \quad O + O_2 \rightarrow O_3$$

Thus, the highly active agent ozone is formed. Another reaction, although less likely, is the disassociation of N_2 to form NO_x. Corona loss or discharge is affected by temperature, humidity, conductor diameter and, especially, precipitation. Corona loss during foul weather is about 45 times higher than corona losses during fair weather. Foul weather is defined as conditions of 95 percent relative humidity, fog or actual precipitation. However, higher corona losses during foul weather do not increase ozone levels since moisture accelerates the decomposition of the ozone. The half-life of ozone under normal atmospheric conditions is one hour. In water, the half-life of ozone reduces to about 20 minutes. The ozone production rate tends to decrease with the increase of conductor diameter, temperature and humidity. The following general equation relates conductor diameter, temperature and humidity to ozone production:[5]

$$Z = A_{(d)} \text{Exp} -(T/B_{(d)} + E/80)$$

where: Z = ozone production rate, g/kWh (ozone production to corona loss ratio)
T = °C
E = partial pressure of water vapor, mmHg
A and B are coefficients depending on the conductor diameter d.

Reason for considering the category

Sources of direct ozone production are not covered in typical SIP inventories. The corona developed around EHV power lines produces ozone. Unlike lower voltage power lines, it is not economically feasible to totally exclude corona discharges from EHV power lines.

Pollutants emitted

Ozone, NO_x

Estimate of the pollutant levels

No estimates of ozone emissions from EHV transmission lines have been found in the literature. Total ozone emissions are the product of corona loss, ozone production to corona loss ratio and length of transmission line. Total ozone emissions from EHV transmission lines in the United States are estimated for this characterization to be approximately 870 TPY, calculated as follows:

Fair weather corona losses: 3 kW per mile
Foul weather losses: 135 kW per mile
Average ozone production to corona loss ratio: 1.92 g/kWh
Assume bad weather occurs 20 percent of the time

Average corona loss
= (0.20 x 135 kW/mile) + (0.80 x 3 kW/mile)
= 29.4 kW/mile

Ozone production
= (corona loss) x (ozone production to corona loss ratio)
= (29.4 kW/mile) x (1.92 g/kWh)
= (56.4 g/mile·hr) x (8,760 hr/yr)
= (56.4 g/mile·hr) x (8,760 hr/yr) x (1 lb/454g) x (1 ton/2000 lb)
= 0.545 tons/mile·yr

There are approximately 1,600 miles of EHV transmission lines based on the Energy Information Administration map dated December 31, 1977. (This estimate includes lines in the following states: Illinois, Michigan, Indiana, Kentucky, West Virginia, Virginia and Ohio.)

Tons ozone = (1,600 miles) x (0.545 tons/mile·yr)
= 870 tons/year

Convert ozone ratio into maximum ground-level oxidant concentration.

$$N_{max} = Q/(\pi e/2)^{1/2} \cdot u \cdot h$$

where: Q = production rate/length of line, 0.0351 kg/km·hr
u = wind speed, 1.6 km/h
h = line height, 12.2m

$$N_{max} = (0.847 \text{ kg/km·day})/(3.14 \times 2.718/2)^{1/2} \times (1.6 \text{ km/h}) \times (12.2\text{m})$$
$$= 8.64 \times 10^{-7} \text{ g/m}^3$$
$$= 0.4 \text{ ppb}$$

Therefore, ozone from EHV lines would increase ground-level oxidant concentration by 0.4 ppb.

Point/area source cutoff

EHV transmission lines would not be considered point sources since emissions from transmission lines would not exceed the point source cutoff for an inventory. In addition, the nature of the activity requires that EHV transmission line emissions should be considered area sources.

Level of detail of information available

production rate of ozone generation per corona loss during foul weather conditions (laboratory and field results)[1,2,3,4,5]

corona losses (laboratory and field results) [2,3,4,5]

Level of detail required by users

length of EHV transmission lines

ozone production rate per corona loss

corona losses

Emission factor requirements

Development of ozone emission factors for EHV lines for different types of atmospheric conditions: dry, humid, cold, warm and foul weather conditions. Climatic data will be needed to develop regional emission factors.

Regional, seasonal or temporal characteristics

Greater emissions occur during periods of foul weather.

Urban or rural characteristics

An urban and rural source

Methodology

Presently no methodology exists for estimating ozone emissions from EHV transmission lines. Average ozone emission factors developed for EHV transmission lines may not represent actual emissions since temperature, pressure, humidity and precipitation vary significantly from month to month and from state to state. Emission factors would need to be developed for several different atmospheric conditions. County-wide ozone emissions can be estimated by determining the number of miles of EHV transmission lines in each county and multiplying by the appropriate emission factor.

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PHOTOCOPIERS AND LASER PRINTERS

Definition/description of category and activity

Photocopiers and laser printers are direct producers of ozone (O_3) and may be considered area sources of ozone emissions.

Process breakdown

The corona assemblies (electrical modules creating electric fields sufficient to ionize atmospheric gases) found in laser printers and photocopiers generate ozone gas as a by-product of the electrophotographic process. Ozone is only generated while the equipment is printing (while the coronas are energized).[1]

Reason for considering the category

Sources of direct ozone production are not covered in typical SIP inventories. The rising popularity of laser printers and photocopiers justifies preliminary study of emissions from these devices.

Pollutants emitted

Ozone

Estimate of the pollutant levels

Underwriters' Laboratories tests office equipment to determine whether equipment violates air quality standards. The Occupational Safety and Health Administration (OSHA) air quality standard for ozone emissions requires that photocopiers and laser printers not increase the sustained ambient ozone concentration by more than 0.1 parts per million by volume (ppm) above background levels. Peak ozone levels may not exceed 0.3 ppm above background levels. The tests are performed in a 1,000 cubic foot room at constant temperature and humidity with air changeover rate not to exceed 500 cubic feet per hour. These test limits approximate typical equipment performance at moderate humidity levels.[2] Using the sustained ozone concentration as a performance standard, a per-machine emission factor can be determined as follows:

$$1.5 \times (1{,}000\ ft^3) \times (0.1 \times 10^{-6}) \times (28.32\ l/ft^3) \times (2.14\ g\ O_3/l) = 0.009\ g\ O_3/hr$$

Data estimating the number of photocopiers and laser printers sold annually in the United States are available through the Computer and Business Equipment Manufacturers Association in an annual publication.[3] The cost of this publication is not justified for this preliminary emissions estimate.

Point/area source cutoff

Emissions from photocopiers and laser printers are widespread and relatively small and should be treated as area sources.

Level of detail of information available

Reference 3 includes estimates of annual sales of laser printers and photocopiers. Employment data which may be used to distribute national emissions to counties are available in *County Business Patterns*.[4]

Level of detail required by users

National population of photocopiers and laser printers

National and county-level total employment in service, finance, insurance and real estate

Emission factor requirements

The emission factor used in this study is a preliminary estimate. More accurate emission factors would relate the size or function of a piece of equipment to its emissions rate.

Regional, seasonal or temporal characteristics

No regional or seasonal characteristics are observed. Since photocopiers and laser printers are used more often during business hours and weekdays, the majority of emissions should be allocated to weekdays between 8:00 a.m. and 6:00 p.m.

Urban or rural characteristics

Photocopiers and laser printers are most often used in businesses, institutions and industry, all of which are more common in urban than rural areas.

Methodology

I. Estimate national emissions levels

A. Estimate the national population of photocopiers and laser printers
   1. Determine the annual sales of the equipment
   2. Determine the typical useful life of the equipment
      a. Use survey data
      b. Default value - three years
   3. Multiply the annual sales and the useful life to estimate the national population of equipment

B. Determine the emissions rate of the equipment
   1. Use field testing data if possible
   2. Default value: 0.009 g/hr

C. Determine the activity level
   1. Use survey data if possible: hrs/yr of activity
   2. Default value: 2,080 hrs/yr (8 hrs/day x 260 days/yr)

D. Multiply the results from A, B and C to estimate national emissions

II. Distribute national emissions to the county level according to total county employment

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PULP BLEACHING WITH OZONE

Definition/description of category and activity

Most pulp is bleached using chlorine, hypochlorite, oxygen, chlorine dioxide and/or peroxide in a series of one to ten stages. Each step includes three processes: mixing, retention and washing. The number of stages depends on the pulp qualities that are desired. Due to the environmental effects of chlorination processes, particularly in the wastewater effluent, non-chlorinated bleaching processes (e.g., bleaching with ozone) are being developed. Currently, no full-scale ozone bleaching operations are in service, although the first is scheduled to come online within two years. Prototypical ozone systems are closed, recycling both wastewaters and gases. Ozone is generated onsite from recycled and make-up oxygen. The ozone is completely consumed in the closed reactor.[1,2]

Process breakdown

AP-42 emission factors have been developed for many paper and pulp manufacturing processes.[3] However, no emission factors for pulp bleaching with ozone are available from *AP-42* or the National Council of the Paper Industry for Air and Stream Improvement (NCASI). Potential sources of ozone are fugitive losses from the ozone generator and the ozone reactor (below the fluffers shown in Figure 1).

Reason for considering the category

Pulp bleaching with ozone is a new, innovative technology which replaces traditional pulp bleaching emission sources by employing ozone directly.

Pollutants emitted

Ozone (potential)

Estimate of the pollutant levels

Based on literature descriptions of pilot plants, closed bleaching reactors and recycling of waste gases should eliminate the potential for any significant ozone emissions. The potential for corrosion from significant fugitive sources during the generation or bleaching process should ensure minimization of any fugitive emissions. As ozone bleaching capacity is brought online, studies of atmospheric emissions will serve to test these assumptions regarding ozone and other atmospheric emissions.

Point/area source cutoff

Pulp and paper plants are typically large point sources due to their boilers emissions.

Level of detail of information available

Pulp and paper plants are identified in the point source inventories.

No studies on atmospheric emissions from the ozone bleaching process have been undertaken.

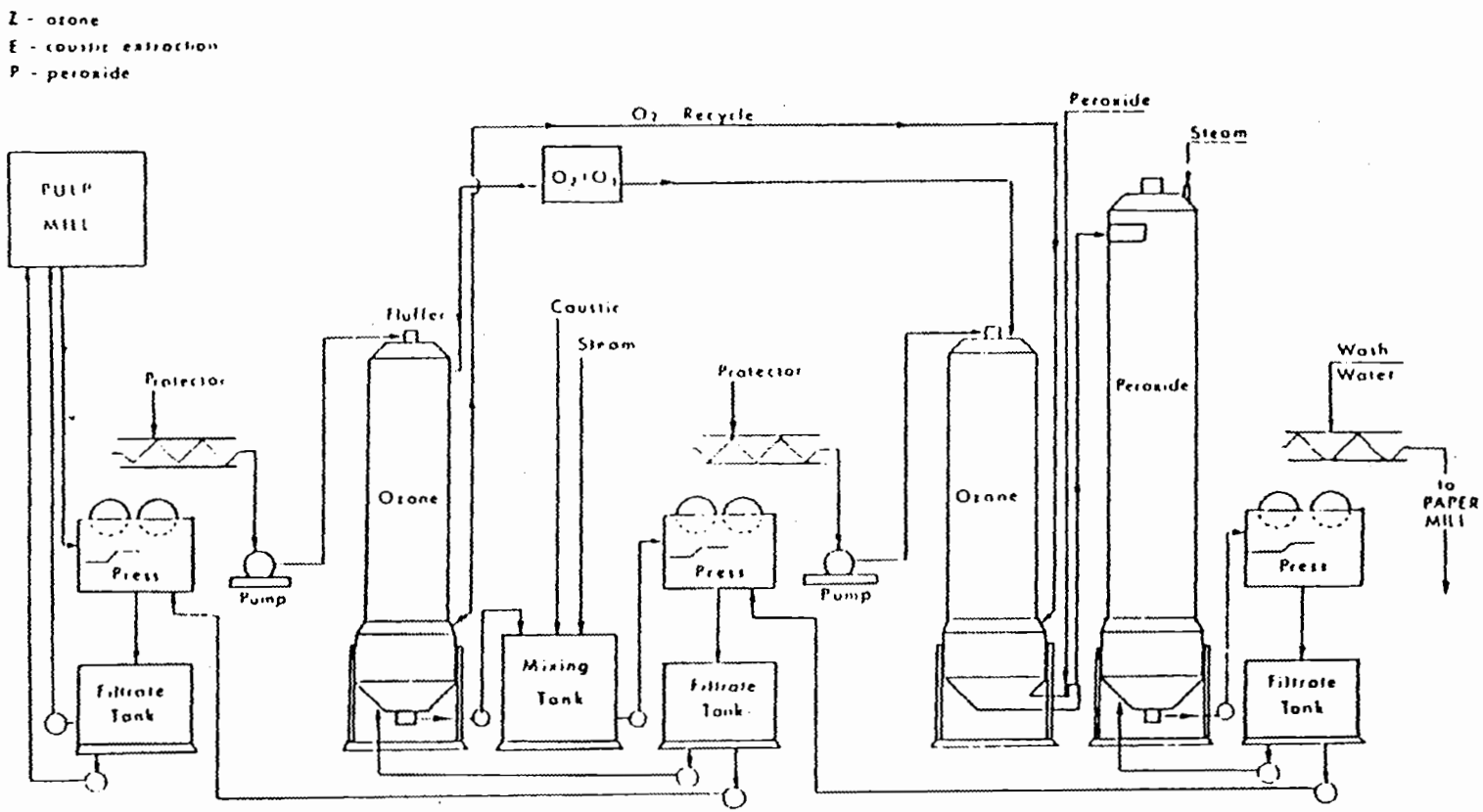

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Figure 1. Pulp bleaching with ozone.[1]

Level of detail required by users

Emissions by plant and processes for point source inventories

Emission factor requirements

If applicable, ozone or other pollutants emitted per ton air-dry pulp

Regional, seasonal or temporal characteristics

None

Urban or rural characteristics

None

Methodology

Point source inventories are structured to include potential emissions if ozone or other emissions are detected after these processes are implemented on a full-scale basis. Pulp and paper mills are already in point source inventories due to boiler and pulp cooking emissions.

References

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ULTRAVIOLET (UV) AND ELECTRON BEAM (EB) CURABLE COATING

Definition/description of category and activity

Radiation curable coatings and inks (ultraviolet (UV) and electron beam (EB)) are high-solid formulations used as substitutes for conventional solvent-based thermal curable systems. Traditionally, coatings consist of a solid polymer dissolved in a solvent and further diluted with solvent. The solvent ranges from 50 to 90 percent of the coating formulations.[1] After the coating is applied, the substrate being coated is sent through a dryer to evaporate the solvent. Radiation curable coating technology appears to be transferable to most conventional ink and coating applications. The technology is currently being used in the applications listed in Table 1.

TABLE 1. CURRENT APPLICATIONS OF UV CURABLE TECHNOLOGY

Surface Treatment	Graphic Arts Wood Finishes Metal Coatings Plastic Coatings Paper Varnishes Resilient Flooring
Electronics	Printed Circuits (negative photoresists) Sealants (encapsulation) Protective Coatings (optical fibers) Patterning (video disks)
Pigmented Resins	UV Curable Inks Printing Plates Dental Materials
Adhesives	Laminates Sealants Bonding Pressure Sensitive

The radiation source for these systems is either an ultraviolet light or an accelerated electron beam. Theoretically, radiation curable coatings can be solvent-free, but to retain desirable properties such as viscosity and easy application, some solvent is added. Generally, radiation curable coatings use 40 to 60 percent less solvent by weight than conventional thermal cure systems.[2,3] The surface coating and printing industries have adopted UV curable coating technology in large part because of EPA's increasing regulation of VOC and the disposal of solvents; the Department of Housing and Urban Development's (HUD's) regulation of formaldehyde in particle board and the coatings used in cabinet construction; and OSHA's concerns in limiting exposure to formaldehyde for workers.

Process breakdown

UV finishing uses UV energy to initiate free-radical polymerization of certain chemicals. Typically, the main component of a UV coating is an acrylate resin (oligomer) to which a photoinitiator has been added. The photoinitiator assures the proper reaction rate of the formulation under the UV light. The introduction of

different monomers to the coatings has ameliorated some initial problems with toxicity and allergic reactions on the part of employees working with radiation curable coatings.

UV curable systems convert light energy into chemical energy; EB systems convert electrical energy into chemical energy. In EB systems, electrons are accelerated to a high velocity and directed at the substrate/coating. The electron bombardment causes crosslinking of the monomers in the coating and the liquid film becomes solid instantaneously.

Reason for considering the category

UV and EB curing technologies are emerging as a potential method for significantly reducing VOC emissions from conventional coating processes. However, the level of ozone and toxic pollutant emissions from these technologies are not yet well characterized.

Pollutants emitted

Radiation curable coating systems which use solvent-containing coatings emit VOC. Particulate matter may be emitted when paint sprays are atomized. Ozone formation may result under certain circumstances at very low wavelengths. In addition, some radiation curable coating components are thought to be mildly toxic, but not much is known about long-term exposure to coating formulas used in UV and EB curing. Each commercial formulation would need to be examined individually to determine toxicity. Some highly reactive coatings (i.e., acrylate, methacrylate) may cause skin and eye irritation. A monomer (2-ethylhexyl acrylate) and a crosslinker (neopentyl glycol diacrylate) were found to cause tumors in mice when exposed to chronic dermal contact.[4] Several journal articles indicate that the second generation of acrylate coatings is considerably less toxic than the original acrylate coatings.

Estimate of pollutant levels

Point and area source VOC emissions from coating operations in furniture manufacturing and flatwood production were reported as 116,493 tons and 19,148 tons, respectively, in 1985.[5] Assuming that a typical UV or EB curable coating contains half as much solvent as a conventional thermal cure coating and full use of UV and EB coating technology in all coating industries, 1985 furniture manufacturing and flatwood production emissions for UV and EB coating would be half those of conventional coatings.

Point/area source cutoff

UV and EB curable coatings are replacing current coatings-related point and area sources. Their production and use would have large point source, small point source and some area source components.

Level of detail of information available

Although some broad generalizations would need to be made, emissions from UV and EB curable coatings could be estimated at the national level and then allocated to the county using surrogates such as manufacturing or industrial employment. Market penetration of UV and EB curable coatings is difficult to determine; however, most sources indicate that UV and EB curable coating use is increasing in almost all surface coating applications.

Level of detail required by users

Amount and type of coatings used, by facility

Number of coating facilities per county

Emission factor requirements

More research must be done to determine emission factors for UV and EB curable coatings. Current estimates assume solvent use (and therefore, emissions) in UV and EB coatings at half the conventional coatings' solvent use.

Regional, seasonal or temporal characteristics

The use of UV and EB curable coatings is not expected to have any regional, seasonal or temporal characteristics.

Urban or rural characteristics

Since most UV and EB curable systems are expected to be used in industrial rather than consumer or commercial settings, these systems may have a more urban characteristic.

Methodology

Two methods could be used to determine VOC emissions from UV and EB curable coatings processes. The first would use current assumptions concerning solvent use in UV and EB coating and emission factors for conventional coating applications. The result might be a range of emissions representing 40 to 60 percent of the VOC emissions from conventional uses of solvents in the applicable coatings categories (e.g., the categories listed in Table 1). The second method may be developed when more information is available on UV and EB curable coating use, market penetration, solvent content, emission factors for air toxics and ozone, etc. The second methodology would result in more detailed emissions estimates than use of the first methodology.

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WELDING

Definition/description of category and activity

Welding is the joining of two metallic surfaces using heat and a metallic filler. There are three general types of welding: true welding includes fillers with melting points at or below the melting point of the base metal and greater than 450°C and involves melting of the base metal; soldering encompasses filler melting points less than 450°C in which the base metal is not melted and a mechanical joint is produced; and brazing where fillers have melting points greater than 450°C but below that of the base metal resulting in a metallurgical joint that does not require the base metal to be melted. Prior to welding, a flux is used to dissolve oxides and promote release of trapped gases and slag from the metallic surface. These fluxes typically contain boron, fluorine, chlorine, potassium and/or sodium.[1,2,3]

The heat source is usually a torch or an electric arc. Torches are fueled with mixtures of oxygen or air and acetylene, hydrogen, methane, natural gas, LPG, etc. In torch welding, the filler is a metallic alloy rod; in arc welding, the filler is the electrode material and/or a filler rod. The rod has a chemical coating (e.g., a mineral organic coat). Arcs may or may not be shielded by a gas generated from a chemical coating on the electrode or injected around the arc. Typical gases are argon, helium and CO_2. These gases may have some oxygen in the mixture, depending on the application.[1,2,3]

Process breakdown

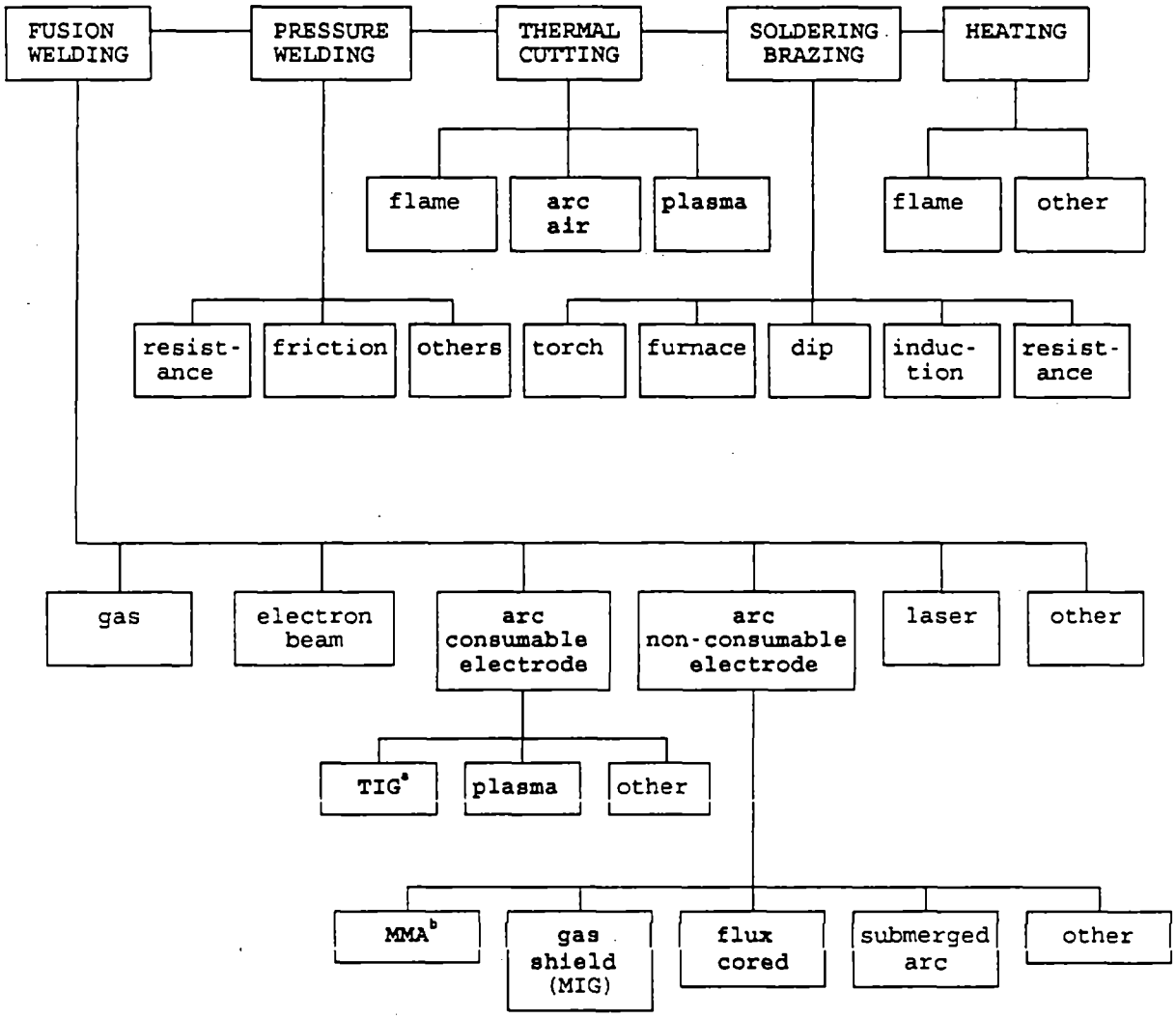
Welding occurs both indoors and outside. Fumes and gases may be directly vented to the atmosphere or subject to control (e.g., fabric filters or electrostatic precipitators (ESP)). Welding equipment may range from a small torch and cylinder for small or patch jobs ranging to large industrial units for repetitive applications. Figure 1 indicates the relation of welding types.

Reason for considering the category

This source was originally considered a direct ozone source from electric arc welding. Direct ozone sources are not currently inventoried. However, other pollutants including NO_x, CO, VOC species and particulate matter are also emitted.

Pollutants emitted

Ozone, NO_x, CO, particulate matter and VOC (including aldehydes, alcohols, ketones and many other hydrocarbon species) are emitted from welding activities. The principal source of emissions is arc welding. Ozone is generated from the action of UV from the arc on O_2 in the atmosphere. NO_2 can result from a photochemical dissociation of N_2, but is principally formed from reaction of atmospheric nitrogen and oxygen at high temperatures. CO is formed from CO_2 in shielding atmospheres and oxidation of carbon in steel welding. VOC emissions originate from the coating on the electrode or filler and from any residual degreasing agent (typically trichloroethylene) on the metal surface. According to one reference, typical carbon steel electrodes may contain zero to 30 percent organics by weight. Particulate matter is generated from the vaporization and rapid condensation of electrode and flux materials and are typically metal oxides, including toxic species.[4,5]



KEY: Categories in bold are principal welding types of concern for emissions.

[a]TIG is Tungsten Inert Gas
[b]MMA is Manual Metal Arc

Figure 1. General categories of welding.

Estimate of the pollutant levels

One estimate placed total emissions at 0.5 to 1.0 percent of total welding consumables (gases, fluxes, fillers and electrodes). In the United Kingdom, this estimate is approximately 400 Mg/year. (The estimate was not speciated.)[4]

Gaseous emissions from arc welding have been measured at three to 150 ppm CO and 0.25 to seven ppm NO_2 in one study.[5]

Fume generation processes involved during welding are complex and not completely understood. Each combination of equipment, filler, electrode, base metal, gas and flux has distinct emissions characteristics.

Point/area source cutoff

Individual welding processes are likely to be small emitters of any currently inventoried pollutant and are not represented in the point source inventory.

Level of detail of information available

No emission factors were found.

Consumable welding material totals are likely to be available, but at an unknown level of resolution (contact the American Welding Society).

Construction and metal fabrication activity

Level of detail required by users

Emissions by county

Ozone, CO, NO_x and particulate matter emissions by welding type or application

Emission factor requirements

One approach would use emission factors based on consumption of welding materials. This approach implies welding materials could be resolved by application. Alternately, construction and metal fabrication activity are potential surrogate indicators if an appropriate emission factor could be derived.

Regional, seasonal or temporal characteristics

None known

Urban or rural characteristics

Principally an urban source

Methodology

The material researched to date indicates no current methodology. Average emission factors on a unit basis (per welding hour, per unit gas consumed, per filler rod) were not found. Another option using construction and metal fabrication activity as surrogates would also require development of an emission factor. Due to the many different types of welding and applications (see Figure 1), development of emission factors would likely be difficult. Research has been done as to the types and concentrations of particulates (oxides) and gases emitted to ensure compliance with OSHA standards for exposure to some of the toxics emitted. No data on ozone formation rates in arc welding were located. Further information may be available in the industry and scientific literature.

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FIREPLACES

Definition/description of category and activity

Wood combustion produces smoke which is a complex mixture of PM_{10}, oxides of sulfur and nitrogen, organic material (including polycyclic organic matter (POM)) and mineral constituents. Emissions of organic material, CO and PM_{10} from fireplaces result from incomplete combustion of the wood. The mixture of constituents of the smoke emitted can vary with the design of the fireplace, length of time for the burn, type of wood, size of the wood and moisture content in the wood.[1,2] Like wood stoves, fireplaces are used in residences, lodges, etc., for supplemental heating as well as aesthetic effects. Unlike wood stoves, fireplaces are usually not used continuously and thus do not emit pollutants in the large quantities associated with wood stoves. Generally, fireplaces are less efficient at combustion than wood stoves.

Process breakdown

Since fireplaces are not enclosed fireboxes (as are wood stoves), fugitive emissions often escape into the room being heated. Fireplaces are equipped with duct work leading to stacks to vent the emissions from wood combustion. The plume rise associated with these emissions is minimal. The two types of fireplaces include masonry or brick fireplaces, which are integral to the structure, and prefabricated fireplaces (usually metal) installed on site as a package. While PM from masonry fireplaces are slightly higher than those from prefabricated fireplaces operated at the same burn rate, CO emissions are substantially higher.[3] The State of Colorado has established that the particulate emission factors for fireplaces are sensitive to the burn rate, with higher burn rates resulting in lower emissions. The same study also showed that CO emissions are considerably higher at low burn rates.[3]

Reason for considering the category

A recent estimate puts the number of residential wood combustion (RWC) units (i.e., fireplaces and wood stoves) in the United States in 1989 at 30 million.[2] Slightly more than 50 percent of RWC units are fireplaces and the remainder are wood stoves. These devices are considered among the largest anthropogenic sources of PM_{10} and CO in the country.[2] Typically, RWC units are used in the winter when organic and NO_x emissions from this source are not likely to have any significant impact on ozone formation in a study area. However, given the stability of the cold air in the winter, PM_{10} emissions can seriously impair visibility in a given area. EPA research indicates that emissions of CO in the winter months from RWC units can have some significant detrimental effects on the health of the population in a given area.

Pollutants emitted

Pollutants emitted from fireplaces include CO, NO_x, SO_x, organic material (such as POM and aldehydes) and PM_{10}.

Estimate of the pollutant levels

Emissions estimates for total U.S. residential wood combustion (fireplaces and wood stoves) in the 1985 NAPAP Inventory are as follows:[4]

11,077	TPY of SO_x
80,774	TPY of NO_x
1,459,464	TPY of VOC
1,088,598	TPY of TSP
6,721,128	TPY of CO

The State of Oregon estimated the following emissions from a 1987 state inventory of 335,632 fireplaces:[5]

7,012	TPY of PM_{10}
44,812	TPY of CO

Point/area source cutoff

Residential wood combustion in fireplaces is not considered a point source because emissions per fireplace fall well below ten TPY.

Level of detail of information available

(1) *AP-42* emission factors for residential fireplaces, based on tests burning primarily oak, fir or pine, with moisture content ranging from 15 to 35 percent:

14	g TSP/kg of wood burned
0.2	g SO_x/kg of wood burned
1.7	g NO_x/kg of wood burned
85	g CO/kg of wood burned
13	g VOC/kg of wood burned

(2) Emission factors from Environment Canada for fireplaces:[6]

25	g TSP/kg of wood burned
0.8	g SO_x/kg of wood burned
0.5	g NO_x/kg of wood burned
90	g CO/kg of wood burned

(3) Emission factors from the State of Colorado for fireplaces:[3]

14.4	g TSP/kg of wood burned
76	g CO/kg of wood burned
1.7	g POM/kg of wood burned

(4) A State of Colorado survey showed that an average of 1.28 and 0.61 cords of wood are burned in stoves and fireplaces, respectively, during an average season in the Denver metropolitan area.[7]

(5) The State of Oregon has compiled an inventory of total number of fireplaces in the state and estimated the total amount of wood consumed by fireplaces was 301,257 cords in 1987.

(6) New emission factors for fireplaces are currently being developed by EPA.[8]

Level of detail required by users

Amount of wood used by fireplaces (by county)

Number of fireplaces per county

Amount of wood used per fireplace

Emission factor requirements

Amount of pollutant emitted per unit use of wood

Regional, seasonal or temporal characteristics

Residential wood combustion in fireplaces usually occurs in winter to supplement heating needs or for aesthetic purposes.

Urban or rural characteristics

An urban and rural source

Methodology

Traditionally, emissions from fireplaces are estimated using the *AP-42* emission factors expressed in grams of pollutant emitted per kilogram of wood burned and multiplying them by the amount of wood burned. The *AP-42* emission factors are based on tests at an average burn rate, and thus a more thorough emission factor representative of the type of wood and burn rate in an airshed may be needed. More accurate emissions could be determined if new emission factors were developed distinguishing between fireplace type (masonry or prefabricated), burn rates and type of wood (softwoods or hardwoods) burned.

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KEROSENE SPACE HEATERS

Definition/description of category and activity

Kerosene space heaters are used throughout the United States, usually as a supplementary heat source to electric, fuel oil or natural gas furnaces. The use of kerosene space heaters has increased dramatically from approximately 3,400 kerosene heaters sold in 1973 to about ten million sold by 1988.[1] There are three basic designs: radiant heaters (blue flame), convective heaters (white flame) and two-stage convective heaters. Most portable kerosene space heaters use K-1 grade kerosene fuel; some early models also used K-2 fuels.[2-15]

Process breakdown

Emissions from kerosene space heaters result from fuel combustion and fuel evaporation (fugitive emissions).

Most emissions from kerosene space heaters are trapped indoors where the heater is being used. Most kerosene space heaters are unvented, thereby emitting all off-gases and particulate matter within the room or house being heated. In addition, there is a potential for evaporative emissions of kerosene from spillage during filling of the fuel tank and leaking tanks and lines. The amount of pollutants emitted to the outdoors is dependent on the pollutant and the relative "tightness" of the house. Particulate matter and many volatile components may settle or become adsorbed to surfaces in the house while gaseous pollutants have a greater tendency to migrate from the structure.[2-15]

Reason for considering the category

The increase in the use of kerosene space heaters is a relatively recent occurrence and was considered a minor source in previous emission inventories. There have been no *AP-42*[15] factors and little guidance on assessing kerosene space heater emissions.

There are a number of gaps in the existing base of knowledge:

- Usage statistics for kerosene space heaters are not well compiled.
- Most data have been generated using a limited range of heater ages, conditions and operational settings. Until better usage statistics are available, more laboratory testing may be unwarranted.
- Emission rates of organic compounds from indoor combustion sources are not well known.
- SO_x emissions may not be adequately understood, especially in the conversion of SO_2 to SO_3 in new, catalyst-equipped kerosene heaters.

Many of these data gaps will need to be filled to adequately assess the magnitude of kerosene space heater emissions. Improvements in test methodologies and the use of test houses in studies would allow for the development of realistic emission factors.

Pollutants emitted

CO, CO_2, NO, NO_2, SO_2, formaldehyde (HCHO), suspended particles and a number of potentially hazardous and toxic hydrocarbons are emitted from kerosene space heaters.

Estimate of the pollutant levels

Many of the cited references include emission factors and estimates of the levels of pollutant emissions from individual heaters. However, a critical assessment of these and other sources not cited was not undertaken in this effort and none of the references cited gave estimates of the overall emissions from this source category. Additional effort is warranted to adequately assess these data sources.

Point/area source cutoff

Emissions from individual heaters are less than ten tons per year. The emissions potential from individual heaters and the potential number of heaters in use indicate that this category should be inventoried as an area source.

Level of detail of information available

Information on the use, grade and distribution of kerosene by small scale retail outlets may be available from the same sources supplying gasoline and diesel distribution information. Information on the age, burner type and condition of kerosene space heater equipment is not currently available from the literature, but may be available from industry sources. Emission factors are available from U.S. Department of Energy (DOE), EPA and U.S. Consumer Product Safety Commission studies and literature. However, usage patterns, age of heaters, grade of kerosene and regional variability have not been characterized.

Level of detail required by users

The number, condition and annual usage pattern for kerosene space heaters and the usage rates and grade of kerosene used in the defined area are required to estimate the emissions from this source category.

Emission factor requirements

Emission factors based on heater type, age, condition and fuel type (K-1 or K-2 grade kerosene) need to be developed. Much of the information needed to generate these emission factors has been presented in EPA and DOE studies. However, the methodology to attain usage statistics for both fuel and heaters also requires development. The development of fuel efficient burners will change the emission rates over time. Table 1 shows the average emission factors from the cited references for each type of heater with some consideration of the burn characteristics (initial start-up, steady state burning after start-up or a combination of the two).

TABLE 1. AVERAGE EMISSION FACTORS FOR KEROSENE SPACE HEATERS FROM CITED REFERENCES

Heater Type	Burn Type	Average Emission Factor (Grams Per Gallon Kerosene)[a]					
		CO	SO_2	NO	NO_x	HCHO	Particulates
Convective	Initial	14.79	0.00	0.11	0.65	0.03	0.02
Convective	Steady	18.76	0.00	0.07	0.59	0.06	0.02
Convective	Combined[b]	13.48	1.31	1.15	2.10	0.03	1.80
Radiant	Combined	12.04	1.33	0.06	0.55	0.02	0.97
Two-Stage	Combined	1.30	0.00	0.61	0.31	0.03	0.24

[a]The averages are developed from several references where the type of heater and the burn characteristics were defined.
[b]The combined burn emission factors do not reflect the combination of factors from initial and steady burn studies, but the results of separate studies.

Regional, seasonal or temporal characteristics

As a supplementary heat source, kerosene heaters are used when the temperature is relatively low (primarily during the winter months). Their use would be expected to be greatest in northern regions and least in the southwest, although kerosene space heaters are used throughout the country.

Urban or rural characteristics

No urban or rural preference is expected.

Methodology

No methodological guidelines have been developed to date. Information on fuel usage will most likely be available through distributors. Information on heater age, type and condition should be developed before an accurate assessment of emissions can be undertaken.

A possible methodology to estimate emissions from kerosene space heaters would assume a certain population of heaters with defined characteristics giving a derived number of heaters. This derived number of kerosene heaters would then be multiplied by the average amount of fuel burned for the prevailing weather conditions of the region and an appropriate emission factor. The emission factor may be weighted to reflect differing characteristics among the kerosene heater population.

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ROCKET LAUNCHES AND TEST FIRINGS

Definition/description of category and activity

Rocket launches and test firings release large quantities of hydrogen chloride, chlorine, aluminum oxide, NO_x, CO, CO_2 and PM, resulting in a temporary localized degradation in air quality near the launch or test site. In addition, these activities may release pollutants to the upper atmosphere which contribute to the problems of acid rain and depletion of the ozone layer. At this time, the Space Shuttle Program is the most significant source of air pollution in this category.[1,2,3]

The main air quality effect at launches and test firings is from the combustion of the Space Shuttle's solid rocket motors (SRMs). During a normal launch, a ground cloud composed of hot exhaust products from the SRMs, the main liquid propulsion engines, steam from launch platform cooling and acoustic damping water injection, and sand and dust, forms at the base of the launch platform. At higher altitudes, the release of hydrogen chloride can produce acid rain under certain meteorologic conditions. As the Space Shuttle passes through the stratosphere, hydrogen chloride, nitric oxide and aluminum oxide particles may be emitted, possibly resulting in the destruction of ozone molecules.[1,2,3]

Process breakdown

Rocket launches and test firings are two different processes and should be separated for the purpose of characterizing emissions. Rocket launch emissions are commonly broken down into atmospheric layers. They should be addressed by rocket type. If possible, emissions should be separated by stage in the launch or test firing sequence.

Reason for considering the category

These sources emit large amounts of toxic pollutants during the launch or test firing sequence. The category should be consistently regulated, as is the test facility in Utah. Expected emissions generated from SRM static tests at the facility will exceed 250 tons per year.[2] Therefore, the facility is considered a major point source and subject to Prevention of Significant Deterioration (PSD) regulations.

Pollutants emitted

Aluminum oxide	Nitrogen oxides
Carbon monoxide	Particulate matter
Hydrogen chloride	PM_{10}
Carbon dioxide	Chlorine

Estimate of the pollutant levels

National emissions estimates are not available. However, data in an Environmental Impact Statement of the Morton Thiokol, Incorporated facility indicate that the SRM contains approximately one million pounds of propellant. Emission levels from a single two-minute test firing are as follows:

Aluminum oxide	166 tons/fire
Carbon monoxide	133 tons/fire

Hydrogen chloride	118 tons/fire
Carbon dioxide	20 tons/fire
Nitrogen oxides	8 tons/fire
Others (N_2, H_2, etc.)	65 tons/fire
Particulate matter	9 tons/fire
PM_{10}	104 tons/fire
Chlorine	12 tons/fire
Water	52 tons/fire

Point/area source cutoff

Expected emissions from launching and test firing exceeds 250 tons per episode. Therefore, launch sites and test sites should be considered major point sources.

Level of detail of information available

Environmental Impact Statements for all the launch and test firing sites involved in the Space Shuttle Program are available. It is not known if the data for any other rocket types are available. The National Aeronautics and Space Administration (NASA) has conducted intensive analytical studies and developed mathematical models which use the characteristics of the rocket exhaust products and launch site meteorology to predict the rise, growth and dispersal of the ground cloud.[4] National security concerns limit access to some activity data, but most activity data are available from the Department of Defense and NASA.

Level of detail required by users

Emissions by site

Site locations

Launch or test frequency, rocket type, activity type, fuel

Emission factor requirements

Emission factors for the various pollutants have been calculated as pounds of pollutant per test firing. The emissions reported in the Environmental Impact Statements should be examined individually to determine the volatility of the pollutants.[5]

Regional, seasonal or temporal characteristics

These activities are restricted to Space Shuttle facilities, including Marshall Space Flight Center, Alabama; Kennedy Space Center, Florida; White Sands Test Facility, New Mexico; Thiokol/Wasatch Division, Utah; and Vandenberg Air Force Base and Santa Susana, California. Figure 1 shows the locations of space shuttle facilities. Launches and test firings are conducted year-round and may take place at anytime of the day.[2]

Urban or rural characteristics

Principally a rural source

Methodology

- Compile sites of launches and test firings.
- Determine the number of launches and test firings per year.
- Break down the category by launch or test fire and the type of rocket and fuel involved.
- Conduct field test or use existing emission factors to determine emissions of pollutants/site/year.
- Calculate total annual emissions by county (by multiply the emission factor by the activity data).

References

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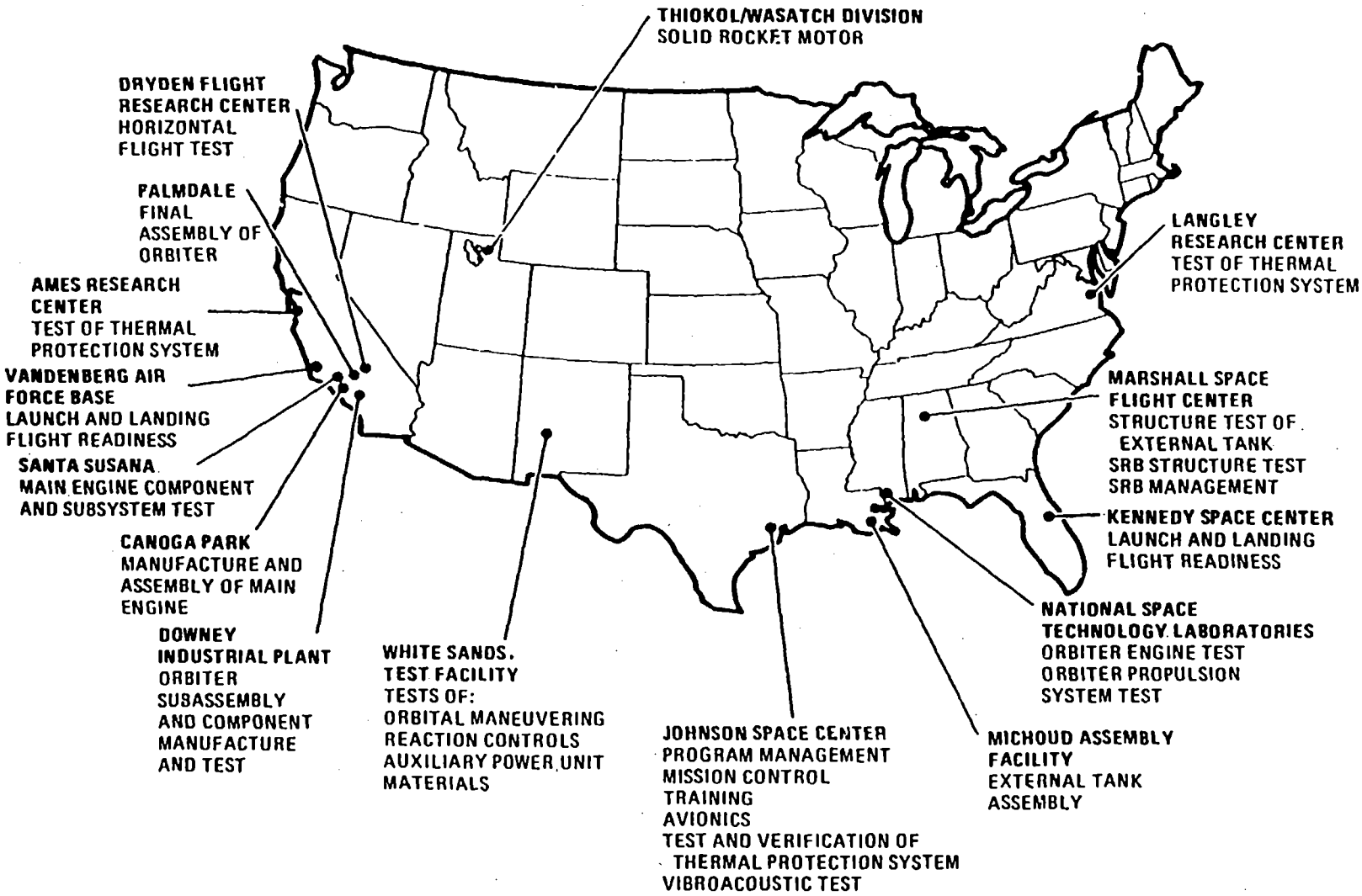

Figure 1. Locations of the Space Shuttle facilities.[2]

CH-91-57

SMALL ELECTRIC UTILITY BOILERS

Definition/description of category and activity

Electric utility boilers which release less than 100 TPY of any of the priority pollutants (CO, VOC, SO_2, NO_x and TSP) are unaccounted for in the NEDS/AIRS inventory. These small boilers are the primary electric generators for many rural communities. Although small boilers are currently defined as those boilers releasing less than 100 TPY of any priority pollutant, new SIP guidelines require cutoffs of ten TPY for some nonattainment areas.[1] The wide variety in engineering designs, fuels and regulation practices results in a range of possible emissions and complicated characterization.

Process breakdown

Small electric utility boilers can be categorized by the following characteristics: fuel source, such as natural gas, distillate oil, residual oil, anthracite coal and bituminous coal; boiler type, such as cyclone furnace, spreader stoker or overfeed stoker; capacity, in megawatts generated; and location, such as county. Emissions from a given boiler may originate from cooling towers or smoke stacks or may be fugitive emissions.

Reason for considering the category

Presently, only large electric boilers which release greater than 100 TPY of any criteria pollutant are inventoried. Although data are available to adequately consider smaller utility boilers as point sources,[2] NEDS does not address small boilers as either point or area sources.

Contributions to air pollution by small boilers may be significant since they are the primary generators of electricity for many midwestern and western communities, emissions may not be closely regulated and often they are older facilities lacking pollution control devices. For example, according to U.S. Department of Energy records, 86 of Utah's 89 electricity generating units are small, with capacities of less than 50 megawatts.[3]

Pollutants emitted

CO, NO_x, SO_2, VOC, TSP

Estimates of pollutant levels

Based on Energy Information Administration (EIA) and NAPAP data, it is estimated that in 1988, small fossil fuel steam electric generating units emitted a maximum of 563,569 tons of SO_2 and 310,799 tons of NO_x nationwide. Therefore, a maximum of 3.4 percent of all SO_2 and 4.5 percent of all NO_x emissions from electric-generating boilers can be attributed to small (and unaccounted) boilers. Note that both values are within the margin of error for the NAPAP inventory and could be due to differences in methodologies. Comparable data are not available for VOC, TSP or CO.[4,5]

AP-42 provides emission factors for a variety of fossil fuel combustion types.[6] However, *AP-42* does not document to what extent these factors are applicable to small electricity-generating units. However, facility designs for small and large units are comparable enough that these emission factors should provide adequate estimates until more specific factors are developed. Tables 1 through 4 are taken from *AP-42*

TABLE 1. EMISSION FACTORS FOR EXTERNAL BITUMINOUS AND SUBBITUMINOUS COAL COMBUSTION (*AP-42* TABLE 1.1-1)

Firing Configuration	Particulate[b]		Sulfur Oxides[c]		Nitrogen Oxides[d]		Carbon Monoxide[e]		Nonmethane VOC[e,f]		Methane[e]	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Pulverized coal fired												
Dry bottom	5A	10A	19.5S (17.5S)	39S(35S)	10.5 (7.5)[g]	21 (15)[g]	0.3	0.6	0.04	0.07	0.015	0.03
Wet bottom	3.5A[h]	7A[h]	19.5S (17.5S)	39S(35S)	17	34	0.3	0.6	0.04	0.07	0.015	0.03
Cyclone furnace	1A[h]	2A[h]	19.5S (17.5S)	39S(35S)	18.5	37	0.3	0.6	0.04	0.07	0.015	0.03
Spreader stoker												
Uncontrolled	30[j]	60[j]	19.5S (17.5S)	39S(35S)	7	14	2.5	5	0.04	0.07	0.015	0.03
After multiple cyclone With fly ash reinjection from multiple cyclone	8.5	17	19.5S (17.5S)	39S(35S)	7	14	2.5	5	0.04	0.07	0.015	0.03
No fly ash reinjection from multiple cyclone	6	12	19.5S (17.5S)	39S(35S)	7	14	2.5	5	0.04	0.07	0.015	0.03
Overfeed stoker[k]												
Uncontrolled	8[m]	16[m]	19.5S (17.5S)	39S(35S)	3.25	7.5	3	6	0.04	0.07	0.015	0.03
After multiple cyclone	4.5[n]	9[n]	19.5S (17.5S)	39S(35S)	3.25	7.5	3	6	0.04	0.07	0.015	0.03
Underfeed stoker												
Uncontrolled	7.5P	15P	15.5S	31S	4.75	9.5	5.5	11	0.65	1.3	0.4	0.8
After multiple cyclone	5.5[n]	11[n]	15.5S	31S	4.75	9.5	5.5	11	0.65	1.3	0.4	0.8
Handfired units	7.5	15	15.5S	31S	1.5	3	45	90	5	10	4	8

[a] Factors represent uncontrolled emissions unless otherwise specified and should be applied to coal consumption as fired.

[b] Based on EPA Method 5 (front half catch) as described in Reference 12. Where particulate is expressed in terms of coal ash content, A, factor is determined by multiplying weight % ash content of coal (as fired) by the numerical value preceding the "A." For example, if coal having 8% ash is fired in a dry bottom unit, the particulate emission factor would be 5 x 8, or 40 kg/Mg (80 lb/ton). The "condensible" matter collected in back half catch of EPA Method 5 averages <5% of front half, or "filterable", catch for pulverized coal and cyclone furnaces; 10% for spreader stokers; 15% for other stokers; and 50% for handfired units (References 6, 19, 49).

(continued)

[c] Expressed as SO_2, including SO_2, SO_3 and gaseous sulfates. Factors in parentheses should be used to estimate gaseous SO_x emission for subbituminous coal. In all cases, "S" is weight % sulfur content of coal as fired. See Footnote b for example calculation. On average for bituminous coal, 97% of fuel sulfur is emitted as SO_2, and only about 0.7% of fuel sulfur is emitted as SO_3 and gaseous sulfate. An equally small percent of fuel sulfur is emitted as particulate sulfate (References 9, 13). Small quantities of sulfur ar also retained in bottom ash. With subbituminous coal generally about 10% more fuel sulfur is retained in the bottom ash and particulate because of the more alkaline nature of the coal ash. Conversion to gaseous sulfate appears about the same as for bituminous coal.

[d] Expressed as NO_2. Generally, 95 - 99 volume % of nitrogen oxides present in combustion exhaust will be in the form of NO, the rest NO_2 (Reference 11). To express factors as NO, multiply by factor of 0.66. All factors represent emission at baseline operation (i.e., 60 - 110% load and no NO_x control measures, as discussed in text).

[e] Nominal values achievable under normal operating conditions. Values one or two orders of magnitude higher can occur when combustion is not complete.

[f] Nonmethane volatile organic compounds (VOC), expressed as C_2 to C_{16} n-alkaline equivalents (Reference 58). Because of limited data on NMVOC available to distinguish the effects of firing configuration, all data were averaged collectively to develop a single average for pulverized coal units, cyclones, spreaders and overfeed stokers.

[g] Parenthetic value is for tangentially fired boilers.

[h] Uncontrolled particulate emissions, when no fly ash reinjection is employed. When control device is installed, and collected fly ash is reinjected to boiler, particulate from boiler reaching control equipment can increase by up to a factor of two.

[i] Accounts for fly ash settling in an economizer, air heater or breeching upstream of control device or stack. (Particulate directly at boiler outlet typically will be twice this level.) Factor should be applied even when fly ash is reinjected to boiler from boiler, air heater or economizer dust hoppers.

[k] Includes traveling grate, vibrating grate and chain grate stokers.

[m] Accounts for fly ash settling in breeching or stack base. Particulate loadings directly at boiler outlet typically can be 50% higher.

[n] See text for discussion of apparently low multiple cyclone control efficiencies, regarding uncontrolled emissions.

[p] Accounts for fly ash settling in breeching downstream of boiler outlet.

TABLE 2. UNCONTROLLED EMISSION FACTORS FOR ANTHRACITE COMBUSTION (*AP-42* TABLE 1.2-1)

Boiler Type	Particulate[b]		Sulfur Oxides[c]		Nitrogen Oxides[d]		Carbon Monoxide[e]		Volatile Organics	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	Nonmethane	Methane
Pulverized coal fired	f	f	19.5S	39S	9	18	f	f	f	f
Traveling grate stoker	4.6[g]	9.1[g]	19.5S	39S	5	10	0.3	0.6	f	f
Hand fed units	5[h]	10[h]	19.5S	39S	1.5	3	f	f	f	f

[a] Factors are for uncontrolled emissions and should be applied to coal consumption as fired.
[b] Based on EPA Method 5 (front half catch).
[c] Assumes, as with bituminous coal combustion, most fuel sulfur is emitted as SO_x. Limited data in Reference 5 verify this for pulverized anthracite fired boilers. Emissions are mostly SO_2, with 1 - 3 % SO_3. S indicates that weight % sulfur should be multiplied by the value given.
[d] For pulverized anthracite fired boilers and hand fed units, assumed to be similar to bituminous coal combustion. For traveling grate stokers, see References 8, 11.
[e] May increase by several orders of magnitude with boilers not properly operated or maintained. For traveling grate stokers, based on limited information in Reference 8. For pulverized coal fired boilers, substantiated by additional data in Reference 14.
[f] Factors in Table 1.1-1 may be used, based on similarity of anthracite and bituminous coal.
[g] References 12-13, 15-18. Accounts for limited fallout that may occur in fallout chambers and stack breeching. Factors for individual boilers may be 2.5 - 25 kg/Mg (5 - 50 lb/ton), highest during soot blowing.
[h] Reference 2.

TABLE 3. UNCONTROLLED EMISSION FACTORS FOR FUEL OIL COMBUSTION (*AP-42* TABLE 1.3-1)

Boiler Type[a]	Particulate Matter[b]		Sulfur Dioxide[c]		Sulfur Trioxide		Carbon Monoxide[d]		Nitrogen Oxide[e]		Volatile Organics[f] Nonmethane		Volatile Organics[f] Methane	
	kg/10^3l	lb/10^3gal	kg/10^3l	lb/10^3gal	kg/10^3l	lb/10^3gal	kg/10^3l	lb/10^3gal	kg/10^3l	lb/10^3gal	kg/10^3l	lb/10^3gal	kg/10^3l	lb/10^3gal
Utility Boilers														
Residual Oil	g	g	19S	157S	0.34S[h]	2.8S[h]	0.6	5	8.0 (12.6)(5)[i]	67 (105)(42)[i]	0.09	0.76	0.03	0.28
Industrial Boilers														
Residual Oil	g	g	19S	157S	0.24S	2S	0.6	5	6.6[j]	55[j]	0.034	0.28	0.12	1.0
Distillate Oil	0.24	2	17S	142S	0.24S	2S	0.6	5	2.4	20	0.024	0.2	0.006	0.052
Commercial Boilers														
Residual Oil	g	g	19S	157S	0.24S	2S	0.6	5	6.6	55	0.14	1.13	0.057	0.476
Distillate Oil	0.24	2	17S	142S	0.24S	2S	0.6	5	2.4	20	0.04	0.34	0.026	0.216
Residential Furnaces														
Distillate Oil	0.3	2.5	17S	142S	0.24S	2S	0.6	5	2.2	18	0.085	0.713	0.713	1.76

[a] Boilers can be approximately classified according to their gross (higher) heat rate as shown below:
Utility (power plant) boilers: $>108 \times 10^9$ J/hr ($>100 \times 10^6$ Btu/hr)
Industrial boilers: 10.6×10^9 to 108×10^9 J/hr (10×10^6 to 100×10^6 Btu/hr)
Commercial boilers: 0.5×10^9 to 10.6×10^9 J/hr (0.5×10^6 to 10×10^6 Btu/hr)
Residential furnaces: $<0.5 \times 10^9$ J/hr ($<0.5 \times 10^6$ Btu/hr)

[b] References 3-7 and 24-25. Particulate matter is defined in this section as that material collected by EPA Method 5 (front half catch).

[c] References 1-5. S indicates that the weight % of sulfur in the oil should be multiplied by the value given.

[d] References 3-5 and 8-10. Carbon monoxide emissions may increase by factors of 10 to 100 if the unit is improperly operated or not well maintained.

[e] Expressed as NO_2. References 1-5, 8-11, 17 and 26. Test results indicate that at least 95% by weight of NO_x is NO for all boiler types except residential furnaces, where about 75% is NO.

[f] References 18-21. Volatile organic compound emissions are generally negligible unless boiler is improperly operated or not well maintained, in which case emissions may increase by several orders of magnitude.

[g] Particulate emission factors for residual oil combustion are, on average, a function of fuel oil grade and sulfur content:
Grade 6 oil: $1.25(S) + 0.38$ kg/10^3 liter [$10(S) + 3$ lb/10^3 gal] where S is the weight % of sulfur in the oil. This relationship is based on 81 individual tests and has a correlation coefficient of 0.65.
Grade 5 oil: 1.25 kg/10^3 liter (10 lb/10^3 gal)
Grade 4 oil: 0.88 kg/10^3 liter (7 lb/10^3 gal)

[h] Reference 25.

[i] Use 5 kg/10^3 liters (42 lb/10^3 gal) for tangentially fired boilers, 12.6 kg/10^3 liters (105 lb/10^3gal) for vertical fired boilers, and 8.0 kg/10^3 liters (67 lb/10^3 gal) for all others, at full load and normal (>15%) excess air. Several combustion modifications can be employed for NO_x reduction: (1) limited excess air can reduce NO_x emissions 5-20%, (2) staged combustion 20-40%, (3) using low NO_x burners 20-50%, and (4) ammonia injection can reduce NO_x emissions 40-70% but may increase emissions of ammonia. Combinations of these modification have been employed for further reductions in certain boilers. See Reference 23 for a discussion of these and other NO_x-reducing techniques and their operational and environmental impacts.

[j] Nitrogen oxides emissions from residual oil combustion in industrial and commercial boilers are strongly related to fuel nitrogen content, estimated more accurately by the empirical relationship:
kg NO_2/10^3 liters $= 2.75 + 50(N)^2$ [lb NO_2/10^3gal $= 22 + 400(N)^2$] where N is the weight % of nitrogen in the oil. For residual oils having high (>0.5 weight %) nitrogen content, use 15 kg NO_2/10^3 liter (120 lb NO_2/10^3 gal) as an emission factor.

TABLE 4. UNCONTROLLED EMISSION FACTORS FOR NATURAL GAS COMBUSTION (*AP-42* TABLE 1.4-1)

Furnace Size & Type (10^6 Btu/hr heat input)	Particulate[b]		Sulfur Dioxide[c]		Nitrogen Oxides[d]		Carbon Monoxide[e]		Volatile Organics			
									Nonmethane		Methane	
	$kg/10^6m^3$	$lb/10^6ft^3$	$kg/10^6m^3$	$lb/10^6ft^3$	$kg/10^6m^3$	$lb/10^6ft^3$	$kg/10^6m^3$	$lb/10^6ft^3$	$kg/10^6m^3$	$lb/10^6ft^3$	$kg/10^6m^3$	$lb/10^6ft^3$
Utility boilers (> 100)	16 - 80	1 - 5	9.6	0.6	8800[h]	550[h]	640	40	23	1.4	4.8	0.3
Industrial boilers (10 - 100)	16 - 80	1 - 5	9.6	0.6	2240	140	560	35	44	2.8	48	3
Domestic and commercial boilers (< 10)	16 - 89	1 - 5	9.6	0.6	1600	100	320	20	84	5.3	43	2.7

[a]Expressed as weight/volume fuel fired.
[b]References 15-18.
[c]Reference 4. Based on avg. sulfur content of natural gas, 4600 $g/10^6m^3$ (2000 $gr/10^6$ scf).
[d]References 4-5, 7-8, 11, 14, 18-19, 21.
[e]Expressed as NO_2. Tests indicate about 95 weight % NO_x is NO_2.
[f]References 4, 7-8, 16, 18, 22-25.
[g]References 16, 18. May increase 10 - 100 times with improper operation or maintenance.
[h]For tangentially fired units, use 4400 $kg/10^6$ m^3 (275 $lb/10^6$ ft^3). At reduced loads, multiply factor by load reduction coefficient in Figure 1.4-1. For potential NO_x reductions by combustion modification, see text. Note that NO_x reduction from these modifications will also occur at reduced load conditions.

and summarize emission factors for bituminous and subbituminous coal, anthracite coal, fuel oil and natural gas combustion, respectively.

Point/area source cutoff

Electric-generating boilers which release greater than 100 TPY of CO, SO_2, NO_x, TSP or VOC are already included in the inventory as point sources. Those which release smaller quantities of pollutants, presently unaccounted for in NEDS, could either be grouped as area sources or treated as individual point sources.

Level of detail of information available

Adequate data are available to quantify pollutant emissions from small utility boilers as individual point sources.[2,3,7,8,9] The EIA provides data on quantity and type of fossil fuel consumed by every electric generating unit in the United States.[7] Facility names and county location are specified. The EIA has also supplemented this facility-specific data with information on capacity, unit design and air pollution control devices employed by each plant.[3] Emission factors are available from *AP-42*.

Level of detail required by users

SO_2, NO_x, VOC, CO and TSP emissions by county for small electric utility boilers

Regional, seasonal or temporal characteristics

Small electric utility boilers are likely to dominate energy supplies in sparsely populated regions of the country, such as the midwestern, southwestern and mountain states. In areas where small towns are isolated by large expanses of land, small electric utility boilers are likely to be the only source of electricity generation. As is the case with larger facilities, peak demand varies with season and time of day. Winter and the hours between 9:00 a.m. and 5:00 p.m. have increased usage and, therefore, increased emissions. Peaking units which operate only during periods of high energy demand contribute emissions on a sporadic and short-term basis.

Urban or rural characteristics

Small electric utility boilers are prevalent in rural areas and small towns.

Methodology

The EIA has inventoried all electric utility boilers for each state on a county level, as described above.[3] Large units which are already assessed in NEDS as point sources should be identified and removed from that inventory. EIA fuel consumption data for small units should be integrated into this database. *AP-42* emission factors should then be applied to each small boiler on a unit-by-unit basis. Finally, emission values could be adjusted for pollution control devices.

References

1. Kersteter, Sharon L. *Procedures for the Preparation of Emission Inventories for Precursors of Ozone, Volume I*, EPA-450/4-88-021 (NTIS PB89-152409), U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1988.

2. *Electric Power Annual* (and associated data tapes), DOE/EIA-0348(88), U.S. Department of Energy, Energy Information Administration, Washington, DC, 1988.

3. *Inventory of Power Plants in the United States* (and associated data tapes), DOE/EIA-0095(88), U.S. Department of Energy, Energy Information Administration, Washington, DC, 1988.

4. *Federal Energy Data System (FEDS) Statistical Summary Update*, DOE/EIA-0192, U.S. Department Energy, Energy Information Administration, Washington, DC. Annual publication.

5. Saeger, M., *et al. The 1985 NAPAP Emissions Inventory, (Version 2): Development of the Annual Data and Modelers' Tapes*, EPA-600/7-89-012a (NTIS PB91-119669), U.S. Environmental Protection Agency, Research Triangle Park, NC, November 1989.

6. *Compilation of Air Pollutant Emission Factors*, Fourth Edition and Supplements, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1985 through September 1991.

7. *Cost and Quality of Fuels for Electric Utility Plants* (and associated data tapes), DOE/EIA-0191(88), U.S. Department of Energy, Energy Information Administration, Washington, DC, 1988.

8. *State Energy Data Report, Consumption Estimates 1960-1988* (and associated data tapes), DOE/EIA 0214(88), U.S. Department of Energy, Energy Information Administration, Washington, DC, 1988.

9. *1980 National Emissions Data System (NEDS) Fuel Use Report*, EPA-450/4-82-011 (NTIS PB82-237173), U.S. Environmental Protection Agency, Research Triangle Park, NC, 1982.

WOOD STOVES

Definition/description of category and activity

Wood combustion produces smoke which is a complex mixture of PM_{10}, oxides of sulfur and nitrogen, organic material, POM and mineral constituents. Emissions of organic material, CO and PM_{10} from wood stoves result from incomplete combustion of the wood. The mixture of constituents of the smoke emitted can vary with the design of the stove, length of time for the burn, type of wood, size of the wood and moisture content in the wood. Typically, wood stoves are enclosed fire boxes and are used domestically for space heating to supplement conventional heating systems. Fires in wood stoves are generally maintained continuously throughout the winter season.[1,2]

Process breakdown

As indicated above, most wood stoves are fairly airtight and vent emissions through a stack in the roof. These stacks are usually low with very little plume rise. There are two types of stoves, the conventional and the catalytic stove. Catalytic stoves typically have lower emissions than conventional stoves. Higher burn rates (amount of wood burned per hour) generally result in lower emission factors for all stoves. However, lower burn rates result in lower emission rates for particulate emissions from catalytic stoves. Lower burn rates do not affect particulate emissions in any definite way and vary with stove type.[3] The lowest particulate emission factors occur when the wood moisture content is 20 to 26 percent (wet basis). Moisture contents above or below this range result in higher emission factors.[3] Larger "charge size" generally results in higher emission factors for TSP, CO and VOC and larger fireboxes in stoves generally result in higher particulate emissions. Larger wood pieces result in lower emission factors for CO, VOC and TSP.

Reason for considering the category

A recent estimate puts the number of RWC units (i.e., fireplaces and wood stoves) in the United States in 1989 at 30 million. Slightly more than 50 percent of RWC units are fireplaces and the remainder are wood stoves. These devices are among the largest anthropogenic sources of PM_{10} and CO in the country.[2] Typically, RWC units are used in the winter when organic and NO_x emissions from this source are not likely to have any significant impact on ozone formation in a study area. However, given the stability of the cold air in the winter, PM_{10} emissions can seriously impair visibility in a given area in the winter. EPA research indicated that winter CO emissions from RWC units can have some significant detrimental effects on the health of the population in a given area.[2]

Pollutants emitted

Pollutants emitted from wood stoves include CO, NO_x, SO_x, organic material (such as POM and aldehydes) and PM_{10}.

Estimate of the pollutant levels

Emissions estimates for total U.S. residential wood consumption (fireplaces and wood stoves) in the 1985 NAPAP Inventory are as follows:[4]

11,077 TPY of SO_x
80,774 TPY of NO_x
1,459,464 TPY of VOC
1,088,598 TPY of TSP
6,721,128 TPY of CO

The State of Oregon estimated the following emissions for the state from a 1987 inventory of 384,848 wood stoves:[5]

27,588 TPY of PM_{10}
186,688 TPY of CO

Point/area source cutoff

Residential wood combustion in wood stoves is not considered a point source, since emissions per stove do not exceed ten TPY.

Level of detail of information available

(1) *AP-42* emission factors for combustion in residential wood stoves for four different categories of stoves:[1]

Stove Type	PM_{10}	SO_x	NO_x	CO	VOC (methane)	VOC (nonmethane)
Conventional noncatalytic	15	0.2	1.4	140	32	14
Noncatalytic low emitting	9.6	0.2	-	130	-	-
Pellet-fired noncatalytic	1.6	0.2	6.9	18	-	-
Catalytic	6.6	0.2	1.0	39	13	8.6

(2) Emission factors from Environment Canada for slow combustion wood stoves:[6]

25 g TSP/kg of wood burned
0.8 g SO_x/kg of wood burned
0.5 g NO_x/kg of wood burned
175 g CO/kg of wood burned

(3) Emission factors from Environment Canada for conventional wood stoves:[6]

33 g TSP/kg of wood burned
0.8 g SO_x/kg of wood burned
0.5 g NO_x/kg of wood burned
110 g CO/kg of wood burned

(4) A State of Colorado survey showed that an average of 1.28 and 0.61 cords of wood are burned in stoves and fireplaces, respectively, during an average season in the Denver metropolitan area.[7]

(5) The State of Oregon has compiled an inventory of total number of wood stoves in the state and estimated the total amount of wood consumed by wood stoves (800,071 cords in 1987).[5]

(6) New emission factors for wood stoves are currently being developed by EPA.[8]

Level of detail required by users

Emissions by county

Amount of wood used by wood stoves (by county)

Number of wood stoves per county

Amount of wood used per unit (stove)

Emission factor requirements

Amount of pollutant emitted per unit use of wood

Regional, seasonal or temporal characteristics

Residential wood combustion in wood stoves usually occurs in winter when stoves are used for supplementing heating.

Urban or rural characteristics

An urban and rural source

Methodology

Emissions from wood stoves are estimated using the *AP-42* emission factors expressed in grams of pollutant emitted per kilogram of dry wood burned (or in pounds of pollutant emitted per ton of dry wood burned) and multiplying them by the amount of wood burned.

References

1. *Compilation of Air Pollutant Emission Factors*, Fourth Edition and Supplements, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1985.

2. Davis, B. and B. Read, *Guideline Series: Guidance Document for Residential Wood Combustion Emission Control Measures*, EPA-500/2-89-015 (NTIS PB90-130444), U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1989.

3. *Technical Support Document for Residential Wood Combustion*, EPA-450/4-85-012, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1986.

4. Saeger, M., *et al. The 1985 NAPAP Emissions Inventory, (Version 2): Development of the Annual Data and Modelers Tapes*, EPA-600/7-89-012a (NTIS PB91-119669), U.S. Environmental Protection Agency, Research Triangle Park, NC, November 1989.

5. Telecon. Chadha, Ajay, Alliance Technologies Corporation, with Steve Crane, Oregon Air Pollution Control Division. Estimates of emissions from wood stoves and fireplaces in Oregon. August 1, 1990.

6. *Methods Manual for Estimating Emissions of Common Air Contaminants from Canadian Sources*, ORTECH International (in development).

7. *Denver Metro Woodburning Survey*, Colorado Department of Health, Air Pollution Control Division, Denver, CO, June 1988.

8. Telecon. Chadha, Ajay, Alliance Technologies Corporation, with Michael Hamlin, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Revision of existing *AP-42* emission factors for wood stoves and fireplaces. July 23, 1990.

BACKYARD CHARCOAL GRILLS

Definition/description of category and activity

Organic gases are emitted when charcoal lighter fluid is used to soak and light charcoal briquettes in backyard grills. The lighter fluid, composed almost entirely of volatile constituents such as petroleum naphtha and petroleum distillates, evaporates to contribute to the VOC burden in the atmosphere. Some VOC are also emitted during the combustion of the charcoal and increase as the flame dies down.[1] NO_x and CO are also emitted from charcoal grills.

Process breakdown

Not applicable for this category

Reason for considering the category

In 1989, SCAQMD was the first regulatory agency to investigate charcoal lighter fluid as a source of atmospheric VOC. SCAQMD performed a detailed investigation of pollutant emissions from various methods of igniting charcoal in grills.[1] Additional work was done by the Clorox Company and AEERL to estimate VOC emissions from evaporation of lighter fluid and ignition of charcoal.[2] However, no standard emission factors are currently available for estimating VOC, NO_x or CO emissions from charcoal grills. SCAQMD has proposed a working group with the barbecue industry to develop a standard emissions test procedure and ultimately develop emission factors.[3] Emissions estimates from charcoal grills are important since grills have fairly significant VOC emissions and activity typically occurs in the summer months which coincides the ozone season.

Pollutants emitted

VOC from evaporation and combustion

NO_x and CO during combustion

Estimate of the pollutant levels

Based on estimates provided by the Barbecue Industry Association (BIA) for 1989 U.S. lighter fluid sales,[4] AEERL derived a best estimate of 1,110 tons of VOC emitted from evaporation of lighter fluid and 14,500 tons of VOC from evaporation and combustion combined.[2]

Point/area source cutoff

Due to the nature of the activity, backyard grills are not considered to be point sources.

Level of detail of information available

Some emissions estimates have been reported by EPA based on test data from Clorox and AEERL.

The BIA has consumption estimates for lighter fluid and charcoal in the United States.

Some information is available on the types (i.e., gas, electric, charcoal, etc.) and numbers of background grills used.

Level of detail required by users

Data on consumption of lighter fluid and charcoal on a county level

Estimate of population of grills by type on a county level

Emission factor requirements

Amount of lighter fluid and charcoal used in the study area

Emissions of VOC, NO_x and CO per unit use of charcoal and lighter fluid

Regional, seasonal or temporal characteristics

Charcoal grills are used primarily in the summer months.

Urban or rural characteristics

Principally an urban source

Methodology

BIA national estimates of annual consumption of lighter fluid and charcoal briquettes may be apportioned by assuming that 80 percent is used in the ozone season and 20 percent is used in the non-ozone season. Emissions generated in the non-ozone season may be allocated to counties, based on the number of single family dwellings in each county. Multiplying this estimate by the emission factors will result in estimates of county-level emissions from charcoal grilling generated during the non-ozone season. In the ozone season (summer), charcoal grills are used in backyards, parks and other recreation areas. Total ozone season usage can then be apportioned to type of use (backyards or recreation areas). Usage in recreation areas can be allocated to the various recreation areas based on attendance records; multiplying the resulting usage by an emission factor would yield emissions for the recreation area. The remaining percent of national ozone season usage can be used to estimate emissions from backyard grilling. The county-wide emissions from this source can be estimated by apportioning this usage to counties by the number of single family dwellings and multiplying by the emission factors.

References

1. *A Comparative Study of Organic, Carbon Monoxide, and Oxides of Nitrogen Emissions from Various Charcoal Igniting Methods*. South Coast Air Quality Management District (SCAQMD), El Monte, CA, 1989.

2. Campbell, D.L. and Stockton, M.B., *Estimation of Emissions from Charcoal Lighter Fluid and Review of Alternatives*, EPA-600/2-90-003 (NTIS PB90-186313), U.S. Environmental Protection Agency, Research Triangle Park, NC, January 1990.

3. Telecon. Chadha, Ajay, Alliance Technologies Corporation, with Suzanne Vetrano, The Clorox Company, Pleasanton, CA. Lighter fluid emissions testing methodologies. July 31, 1990.

4. Telecon. Chadha, Ajay, Alliance Technologies Corporation, with Sandy Burton, Barbecue Industry Association, Naperville, IL. Lighter fluid statistics. July 24, 1990.

COMMERCIAL CHARBROILING

Definition/description of category and activity

Charbroiling is the most common method of cooking meat at fast food and full service restaurants. The typical pollutants emitted from commercial charbroiling consist of VOC, mainly aldehydes, and PM, mainly fat, grease and carbon, where 93 percent of PM is less than one μm in size. Charbroilers are used to cook steaks, hamburger patties, chicken and other foods.[1] Full service restaurants normally operate flame-fired broilers during dinner hours, whereas fast-food establishments have direct-flame patty broilers with peak operations from 11:00 a.m. to 2:00 p.m. and from 5:00 p.m. to 9:00 p.m.

Process breakdown

Charbroilers consist of three main components, a heating source (typically natural gas), a high temperature radiant surface and a grated grill. The meat is placed on the grill typically located above the radiant surface. Grease from the cooked meat falls on the surface and causing both VOC and PM emissions. These emissions are typically vented to the atmosphere by means of a mechanical exhaust. The configuration of the vent can vary with the location of a charbroiler within an individual facility.

Reason for considering the category

Restaurants and fast-food establishments are typically concentrated in urban areas where VOC and PM emissions are of most concern. Most of these emissions are largely uncontrolled, although these establishments must comply with local building and fire codes, as well as with standards for odor and nuisance. It is likely that these emissions could contribute to the formation or build-up of ozone.

Pollutants emitted

The pollutants emitted consist mostly of reactive VOC and PM. Charbroilers using natural gas for heating source also emit small amounts of NO_x, SO_x, CO_2 and CO.

Estimate of the pollutant levels

SCAQMD has estimated that 1985 daily VOC and PM emissions from charbroilers in the South Coast Air Basin were 1.9 tons and 7.4 tons, respectively.[1]

Point/area source cutoff

Individual commercial charbroilers are unlikely to emit more than 100 tons per year of any pollutant, and thus would not be considered as point sources.

Level of detail of information available

A 1977 study conducted for EPA estimated that approximately nine percent of eating establishments used meat-firing grills.[2] The same study also provided emission factors for VOC and PM emissions from charbroilers in California restaurants, as given below:

1,000 lbs VOC/year-restaurant
3,000 lbs PM/year-restaurant

Level of detail required by users

An inventory of commercial eating establishments that use charbroilers to fire the meat

Emission factors which reflect the amount of meat used at various types of establishments and the type of meat used

Emission factor requirements

A more accurate characterization of the emissions resulting from commercial charbroilers (e.g., using source testing equipment)

An estimate of amount and type (chicken, beef, pork) of meat used by establishments of various sizes

Regional, seasonal or temporal characteristics

A typical restaurant operates six or seven days a week, from 10:00 a.m. to 10:00 p.m.. Emissions are likely to be highest during lunch (11:00 a.m. to 2:00 p.m.) and dinner (5:00 p.m. to 9:00 p.m.) hours. It is unlikely that this source will show much regional differences.

Urban or rural characteristics

Principally an urban source

Methodology

- Obtain the number of restaurants in an area from *County Business Patterns*[3] and assume that a certain percent of these establishments use charbroilers.
- Obtain estimates of sales of various meats to commercial establishments in a given county.
- Using the emission factors based on amount and type of meat fired in commercial establishments, calculate emissions of VOC and PM.

References

1. *Final Air Quality Management Plan 1989*, South Coast Air Quality Management District, El Monte, CA, March 1989.
2. *Methods for Assessing Area Source Emissions in California*, California Air Resources Board, Sacramento, CA, December 1982.
3. *County Business Patterns*, U.S. Department of Commerce, Bureau of the Census, Washington, DC. Annual publication.

COMMERCIAL DEEP FAT FRYING AT RESTAURANTS

Definition/description of category and activity

Deep fat frying involves the cooking of foods in hot oils or greases. Potatoes are considered the most commonly fried food; other foods include doughnuts, fritters, croquettes and breaded and batter-dipped fish and meat. VOC, PM and entrained fat particles are emitted during frying. In general, fish and meat products, which contain higher percentages of fats and oils, produce greater emissions than vegetable products.[1] Where natural gas is used to heat the oil, small amounts of NO_x, SO_x, CO_2 and CO and additional amounts of PM may be emitted.[2]

Full service restaurants normally operate deep-fat fryers during dinner hours, whereas fast-food establishments have deep-fat fryers in peak operations from 11:00 a.m. to 2:00 p.m. and from 5:00 p.m. to 9:00 p.m.[3]

Process breakdown

Preparation of food before deep frying may involve slicing (potatoes), dough-making (doughnuts, fritters, croquettes) and breading or batter preparation (breaded or batter-dipped fish and meat).

The principal frying equipment is an externally heated cooking oil vat. Oil temperatures are usually controlled to between 325 and 450 degrees Fahrenheit. Electricity, gas or other energy sources can be used to heat the vat. The products to be fried are either manually or mechanically inserted into the hot oil and removed after a definite time interval.[1]

During frying, moisture in the foods is released as steam. Some cooking oils, as well as animal or vegetable oils from the food, are steam distilled and released as VOC or as oil droplets during frying. Excessive smoking (PM release) may be due to overheating of the food or to steam distillation of finely divided fat and oil products from old cooking oil or the food. Some meat product fryers require control equipment to bring them into compliance with visible emission regulations.[1]

Natural gas consumption is included in the fuel combustion category; therefore, NO_x, SO_x, CO_2, CO and PM emissions from natural gas combustion for deep fat frying is not counted in the deep fat frying category.

Reason for considering the category

Restaurants and fast food establishments are typically concentrated in urban areas where VOC, PM, NO_x, SO_x, CO_2 and CO emissions are of greatest concern. Most of these emissions are largely uncontrolled, although these establishments must comply with local building and fire codes, as well as with standards for odor and nuisance.

Pollutants emitted

VOC, PM, NO_x, SO_x, CO_2 and CO

Estimate of the pollutant levels

SCAQMD has estimated the following emissions from deep-fat frying in the South Coast Air Basin during 1987:[3]

VOC	1,687 tons per year
PM	901 tons per year

Point/area source cutoff

Individual restaurant deep fat frying activity is unlikely to emit more than ten tons per year of any pollutant and should be considered an area source.

Level of detail of information available

Reference 3 estimates reactive organic gas (ROG) and PM for the SCAQMD using the following:

- Estimate of the process flow during peak and off-peak hours
- Estimated number of deep fat fryers in each county in the District (distributed to individual basins by population)
- Total organic gas (TOG) and PM emission factors based on limited source tests

TOG	135 lbs TOG per year-fryer
PM	54 lbs PM per year-fryer

  ROG emission estimates are obtained by multiplying TOG emissions by a factor of 0.749 tons ROG per ton TOG.
- District, basin and county population estimates

VOC emissions are assumed to be the same as ROG emissions (the VOC definition excludes ethane; otherwise, the two definitions are identical).

Level of detail required by users

Emissions by county

County-level deep fat frying food production, by food type (vegetable product, meat product, breaded or batter-dipped, and other categories)

Emission factors for each food type

Emission factor requirements

The source tests used by SCAQMD are limited to potato fryers. More testing is necessary to develop emission factors for other food products, particularly the meat products, which have higher percentages of fats and oils.

Regional, seasonal or temporal characteristics

A typical full service restaurant will operate deep fryers mostly in the evenings. Peak times for fast food restaurants are from 11:00 a.m. to 2:00 p.m. and from 5:00 p.m. to 9:00 p.m.[3] Emissions are likely to be highest during these times. It is unlikely that this source will show much regional variation.

Urban or rural characteristics

Principally an urban source

Methodology

Estimates can be made using the SCAQMD and related emission factors.

- The SCAQMD emission factors are given as tons per year-fryer. Data provided by SCAQMD can also be used to generate alternative per year-person or per year-restaurant emission factors.
- The emission factors and production figures (or surrogates) can be used to estimate emissions in each county.

Alternatively, if product-specific emission factors are developed (emissions per pound of product fried), more precise emission estimates can be made.

- Much more specific information will be needed in order to use these emission factors. Product-specific deep fat frying quantities will be needed.
- The emission factors and production figures (or surrogates) can be used to estimate emissions in each county.

References

1. *Air Pollution Engineering Manual*, Second Edition, AP-40, U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1973.
2. *Area Source Emissions for C/Y 1987 from Residential Fuel Combustion of Natural Gas for Cooking in the SCAQMD Air Basins*, CES No. 54585, South Coast Air Quality Management District, El Monte, CA, June 15, 1988.
3. *Area Source Emissions from Deep Fat Frying*, CES No. 66811, South Coast Air Quality Management District, El Monte, CA, October 19, 1988.

RESIDENTIAL DEEP FAT FRYING

Definition/description of category and activity

Deep fat frying involves the cooking of foods in hot oils or greases. Commonly fried foods include potatoes, breaded and batter-dipped fish and meat, and foods such as fritters or doughnuts. VOC, PM and entrained fat particles are emitted during frying. In general, fish and meat products, which contain higher percentages of fats and oils, produce greater emissions than vegetable products.[1] Where natural gas is used to heat the oil, small amounts of NO_x, SO_x, CO_2 and CO and additional amounts of PM may be emitted.[2]

Process breakdown

Preparation of food before deep frying may involve slicing (potatoes), dough-making (doughnuts, fritters, croquettes) and breading or batter preparation (breaded or batter-dipped fish and meat).

The principal frying equipment is an externally heated cooking oil vat. Electricity, gas or other energy sources can be used to heat the vat. The products to be fried are manually inserted into the hot oil and removed after a definite time interval.[1]

During frying, moisture in the foods is released as steam. Some cooking oils, as well as animal or vegetable oils from the food, are steam distilled and released as VOC or as oil droplets during frying. Excessive smoking (PM release) may be due to overheating of the food or to steam distillation of finely divided fat and oil products from old cooking oil or the food.[1]

Natural gas combustion is included in the fuel combustion category; therefore, NO_x, SO_x, CO_2, CO and PM emissions from natural gas combustion for deep fat frying are not counted in the deep-fat frying category.

Reason for considering the category

In urban areas, VOC, PM, NO_x, SO_x, CO_2 and CO emissions are of most concern. Most kitchens have hood filters over the stove, which may trap some particulate matter or suspended oils or fats from frying done at the stove. Deep fat frying may or may not be conducted under the hood, however, if a self-contained deep fat fryer is used. Any emissions which are not vented to the atmosphere may be an indoor air pollutant concern.

Pollutants emitted

VOC, PM, NO_x, SO_x, CO_2 and CO

Estimate of the pollutant levels

No estimate is available; however, residential deep-fat frying emissions to outdoor air are most likely insignificant.

Point/area source cutoff

Individual home deep fat frying activity is unlikely to emit more than ten tons per year of any pollutant and should be considered an area source.

Level of detail of information available

SCAQMD has estimated the emissions of ROG and PM from commercial cooking of potatoes in deep-fat fryers. VOC emissions are assumed to be the same as ROG emissions (the VOC definition excludes ethane; otherwise, the two definitions are identical). The SCAQMD study can be used to generate an emission factor based on fried food production. The SCAQMD emission factor is based on emission tests using commercial, deep-fat potato fryers.[3]

Level of detail required by users

Emissions by county

County-level deep-fat frying food production, by food type (vegetable product, meat product, breaded or batter-dipped and other categories)

Emission factors for each food type

Emission factor requirements

The source tests used by SCAQMD are limited to potato fryers. More testing is necessary to develop emission factors for other food products, particularly the meat products, which have higher percentages of fats and oils. The SCAQMD emission factors may be a reasonable approximation for commercial deep-fat frying, given the assumption that potatoes are the most frequently fried product. This may not be a reasonable assumption for residential cooking, where meats may be the more frequently fried products.

In addition, the SCAQMD emission factors have been developed from controlled frying processes. There are likely to be more variations in cooking temperature, cooking time and moisture content in residentially prepared foods. *AP-40* identifies these variables as important factors affecting the amount of emissions expected from deep-fat frying.[1]

Since commercial emission factors are likely to be inappropriate for estimating emissions from residential deep-fat frying, it is necessary to develop improved emission factors for residential cooking.

Regional, seasonal or temporal characteristics

Emissions are likely to be highest during mealtimes. No regional or seasonal variations are expected.

Urban or rural characteristics

None identified

Methodology

County-level residential deep fat frying activity estimates need to be made for the different commonly fried food products.

Activity estimates can be used with the SCAQMD emission factors for rough estimates of VOC and PM emissions.

Preferably, residential, food-specific emission factors should be developed for better estimates of VOC and PM emissions from residential deep-fat frying. These emission factors can be used with the county-level deep-fat frying activities developed for individual food products.

References

1. *Air Pollution Engineering Manual*, Second Edition, AP-40, U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1973.

2. *Area Source Emissions for C/Y 1987 from Residential Fuel Combustion of Natural Gas for Cooking in the SCAQMD Air Basins*, CES No. 54585, South Coast Air Quality Management District, El Monte, CA, June 15, 1988.

3. *Area Source Emissions from Deep Fat Frying*, CES No. 66811, South Coast Air Quality Management District, El Monte, CA, October 19, 1988.

CIGARETTE SMOKE

Definition/description of category and activity

Cigarette smoke contains combustion products (including tobacco-related organics) which are released into the indoor and outdoor atmospheres. Smoke contains volatile organics and metals that are considered toxic. Although cigar and pipe smoking are similar sources, they represent only a small fraction of the total tobacco smoked.

Process breakdown

Smoldering cigarettes

Active inhalation/exhalation

Reason for considering the category

Approximately 575 billion cigarettes are smoked in the United States annually. Although the potential emissions per cigarette are small, cumulative emissions of priority pollutants and air toxics are of interest. Environment Canada currently estimates emissions in this category as a part of Canada's area source inventory.[2]

Pollutants emitted

TSP, CO, NO_x, VOC, methane

Estimate of the pollutant levels

Based on data from the United States Centers for Disease Control, Office on Smoking and Health, 1987 U.S. emissions are estimated below.[3] These data are for unfiltered cigarette smoke and assume combustion of the entire cigarette. On this basis, these estimates may be maximum levels due to presumed reductions from filters and unconsumed cigarette portions.

TSP	14,000 TPY
CO	12,000 TPY
NO_x	12,000 TPY
VOC	44,000 TPY
Methane	1,000 TPY

Point/area source cutoff

Cigarette smoking activity should be considered an area source category.

Level of detail of information available

National/state/county cigarette consumption/sales data

Detailed analysis of mainstream cigarette smoke (U.S. Surgeon General) per cigarette

Level of detail required by users

Cigarette consumption by county

Emissions per cigarette

Emission factor requirements

Emissions per cigarette:[3,4]

Pollutant	mg/cigarette (unfiltered)
Particulate matter	22.5
Organic vapor	67.5
CO	19
NO_x	0.35
Methane	1.5

Regional, seasonal or temporal characteristics

None

Urban or rural characteristics

Emissions vary directly with population

Methodology

Data from the U.S. Surgeon General and the Office on Smoking and Health are sufficient to estimate the number of cigarettes smoked and their average smoke analysis.[3,4] According to one source, emissions do not vary significantly between cigarette brands. The consumption data are updated annually and could be projected based on current trends. TSP, CO, NO_x, VOC and methane can be estimated at the desired level of resolution in this manner. Specific air toxic components have been identified and can be estimated individually.

References

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2. *Cigarette Smoking Area Source Methodology A40*, Environment Canada, Unpublished, 1985.

3. *Smoking, Tobacco and Health*, (CDC)87-8397, U.S. Department of Health and Human Services, Office on Smoking and Health, Washington, DC, October 1989.

4. *Reducing the Health Consequences of Smoking: 25 Years of Progress*, Surgeon General, U.S. Department of Health and Human Services, Office on Smoking and Health, 1989.

BARGE, TANK, TANK TRUCK, RAIL CAR, AND DRUM CLEANING

Definition/description of category and activity

As of 1978, barges, tanks, rail cars, tank trucks and drums have been used to transport about 700 different commodities. Rail tank cars and most tank trucks and drums are in dedicated service (carrying one commodity only) and, unless contaminated, are cleaned only prior to repair or testing. Nondedicated tank trucks (approximately 20,000 trucks or 22 percent of the total in service) and drums (approximately 5.6 million, or 12.5 percent of the total) are cleaned after every trip. Emissions from cleaning these containers and transportation vehicles can be as varied as the types of commodities transported. The commodity transported, the cleaning agent and the management of chemical residues determine emission levels. Cleaning agents include water, steam, detergents, bases, acids and solvents, which are applied with either hand-held pressure wands or with rotating spray nozzles.[1,2,3,4]

Process breakdown

Emissions from cleaning barges, tanks, tank trucks, rail cars and drums result from two sources. First, emissions associated with the chemical residue are extremely variable, depending on the compound and the quantity remaining in the container. They may be affected both by viscosity (which affects the quantity remaining inside the container after unloading) and vapor pressure (which affects the quantity which evaporates). Second, emissions associated with cleaning agents used to clean the receptacles depend primarily on the type of agent used, quantity, ambient temperature and recovery method. The process may be further characterized by location, vehicle or container type and commodity or waste contained.[4]

Reason for considering the category

Localized emissions may be large, especially at treatment, storage and disposal facilities, and at other cleaning stations for the chemical transport industry. Cleaning activities have been the subject of several occupational hygiene reports, some of which describe worker deaths while cleaning toxic chemicals in confined spaces.[5,6,7,8] At least two tank truck cleaning terminals are included in the CERCLIS database of hazardous waste sites, suggesting that releases from this activity are hazardous to human health and the environment.[9,10,11,12]

Pollutants emitted

Primarily VOC; also NO_x and PM_{10}

Estimate of the pollutant levels

No national total emissions data are available, since much of the necessary activity data are missing. However, Section 4.8 of *AP-42* provides certain emission factors as follows:[1]

Compound	VP	Visc.	lb/car	g/car
RAIL TANK CAR CLEANING				
Ethylene glycol	low	high	0.0007	0.3
Chlorobenzene	med	med	0.0346	15.7
o-Dichlorobenzene	low	med	0.1662	75.4
Creosote	low	high	5.1808	2350
TANK TRUCK CLEANING			lb/truck	g/truck
Acetone	high	low	0.686	311
Perchloroethylene	high	low	0.474	215
Methyl methacrylate	med	med	0.071	32.4
Phenol	low	low	0.012	5.5
Propylene glycol	low	high	0.002	1.07

Pollutant	Controlled		Uncontrolled	
	lb/drum	g/drum	lb/drum	g/drum
DRUM BURNING				
Particulate	0.02646	12	0.035	16
NO_x	0.00004	0.018	0.002	0.89
VOC	negligible		negligible	

Reference 2, which first compiled the above values, also estimated that tank truck and rail tank car cleaning contribute less than 0.02 percent to both state and national organic air pollutant burdens. Total particulate emissions from drum burning contribute less than 0.023 percent of any state emissions burden and 0.0007 percent of national emissions burden, while total hydrocarbon emissions from drum washing or burning are negligible. Estimated hydrocarbon emissions in metric tons per year are broken down by state; national totals from trucks and rail cars are 538.05 and 87.47, respectively. However, given that these data are 13 years old and that major legislation (RCRA, Hazardous and Solid Waste Amendments (HSWA), and the Hazardous Materials Transportation Act) has been enacted since this study was completed, the data should be evaluated carefully. Additionally, these data do not address emissions associated with cleaning tanks which previously held waste, hazardous or otherwise.

Point/area source cutoff

Emissions from these activities occur in strictly defined locations, suggesting that this source could be considered a point source. However, it is unlikely that the activity releases greater than ten TPY of VOC, PM_{10} or trace metals emissions at each site. Therefore a more appropriate designation is as an area source category.

Level of detail of information available

Activity data are extremely limited. Mr. Cliff Harveson of the National Tank Truck Carriers Conference stated that no data are collected on dedicated versus nondedicated transport vehicles or frequency of cleaning. No state requires transporters to register this information. He estimates, however, that 15,000 tank trucks in the United States are cleaned on a regular basis, approximately two times during every ten day period. In 1980, *AP-42* reported that 20,000 rail tank cars and tank trucks (22 percent of the total)

are in nondedicated service and would therefore require cleaning between loads of different materials. Approximately 12.5 percent of all drums (5.6 million) are cleaned after every trip. Also presented are breakdowns of major commodity groups and frequency of tank car cleaning (four to ten per day). *AP-42* states that the average amount of residual material cleaned from each rail tank car is 550 pounds, while 220 pounds of material are removed from each tank truck. Approximately 60 gallons of liquid are used per tank truck steam cleaning and 5,500 gallons are used for full flushing. Since drums are difficult to clean, they are often burned. As detailed above, *AP-42* provides emission factors for six cleaning agents. Current breakdowns on the basis of geography, commodity or cleaning agent are not available.

Level of detail required by users

Emissions by county

Barge, tank truck, tank, rail car and drum cleaning stations by county

Annual number cleaned by county

Emission factor requirements

At present, emission factors have been computed for six cleaning agents. Ideally, emission factors should be compiled for all the types of cleaning agents and for general classes of commodities transported. These factors should address VOC, NO_x and PM_{10} releases.

Regional, seasonal or temporal characteristics

Freight transport and the associated cleaning operations occur in industrialized regions of the country. The only seasonal restrictions are likely to be associated with extremes in temperature, when the ambient temperature is either higher than the flash point or below the freezing point of either the compound or the cleaning agent. Since transport operations are conducted 24 hours per day, no substantial temporal characteristics should be exhibited. Cleaning operations, however, are probably only 8:00 a.m. to 5:00 p.m. operations.

Urban or rural characteristics

Cleaning activities are likely limited to industrialized areas.

Methodology

- Define all cleaning agents used in the transportation industry. Conduct field tests to estimate emission factors for each cleaning agent.
- Break down commodities transport into major categories of concern. Conduct field tests to estimate emission factors associated with each category of commodity.
- Determine geographical breakdown of cleaning stations, including private industrial stations and commercial truck washes. Estimate number of vehicles cleaned annually by cleaning agent and commodity carried.

- Calculate annual emissions by county by multiplying usage data by emission factors.

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11. *Superfund Record of Decision (EPA Region 6): Stewco Inc. Site, Harrison County, Texas, September 16, 1988, First Remedial Action, Final Report,* U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, September 1988.

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INNOVATIVE WASTE TREATMENT TECHNOLOGIES

Definition/description of category and activity

The innovative waste treatment category is part of a group defined as emerging technologies. Many of these technologies are in bench-, pilot- or field-scale testing. A few technologies have had more extensive testing or are already established. These waste treatment technologies have been spawned by the need for hazardous waste destruction and remediation activities. Current technologies under development by private corporations, some developed under the auspices of the Superfund Innovative Technology Evaluation (SITE) Program, have been reviewed. These technologies include soil cleaning, vacuum extraction, UV oxidation, steam stripping and thermal stripping and have the potential to emit VOC during application of the processes.[1,2,3,4,5]

These technologies are typically in place for a few months to a few years for remediation purposes. Contaminated materials treated offsite at treatment, storage and disposal facilities are already accounted for in SIP and NEDS inventory methods. For some of these processes, there may be several similar proprietary processes developed by several companies that use different equipment or chemicals but employ the same strategy. The VOC are either inherent in the hazardous waste or are integral to the treatment process. In most cases, VOC control is provided in the process application. Some systems are designed to recover solvents using steam regeneration of the activated carbon or direct condensation of the collected gases. As with any process, however, failure to apply applicable controls or failure of the control system can create the release of VOC.

Process breakdown[1,2,3,4,5]

Soil Cleaning - Soil and groundwater cleaning involves the use of agitation and surfactants to remove adsorbed contaminants from soils. Contamination from waste oil refining, tar chemistry and paint fabrication have been treated in this way. The wastewater is then treated to remove the organic and toxic contaminants such as chlorinated hydrocarbons, aromatics, polychlorinated biphenyls (PCB), phenols, etc. The treatment may include an air stripping step to eliminate VOC.

Vacuum Extraction - VOC and semi-volatiles are removed from soil vapor by drilling wells and creating a negative pressure to draw vapor from the soil. As vapor is removed, organic liquids, organics in soil water and adsorbed organics are driven into the vapor phase and also removed. This technology has been successfully used in the United States and Europe to remove up to several tons of VOC per site. Activated carbon filters are employed to treat the removed vapors before they are released to the atmosphere. The process is also referred to as vapor extraction.

UV Oxidation - Also referred to as advanced UV oxidation, this treatment uses UV light, ozone and H_2O_2 to treat waste and groundwater. The oxidative environment destroys chlorinated organics, pesticides, petroleum components, etc. Off-gases may also be treated using carbon adsorption to ensure capture of VOC and destruction of residual ozone. Residual ozone levels released to the atmosphere have been measured at less than 0.1 ppm in the ambient environment. The three treatment components, UV, ozone and H_2O_2 can be used separately for oxidative treatment, but the combination yields higher cleaning efficiencies.

Steam/Air Stripping - In this process, steam and/or air are injected into the ground through hollow bars. The combination of increased temperature and air motion serves to evaporate VOC and carry them from the soil via the hollow bars to the surface. There the VOC are collected in a metal shroud and treated using carbon adsorption or captured via condensation. Pilot-scale testing indicates that this type of collection system may lose up to ten percent of the released VOC to the atmosphere.[1,2] Some systems use direct flaring of collected VOC.

Thermal Stripping - Thermal stripping involves the indirect heating of soil. Contaminated soil is placed in a heated vessel (i.e., oven). The heat dries the soil and drives off VOC. An afterburner destroys VOC released from the dryer. This treatment requires excavating the soil for treatment and includes the potential for release of trapped soil gases and evaporation of soil liquid during the excavation.

Reason for considering the category

Innovative waste treatment technologies continue to be developed and applied to remediate longstanding water and soil contamination problems and accidental spills. Many technologies have been developed for application to Superfund sites. Remediation may proceed over the course of weeks, months or years and involve the cleanup of a few to hundreds of tons of toxic materials (such as solvents) over the remediation period. There are currently about 1,000 Superfund sites and potentially more than 22,000 sites requiring remediation in the United States. Depending on their locations, VOC removed from contaminated soil or water are likely to be treated prior to release to the atmosphere. However, these sites also have the potential for uncontrolled emissions. Onsite remediation activities are not covered in existing NEDS or SIP inventories. Emissions from fossil fuel combustion used to provide heat for the process are already counted in current area source methodologies.

Pollutants emitted

VOC (Species emitted are dependent on the particular site, but may include nonreactive VOC as well as volatile and semi-volatile air toxics.)

Estimate of the pollutant levels

Pollution levels are unknown. Per site estimates range from a few pounds to a few hundred tons (uncontrolled estimate). One source summarized existing data on in situ ventilation (this covers soil cleaning, vacuum extraction and steam/air stripping).[6] This source indicated uncontrolled VOC emission rates of one to 110 kg/site and uncontrolled VOC emissions of 0.01 to 1.1 kg/day.

Point/area source cutoff

There are no current point or area source categories for these waste treatment technologies. Remediation activities would be easily tracked as point sources through the Superfund Record of Decision (ROD) database.[7]

Level of detail of information available

Method used for remediation and quantity remediated are available on a site-by-site basis through Superfund records, either through the Superfund Health and Safety Coordinator or through Regional Superfund offices. Because these are innovative technologies, manufacturers and consultants have test results on removal efficiency, control equipment and control efficiency. Operations are closely monitored for potential releases.

Level of detail required by users

Emissions per site

Species emitted

Remediation period

Remediation type

Emission factor requirements

Emission factor for each innovative technology or emissions estimate from each remediated site need to be developed.

Regional, seasonal or temporal characteristics

None

Urban or rural characteristics

No special characteristics

Methodology

Emissions from innovative waste technologies may be tracked through point source inventories. Although these sources will be temporary, sites are identifiable through the Superfund program. Identification of sites with VOC contamination can be made first through the ROD database (contact Carol Jacobson, (703)308-8369). Regional Superfund or contractor personnel have the data necessary to estimate the types and amounts of air emissions from waste treatment operations. These data may need to be collected through the regional Superfund offices or on a site by site basis. The Superfund Health and Safety Coordinator (Joe Cocalis, (703)308-8356) has documentation on the locations and types of releases. Collection of these data on a regional or national scale will be time consuming.

Some technologies, such as UV oxidation, may also be used at TSDFs or in other wastewater treatment operations. The emissions from innovative technologies can be tracked through existing point and area source categories by defining emission factors and activity levels for these technologies. Because these technologies undergo extensive lab and field testing prior to full-scale remediation, developers and manufacturers of these technologies will have extensive emissions test data. Manufacturers of successful technologies and applications should be able to provide test data at the appropriate time. Alternatively,

published test results may be used to develop emission factors. Given the extensive variation of technologies and the number of manufacturers, successful field applications should precede emission factor development.

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LANDFILL METHANE

Definition/description of category and activity

Landfill gas is produced by the anaerobic decomposition of organic waste. The gas has a typical composition of 50 percent methane, 50 percent carbon dioxide and trace constituents of nonmethane VOC which include air toxics and compounds contributing to tropospheric ozone.[1]

Process breakdown

After an initial aerobic decomposition stage exhausts the available oxygen in a landfill, anaerobic bacteria decompose organic materials. These anaerobic bacteria produce methane as a byproduct. The amount of methane produced varies widely among landfill facilities and is primarily determined by the characteristics of the landfill facility (e.g., degradable organic and moisture content of the landfill) and the local climate (e.g., precipitation and temperature).

Reason for considering the category

Landfills are an important anthropogenic source of methane, a radiatively important trace gas (RITG) which is estimated to represent 20 percent of the radiative forcing associated with global climate change. Landfill methane has been estimated to account for between four and 15 percent of the global methane budget.[1,2] Although current SIP guidance includes a methodology for estimating VOC emissions from landfills, no guidance is listed for estimating methane emissions from landfills.[3]

Pollutants emitted

Methane (CH_4)

Estimate of the pollutant levels

Using the methodology outlined in Reference 1, the U.S. emissions of methane from landfills are approximately 15,000 tons per year.

Point/area source cutoff

Landfills are now considered point sources of emissions (reactive VOC or CH_4).

Level of detail of information available

Available municipal landfill information varies widely among municipalities and states. Depending on the resources and legal reporting requirements within a state, state and local agencies may keep detailed information regarding specific landfill facilities. The background information document for estimating air emissions from landfills in dry areas (less than 23 inches of precipitation annually) estimates annual VOC emissions from landfills as 13.6 tons per million tons of waste in place, and estimates that VOC constitute about 2,650 parts per million by volume (ppmv).[4] Using information from Reference 4 on gas generation

rate, gas content and waste disposal rate, an emission factor of 860 tons CH_4/yr x 10^6 ton waste was calculated.

Areas with more than 23 inches of precipitation annually are advised to use an additional multiplicative factor of 2.6 (yielding an emission factor of 6,672 tons CH_4 per year per million tons of waste).

Level of detail required by users

number of landfills per county

tons of waste per landfill

annual precipitation

Emission factor requirements

Emission factors are available in current EPA guidance,[3] but are based on studies yielding a high uncertainty (the standard deviation is slightly larger than the emissions rate).[4] Predictive models included in the research require facility-specific gas generation data which are not generally available. Improved emissions estimation depend on the development of a more accurate emission factor. Using the emission factor detailed in this report will ensure consistency between estimations of VOC and methane emissions from landfills.

Regional, seasonal or temporal characteristics

Regional emissions rates may vary due to variations in the precipitation rate. Although the generation rate of methane is sensitive to temperature, the exothermic nature of the decomposition process helps to regulate the actual landfill temperature.[1] No significant seasonal or temporal variations are expected.

Urban or rural characteristics

Landfills are principally urban facilities.

Methodology

- Consult with state, county or local waste management officials to determine the number of landfill facilities and the amount of waste in each facility.
- Using the area's annual precipitation rate as the determining factor, select the proper emission factor.
- Multiply the waste (in millions of tons) in place in the landfill by the emission factor to determine the methane generation rate.

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PACKAGE PLANTS (WASTEWATER TREATMENT)

Definition/description of category and activity

Package plants refer to small, automated (usually) domestic waste treatment plants that do not require full-time supervision. In general, these facilities treat less than one million gallons per day (MGD). Operators visit these plants one to several times per week for testing and maintenance. For example, package plants may be used for subdivision or golf course waste treatment. Principal sources of VOC in wastewater are considered to be from industrial discharge to the plants. However, runoff and domestic household wastes do contain VOC that are detectable in domestic wastewater influent.[1,2]

Process breakdown

Emissions may originate from a variety of treatment processes depending on the specific treatment scheme. These processes include treatment impoundments and tanks, junction boxes, lift stations, sumps and weirs. VOC are stripped to the ambient air as a result of the treatment processes and air-to-water interface.

Reason for considering the category

VOC emissions from POTWs are already included in both NAPAP (SCC 100) and SIP methodologies. However, small wastewater treatment plants may not be well represented in the national database (The Needs Survey[3]). The Needs Survey also explicitly excludes military installations, national park systems and private wastewater treatment.[4] The current national (NAPAP) methodology relies on the Needs Survey for overall and industrial flow in order to allocate POTW emissions. Inclusion of small wastewater systems in SIP inventories relies on the state or local source for flow data.[5]

Pollutants emitted

VOC, including some toxic compounds

Estimate of the pollutant levels

Using the default emission factor discussed below (0.00011 pounds VOC per gallon industrial wastewater[5]) and assuming 16 percent industrial waste, a small wastewater treatment plant (one MGD) would emit at most three TPY VOC. These assumptions are likely to be conservative because most small plants are expected to treat less industrial waste and treat less than one MGD. Although there are 11,000 small wastewater treatment plants (one MGD or less or serving less than 10,000 people), not all these small plants are missing from the Needs Survey. Total national estimates for all POTWs are in the range of 25,000 to 80,000 TPY.[2]

If the Office of Water completes and publishes its study of small systems, this document could be useful to better define the potentially missed emissions. Preliminary results cannot be released and no publication date is set.

Recent data from California at a small (0.125 MGD) domestic wastewater treatment plant measured three micrograms VOC per liter wastewater. At a one MGD plant, this translates to only ten pounds per year. The key missing data are a characterization of the amount and types of wastewater loading to these plants.

Research in the Chicago Metropolitan Sanitation District modeled a 1.2 MGD plant's VOC emissions.[6] Results predicted a minimum of 0.00 TPY emitted to the air (based on a model accounting for volatilization, biodegradation and adsorption) to 0.5 TPY maximum based on a mass balance of influent and effluent concentrations.

Point/area source cutoff

POTWs can be considered point or area sources. Point sources are assigned SCC 5-01-007-xx, but most small wastewater treatment operations are expected to fall below 25 TPY VOC (see above discussion on estimate of pollutant levels).

Level of detail of information available

Total wastewater flow and industrial contribution for most plants are available from Needs Survey. Wastewater flow for all plants is available from EPA through the Water Quality Control Information System (STORET).[7]

Process-specific PC-based emissions estimation software available through OAQPS as the Surface Impoundment Modeling System (SIMS).[8]

Level of detail required by users

Emissions by county or emissions by plant

Wastewater flow by county or plant and VOC loading as industrial contribution to total flow

Emission factor requirements

VOC emissions per unit flow of wastewater or industrial wastewater. The current EPA-recommended default values are sixteen percent industrial wastewater of total flow and 0.00011 pounds VOC emitted per gallon industrial wastewater.

Regional, seasonal or temporal characteristics

Probably little variation, although sources such as golf courses may have higher flows in summer months.

Urban or rural characteristics

Urban and suburban areas

Methodology

National Methodology. The current methodology for estimating emissions from package plants relies on the results of the most recent Needs Survey (1988) to identify county-level wastewater flows and industrial contribution. The Needs Survey may not include of all small wastewater treatment systems. However, an analysis is currently underway by the EPA Office of Water to characterize reporting compliance by small

(less than one MGD) treatment systems.[8] STORET may be a more complete database for identifying wastewater discharges through the National Pollutant Discharge Elimination System (NPDES), but does not track industrial flow and can be costly to access.[7] The sources currently missing from the inventories could be computed by cross-indexing Needs Survey sources and STORET data to identify and locate the unaccounted sources and retrieve flow data. Point sources should be checked for any wastewater treatment systems reported there.

SIP Inventories. Because SIPs are prepared by state and local agencies, Needs Survey data may or may not be used, depending on data availability for a given area. The same strategy of using STORET data on NPDES permits to check for any missing sources is applicable. Where facility-specific data are available, emissions may be estimated at the process level using SIMS. This strategy effectively shifts the sources with sufficient facility-specific information to the point source inventory.

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RECYCLING PROCESSES

Definition/description of category and activity

Recycling is an "umbrella term that encompasses any use, reuse, or reclamation in any manner."[1] Materials most frequently recycled include paper, plastics, glass, solvents and metals. Each material has a different process associated with its recycling, which leads to a broad variety of potential emissions. With few exceptions, recycling processes are energy intensive and the emissions associated with power generation should be considered as an integral part of the activity. However, emission factors provided in *AP-42* and detailed below neglect this important source of air pollution. Waste oil disposal and waste combustion are addressed in separate characterizations.

Process breakdown

Paper: The paper recycling process may be broken down into four key components including power generation, deinking, bleaching and repulping. Each of these processes may release air emissions. In addition to the emissions associated with the generation of energy to power the paper recycling process, breakdown products of the chemicals used in deinking and bleaching may contribute emissions. Chemicals typically used in these two processes include sodium hydrosulfide, hypochlorous acid, chlorine and hydrogen peroxide. The fourth process of concern in paper recycling is repulping.[3]

Plastic: Plastic recycling may be subdivided by the type of resin processed. Low density polyethylene (LDPE) and high density polyethylene (HPDE) recycling account respectively for 32 percent and 31 percent of plastic recycling activity. Eleven percent of the plastic recycled is polystyrene, while ten percent is polypropylene. An additional seven percent of recycled plastic is polyethylene terephthalate (PET), while the remaining five percent is polyvinyl chloride (PVC).[4]

Glass: All glass undergoes basically the same recycling process, involving glass grinding and melting.

Solvents: Waste solvents are organic dissolving agents that are contaminated with suspended and dissolved solids, organics, water, other solvents and/or any substance not added to the solvent during its manufacture. Reclamation is the process of restoring a waste solvent to a condition that permits its reuse, either for its original purpose or for other industrial needs. Sources of waste solvents include solvent refining, polymerization processes, vegetable oil extraction, metallurgical operations, pharmaceutical manufacture, surface coating and cleaning operations (dry cleaning and solvent degreasing).

Pollutants may be released during solvent storage and handling, initial treatment, distillation, purification or waste disposal. Before and after reclamation, solvents are stored in containers ranging in size from 55 gallon drums to 20,000 gallon tanks. Most include venting systems designed to prevent solvent vapors from creating excessive pressure or vacuum inside fixed tank roofs. Uncontrolled venting systems are a likely source of VOC emissions. Another potential source of fugitive emissions exists in handling procedures. These primarily include loading waste solvent into process equipment and filling drums and tanks prior to transport and storage.[2]

Waste solvents are initially treated by vapor recovery or mechanical separation. Vapor recovery entails removal of solvent vapors from a gas stream in preparation for further reclamation. In mechanical separation, undissolved solid contaminants are removed from liquid solvents. Vapor recovery or collection methods employed include condensation, adsorption and absorption. Condensation of solvent vapors is accomplished by water-cooled condensers and refrigeration units. Activated carbon adsorption is the most common method of capturing solvent emissions. Absorption of solvent vapors is accomplished by passing the waste gas stream through a liquid in scrubbing towers or spray chambers. Initial treatment of liquid

waste solvents is accomplished by mechanical separation methods. This includes both removing water by decanting and removing undissolved solids by filtering, draining, settling and/or centrifuging.[2]

After initial treatment, waste solvents are distilled to remove dissolved impurities and separate solvent mixtures. Separation of dissolved impurities is accomplished by simple batch, simple continuous or steam distillation. Mixed solvents are separated by multiple simple distillation methods, such as batch or continuous rectification. In simple distillation, waste solvent is charged to an evaporator. Vapors are then continuously removed and condensed, and the resulting sludge or still bottoms are drawn off. In steam distillation, solvents are vaporized by direct contact with steam which is injected into the evaporator.[2]

After distillation, water is removed from solvent by decanting or salting. Decanting is accomplished with immiscible solvent and water which, when condensed, form separate liquid layers, one or the other of which can be drawn off mechanically. During purification, reclaimed solvents are stabilized, if necessary. Buffers are added to virgin solvents to ensure that pH level is kept constant during use.[2]

Metals: *AP-42* describes the process breakdowns for recycling aluminum, copper, lead, magnesium and zinc. While the specific processes differ for each metal, as shown in the different schematics, each recycling process can be characterized by pretreatment, smelting and refining or casting. These general process stages are described as a whole below, although emissions associated with each type of metal recycling are treated independently in later sections.

Scrap pretreatment involves receiving, sorting, cleaning and concentration to prepare materials for smelting. Mechanical, pyrometallurgical and hydrometallurgical techniques are used for this purpose. Smelting is the production of purified metals by melting and separating the compound from metallic and nonmetallic contaminants and by reducing oxides to their elemental level. Refining and casting is the use of kettle type furnaces in remelting, alloying, refining and oxidizing processes.[2]

Reason for considering the category

Although each recycling process by itself may not amount to significant contributions to air pollution emissions, considered as a whole the source may be substantial. In addition, as treatment costs increase in the future, industries are likely to emphasize the potential for recycling; a true accounting of all of financial, social and environmental costs and benefits should be available to industries as they consider their various options for waste management.[5,6]

Pollutants emitted

VOC, CO, NO_x, SO_x, PM_{10}, Pb. Table 1 provides a more detailed analysis of pollutant emissions.

Estimate of the pollutant levels

Very few studies have been conducted which estimate emissions releases from recycling processes. However, emission factors have been developed and are detailed in Tables 2 through 9.

Point/area source cutoff

It is unlikely that individual recycling plants release greater than 100 tons per year of any of the criteria pollutants. However, some processes may emit ten TPY or greater. Recycling processes may be few enough in number and easy enough to track that it will be feasible to treat them as point sources.

TABLE 1. POLLUTANTS EMITTED FROM RECYCLING PROCESSES[2,6,7]

	Pb	Particulate (PM-10)	SO_x	NO_x	CO	VOC (03)
Paper		X	(X)	(X)	(X)	
Plastic		X	(X)	(X)	(X)	X
Glass		X	(X)	(X)	(X)	
Solvents		E	(X)	(X)	(X)	E
Metals						
aluminum		E	(X)	(X)	(X)	
magnesium		E	(X)	(X)	(X)	
lead	E	E	(X)	(X)	(X)	
copper	E	E	(X),E	(X)	(X)	
zinc		E	(X)	(X)	(X)	

Note:
X = pollutant associated with process; no emission factor available
(X) = pollutant associated with energy generation integral to process
E = pollutant associated with process; emission factor available

TABLE 2. PARTICULATE EMISSION FACTORS FOR SECONDARY ALUMINUM OPERATIONS[a] (*AP-42* TABLE 7.8-1)

Operation	Uncontrolled		Baghouse		Electrostatic precipitator		Emission factor rating
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	
Sweating furnace[b]	7.25	14.5	1.65	3.3	---	---	C
Smelting							
Crucible furnace[b]	0.95	1.9	---	---	---	---	C
Reverberatory furnace[c]	2.15	4.3	0.65[e]	1.3[e]	0.65	1.3	B
Chlorine demagging[d]	500	1000	25	50	---	---	B

[a]Reference 2. Emission factors for sweating and smelting furnaces expressed as units per unit weight of metal processed. For chlorine demagging, emission factor is kg/Mg (lb/ton) of chlorine used.
[b]Based on averages of two source tests.
[c]Uncontrolled, based on averages of ten source tests. Standard deviation of uncontrolled emission factor is 1.75 kg/Mg (3.5 lb/ton), that of controlled factor is 0.15 kg/Mg (0.3 lb/ton).
[d]Based on average of ten source tests. Standard deviation of uncontrolled emission factor is 215 kg/Mg (430 lb/ton); of controlled factor, 18 kg/Mg (36 lb/ton).
[e]This factor may be lower if a coated baghouse is used.

TABLE 3. EMISSION FACTORS FOR MAGNESIUM SMELTING (*AP-42* TABLE 7.12-1)

Type of furnace	Particulates[a] lb/ton	kg/MT
Pot furnace		
Uncontrolled	4	2
Controlled	0.4	0.2

[a]References 2 and 3. Emission factors expressed as units per unit weight of metal processed.

TABLE 4. EMISSION FACTORS FOR SOLVENT RECLAIMING[a] (*AP-42* TABLE 4.7-1)

Source	Criteria pollutant	Emission factor average	
		lb/ton	kg/MT
Storage tank vent[b]	Volatile organics	0.02 (0.004-0.09)	0.01 (0.002-0.04)
Condenser vent	Volatile organics	3.30 (0.52-8.34)	1.65 (0.26-4.17)
Incinerator stack[c]	Volatile organics	0.02	0.01
Incinerator stack	Particulates	1.44 (1.1-2.0)	0.72 (0.55-1.0)
Fugitive emissions			
Spillage[c]	Volatile organics	0.20	0.10
Loading	Volatile organics	0.72 (0.00024-1.42)	0.36 (0.00012-0.71)
Leaks	Volatile organics	NA	NA
Open sources	Volatile organics	NA	NA

[a]Data obtained from state air pollution control agencies and presurvey sampling. All emission factors are for uncontrolled process equipment, except those for the incinerator stack. Average factors are derived from the range of data points available. Factors for these sources are given in terms of pounds per ton and kilograms per metric ton of reclaimed solvent. Ranges in parentheses. NA = not available.
[b]Storage tank is of fixed roof design.
[c]Only one value available.

TABLE 5. FUGITIVE EMISSION FACTORS FOR SECONDARY LEAD PROCESSING[a]
(*AP-42* TABLE 7.11-2)

Operation	Particulate		Lead	
	kg/Mg	lb/ton	kg/Mg	lb/ton
Sweating	0.8 - 1.8	1.6 - 3.5[b]	0.2 - 0.9	0.4 - 1.8[c]
Smelting	4.3 - 12.1	8.7 - 24.2	0.88 - 3.5	1.75 - 7.0
Kettle refining	0.001	0.002	0.0003	0.0006
Casting	0.001	0.002	0.0004	0.0007

[a]Based on amount of lead product, except for sweating, which is based on quantity of material charged to furnace. Fugitive emissions estimated to be 5% of uncontrolled stack emissions.
[b]Sweating furnace emissions estimated from nonlead secondary nonferrous processing industries.
[c]Assumes 23% lead content of uncontrolled blast furnace flue emissions.

TABLE 6. EMISSION FACTORS FOR SECONDARY LEAD PROCESSING[a] (*AP-42* TABLE 7.11-1)

Pollutant	Sweating[b]	Leaching	Smelting		Kettle refining	Kettle oxidation	Casting
			Reverberatory	Blast (cupola)[c]			
Particulate[d]							
Uncontrolled (kg/Mg)	16-35	Neg[e]	162 (87-242)	153 (92-207)	0.02[f]	≤20[g]	0.02[f]
(lb/ton)	32-70	Neg[e]	323 (173-483)[a]	307 (184-413)	0.03[f]	≤40[g]	0.04[f]
Controlled (kg/Mg)	-	Neg	0.50 (0.26-0.77)	1.12 (0.11-2.44)	Neg	-	Neg
(lb/ton)	-	Neg	1.01 (0.53-1.55)	2.24 (0.22-4.88)	Neg	-	Neg
Lead[d]							
Uncontrolled (kg/Mg)	4-8[h]	Neg	32 (17-48)[i]	52 (31-70)[k]	0.006[f]	-	0.007[f]
(lb/ton)	7-16[h]	Neg	65 (35-97)[i]	104 (64-140)[k]	0.01[f]	-	0.01[f]
Controlled (kg/Mg)	-	Neg	-	0.15 (0.02-0.32)[m]	Neg	-	Neg
(lb/ton)	-	Neg	-	0.29 (0.03-0.64)[m]	Neg	-	Neg
Sulfur dioxide[m]							
Uncontrolled (kg/Mg)	-	Neg	40 (36-44)	27 (9-55)	-	-	-
(lb/ton)	-	Neg	80 (71-88)	53 (18-110)	-	-	-
Emission Factor Rating	E		C	C	C	E	C

[a]Neg = negligible. Dash = not available. Ranges in parentheses.
[b]Estimated from sweating furnace emissions from nonlead secondary nonferrous processing industries. Based on quantity of material charged to furnace.
[c]Blast furnace emissions are combined flue gases and associated ventilation hood streams (charging and tapping).
[d]Particulate and lead factors based on quantity of lead product produced, except as noted.
[e]Determined negligible, based on average baghouse control efficiency >99%.
[f]Lead content of kettle refining emissions is 40%.
[g]Essentially all product lead oxide is entrained in an air stream and subsequently recovered by baghouse with average collection efficiency >99%. Factor represents emissions of lead oxide that escape a baghouse used to collect the lead oxide product. Based on the amount of lead produced and represents approximate upper limit for emissions.
[h]Based on assumption that uncontrolled reverberatory furnace flue emissions are 23% lead.
[i]Uncontrolled reverberatory furnace flue emissions assumed to be 23% lead. Blast furnace emissions have lead content of 34%, based on single uncontrolled plant test.
[k]Blast furnace emissions have lead content of 26%, based on single controlled plant test.
[m]Based on quantity of material charged to furnaces.

TABLE 7. PARTICULATE EMISSION FACTORS FOR FURNACES USED IN SECONDARY COPPER SMELTING AND ALLOYING PROCESSES[a,b] (AP-42 TABLE 7.9-1)

Furnace and charge type	Control equipment	Particulate kg/Mg average	Particulate kg/Mg range	Particulate lb/ton average	Particulate lb/ton range	Lead kg/Mg	Lead lb/ton
Cupola							
Scrap iron	None	0.002	-	0.003	-	-	-
Insulated copper wire	None	120	-	230	-	-	-
	ESP[c]	5	-	10	-	-	-
Scrap copper and brass	None	35	30-40	70	60-80	-	-
	ESP	1.2	1-1.4	2.4	2-2.8	-	-
Reverberatory							
High lead alloy (58% Lead	None	-	-	-	-	25	50
Red/yellow brass (15% Lead	None	-	-	-	-	6.6	13.2
Other alloys (7% lead)	None	-	-	-	-	2.5	5.0
Copper	None	2.6	0.4-15	5.1	0.8-30	-	-
	Baghouse	0.2	0.1-0.3	0.4	0.3-0.6	-	-
Brass and bronze	None	18	0.3-35	36	0.6-70	-	-
	Baghouse	1.3	0.3-2.5	2.6	0.6-5	-	-
Rotary							
Brass and bronze	None	150	50-250	300	100-500	-	-
	ESP	7	3-10	13	6-19	-	-
Crucible and pot							
Brass and bronze	None	11	1-20	21	2-40	-	-
	ESP	0.5	3-10	1	6-19	-	-
Electric Arc							
Copper	None	2.5	1-4	5	2-8	-	-
	Baghouse	0.5	0.02-1	1	0.04-2	-	-
Brass and bronze	None	5.5	2-9	11	4-18	-	-
	Baghouse	3	-	6	-	-	-
Electric induction							
Copper	None	3.5	-	7	-	-	-
	Baghouse	0.25	-	0.5	-	-	-
Brass and bronze	None	10	0.3-20	20	0.5-40	-	-
	Baghouse	0.35	0.01-0.65	0.7	0.01-1.3	-	-

[a]Factors for high lead alloy (58 percent lead), red and yellow brass (15 percent lead), and other alloys (7 percent lead) produced in the reverberatory furnace are based on unit weight produced. All other factors given in terms of raw materials charged to unit. Dash indicates no available information.

[b]The information for particulate in Table 7.9-1 was based on unpublished data furnished by the following:
Philadelphia Air Management Services, Philadelphia, PA.
New Jersey Department of Environmental Protection, Trenton, NJ.
New Jersey Department of Environmental Protection, Metro Field Office, Springfield, NJ.
New Jersey Department of Environmental Protection, Newark Field Office, Newark, NJ.
New York State Department of Environmental Conservation, New York, NY.
The City of New York Department of Air Resources, New York, NY.
Cook County Department of Environmental Control, Maywood, IL.
Wayne County Department of Health, Air Pollution Control Division, Detroit, MI.
City of Cleveland Department of Public Health and Welfare, Division of Air Pollution Control, Cleveland OH.
State of Ohio Environmental Protection Agency, Columbus, OH.
City of Chicago Department of Environmental Control, Chicago, IL.
South Coast Air Quality Management District, Los Angeles, CA.

[c]ESP equals electrostatic precipitator.

TABLE 8. UNCONTROLLED PARTICULATE EMISSION FACTORS FOR SECONDARY ZINC SMELTING[a] (*AP-42* TABLE 7.14-1)

Operation	Emissions kg/Mg	Emissions lb/ton
Reverberatory sweating		
clean metallic scrap	Negligible	Negligible
general metallic scrap	6.5	13
residual scrap	16	32
Rotary sweating	5.5-12.5	11-25
Muffle sweating	5.4-16	10.8-32
Kettle sweating		
clean metallic scrap	Negligible	Negligible
general metallic scrap	5.5	11
residual scrap	12.5	25
Electric resistance sweating	<5	<10
Crushing/screening	0.5-3.8	1.0-7.5
Sodium carbonate leaching		
crushing/screening	0.5-3.8	1.0-7.5
calcining	44.5	89
Kettle (pot) melting	0.05	0.1
Crucible melting	DNA	DNA
Reverberatory melting	DNA	DNA
Electric induction melting	DNA	DNA
Alloying	DNA	DNA
Retort and muffle distillation		
pouring	0.2-0.4	0.4-0.8
casting	0.1-0.2	0.2-0.4
muffle distillation	22.5	45
Graphite rod distillation	Negligible	Negligible
Retort distillation/oxidation [b]	10-20	20-40
Muffle distillation/oxidation [b]	10-20	20-40
Retort reduction	23.5	47
Galvanizing	2.5	5

[a]Expressed as units per unit weight of feed material processed for crushing/screening, skimming/residues processed; for kettle (pot) melting and retort and muffle distillation operations, metal product. Galvanizing factor expressed in units per unit weight of zinc used. DNA: Data not available.

[b]Factor units per unit weight of ZnO produced. The product zinc oxide dust is totally carried over in the exhaust gas from the furnace and is recovered with 98-99% efficiency.

TABLE 9. FUGITIVE PARTICULATE UNCONTROLLED EMISSION FACTORS FOR SECONDARY ZINC SMELTING[a] (*AP-42* TABLE 7.14-2)

Operation	Particulate	
	kg/Mg	lb/ton
Reverberatory sweating[b]	0.63	1.30
Rotary sweating[b]	0.45	0.90
Muffle sweating[b]	0.54	1.07
Kettle (pot) sweating[b]	0.28	0.56
Electric resistance sweating[b]	0.25	0.50
Crushing/screening[c]	2.13	4.25
Sodium carbonate leaching	DNA	DNA
Kettle (pot) melting furnace[b]	0.0025	0.005
Crucible melting furnace[d]	0.0025	0.005
Reverberatory melting furnace[b]	0.0025	0.005
Electric induction melting[b]	0.0025	0.005
Alloying retort distillation	DNA	DNA
Retort and muffle distillation	1.18	2.36
Casting[b]	0.0075	0.015
Graphite rod distillation	DNA	DNA
Retort distillation/oxidation	DNA	DNA
Muffle distillation/oxidation	DNA	DNA
Retort reduction	DNA	DNA

[a]Expressed as units per end product, except factors for crushing/screening and electric resistance furnaces, which are expressed as units per unit of scrap processed. DNA: Data not available.
[b]Estimate based on stack emission factor given in Reference 1, assuming fugitive emissions to be equal to 5% of stack emissions.
[c]Average of reported emission factors
[d]Engineering judgment, assuming fugitive emissions from crucible melting furnace to be equal to fugitive emissions from kettle (pot) melting furnace.

Level of detail of information available

Recycling Resources, Inc. has compiled the *Directory of U.S. and Canadian Scrap Plastic Processors and Buyers*.[8] Comparable directories do not appear to be available from any of the trade associations for glass, paper, metal, solid waste or used oil recyclers. Alternatively, individual states have likely inventoried such facilities as part of their recycling oversight activities.

Emission limits specified on state air permits are probably the most complete and accurate source for facility-specific data. As an alternative to this time-intensive effort, data from representative plants in each category may be used to develop emission factors, in cases where they do not yet exist.

An additional source for data and estimates is a forthcoming report by Levin *et al.* of Alliance Technologies Corporation which is expected to thoroughly quantify air emissions from recycling operations.

Level of detail required by users

Although the various processes used in recycling vary considerably with the material processed, each of the technologies utilize emission factors in the format of pounds of pollutant emissions released per ton of material recycled. In each case, the number of processing facilities per county must be determined. The amount of material processed should also be estimated for each facility. In addition, operation/unit-type activity levels by material type should be defined and developed.

Emission factor requirements

VOC, PM_{10}, NO_x, SO_x, Pb, CO emissions per ton of material recycled, broken down for paper, plastic, glass, solvents and metals.

Regional, seasonal or temporal characteristics

Recycling activities occur in more industrialized regions of the country. They operate year-round or on an as-needed basis. Depending on demand for recycled goods and supply of scrap, they may be operated either twenty-four hours per day or only during day-time hours.

Urban or rural characteristics

Most industrial recycling activities are conducted in or near industrial regions.

Methodology

- Determine the number of recycling facilities by county from *County Business Patterns*[9] or from survey of states or trade organizations.
- Estimate tons of material recycled per year at each facility type.
- Apply emission factors for solvent reclamation and secondary metals processes.
- Develop emission factors for paper, plastic and glass recycling.

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8. *1990-91 Directory of U.S. and Canadian Scrap Plastic Processors and Buyers*, Recycling Resources, Inc., Portland, OR, 1990.

9. *County Business Patterns*, U.S. Department of Commerce, Bureau of the Census, Washington, DC. Annual publication.

REFINERY SLUDGE DEWATERING

Definition/description of category and activity

Petroleum refineries generate sludge from API separators, DAF units and biological waste from wastewater treatment. These sludges contain organic components from the petroleum products. In some cases, the sludge is applied directly to landfarms for treatment, but often the sludge is dewatered by centrifuge, vacuum filtration, plate and frame filtration and belt press filtration. Of these methods, the most common is belt filtration because of its high-throughput capacity and comparatively low cost. Sludges may be heated during dewatering to improve efficiency and handling.[1]

Figure 1 displays the belt press dewatering process at a refinery. The dewatering process is usually open to the atmosphere. The resulting filter cake may be landfarmed, landfilled or transported offsite for disposal. Filtrate is directed to wastewater treatment operations.[1]

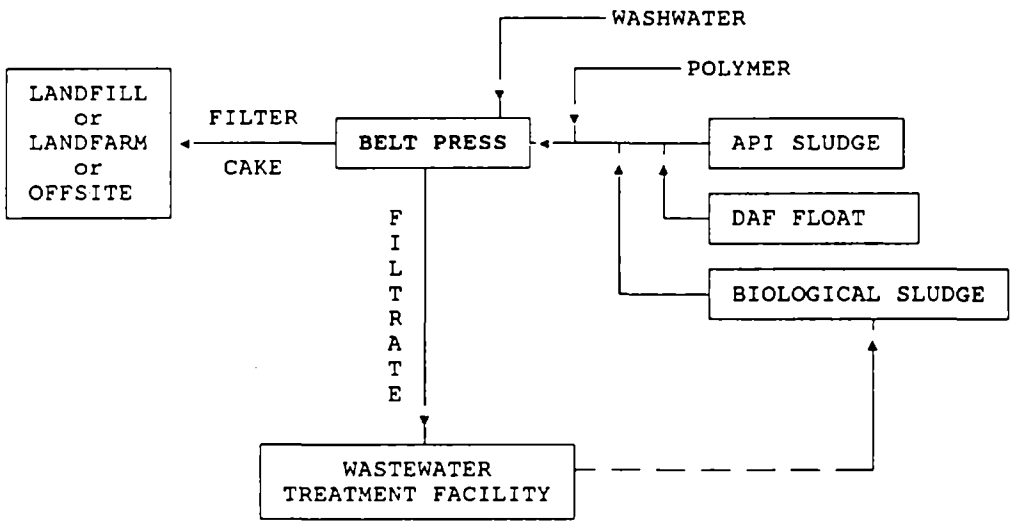

Figure 1. Refinery sludge dewatering process.

Process breakdown

VOC emissions occur at the dewatering operation. Although the equipment is enclosed, the process is vented to the atmosphere with or without controls. Currently, the API separators and wastewater treatment systems at refineries are included as point sources under SCCs 3-06-005-03/4 and 3-06-005-05/6, respectively. Separators with emissions too small to be accounted in point source inventories are treated in the NAPAP area source inventory with other refinery fugitive VOC. Treatment, storage and/or disposal of the wastewaters and filter cake are contained in the NAPAP TSDF area source category.

Reason for considering the category

Other components of refinery and refinery waste emissions are contained in existing categories. Previously, dewatering was not considered to be a source of VOC, but recent test data indicate the dewatering process may be a significant source.[1]

Pollutants emitted

VOC, including xylenes, trimethyl benzene, trimethyl hexane, ethylbenzene, methylcyclohexane, n-heptane, n-hexane, toluene, benzene, ethyltoluene and other petroleum hydrocarbons

Estimate of the pollutant levels

Limited test data are currently available. These results are reported in pounds of emitted species per hour during the test (e.g., pounds xylenes emitted per hour) or pounds of emitted species per pound of influent species (e.g., pounds xylenes emitted per pound xylenes in influent stream). Estimation of total VOC emissions involved summation of the reported species emissions per hour and assumption of a 24 hour per day schedule. Data on refinery throughput per day were then compiled to develop VOC emitted per 1,000 barrels throughput for each of the three tested refineries.[2] The calculated VOC emissions per 1,000 barrels was then applied to 1989 U.S. refinery throughput to estimate total VOC emissions. The generated emission factors range from 0.7 to 6.2 pounds VOC per 1,000 barrels throughput for the three refineries. Based on total 1989 U.S. refinery throughput of 4,891,381 thousand barrels, estimated uncontrolled emissions are 1,500 to 15,000 tons per year. (Some sludges are not dewatered prior to further treatment or disposal; the estimates given do not account for this practice.)

Point/area source cutoff

There are no current point source categories for dewatering. However, the preliminary data presented indicate that belt presses may contribute ten to 100 TPY VOC at a refinery. These levels meet the standards for inclusion in point source inventories for at least some dewatering operations. Emissions below ten TPY should be included in the area source inventory.

Level of detail of information available

Because refinery data are already available from point source inventories, data on refinery throughput are available. The emission test data discussed under **Estimate of Pollutant Levels** defines amounts of the predominant hydrocarbon species emitted. The *Petroleum Supply Annual* publishes yearly refinery throughputs by refinery location.[2]

Level of detail required by users

Identification of sludge treatment process by refinery

Refinery throughput or sludge throughput

Amount of sludge directly landfarmed or landfilled

Emission factor requirements

Emission factor(s) in pounds VOC per throughput (refinery or sludge) for each dewatering process type (i.e, belt, centrifuge, vacuum or plate and frame) need to be developed.

Regional, seasonal or temporal characteristics

None

Urban or rural characteristics

None

Methodology

Dewatering operation emissions are apparently large enough for inclusion in point source inventories. Individual refineries should be asked to identify sludge dewatering processes and define sludge and refinery throughputs, as well as existing control equipment. Dewatering operations that fall below the point source emissions criteria could be treated in the same way that API separators are now treated in area source inventories. Refinery throughput or sludge generation unaccounted for in inventoried point sources could be subtracted from county-level overall refinery throughput. The unaccounted portion could then be applied to the appropriate emission factor to develop county level area source estimates.

There remains a potential for double counting of emissions if the existing TSDF methodologies are altered to include this source. At present, dewatering is apparently unaccounted for in existing SIP and NEDS inventories. Sludge dewatering will not be covered in the draft Control Technologies Guidance for petroleum wastewater facilities due in 1991. Other industries may also have emissions from sludge dewatering if organics are used in the processes that generate the sludge. No information on other industries has been located to indicate the potential for emissions, although it is likely that the petroleum industry has a higher emission potential due to the significant organic content and large throughput of refinery sludges.

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WASTE INCINERATION: DEVELOPING TECHNOLOGIES FOR HAZARDOUS WASTE

Definition/description of category and activity

The passage of federal and state waste clean-up and control statutes over the last ten years has spurred development of waste disposal technologies to replace landfilling, disposal impoundments, deep-well injection, etc. Techniques such as waste minimization, reuse, biological treatment, stabilization and advanced incineration offer alternatives. Incineration, the thermal decomposition of organics via thermal oxidation, provides the highest overall degree of destruction for the broadest range of wastestreams. Incineration and other thermal destruction technologies are expected to show significant growth in the future.[1,2] Some of these technologies are listed in Table 1.

Many different incineration technologies are currently in use or under development. Established incineration technologies include liquid injection, rotary kiln, hearth, fume, fluidized bed reactors and others. A 1986 survey located 208 incinerators, predominantly liquid injection (95) and rotary kiln (42).[1] The other types represented were hearth (32), fume (25) and fluidized bed and others (14). Many other designs under development are expected to compete in the near future. A number of these technologies are mobile or transportable systems that can be delivered to the waste site. EPA has operated a mobile incinerator at the Denny Farm site in McDowell, Missouri since 1985 and has combusted 12.5 million tons of solids and 237 thousand tons of liquids in this period.[3] Several private companies are now developing mobile incineration equipment.

TABLE 1. DEVELOPING TECHNOLOGIES FOR HAZARDOUS WASTE INCINERATION[1,2,4,5,6,7,8]

Anaerobic Pyrolysis	Molten Salt
Circulating Fluidized Bed	Multisolid Fluidized Bed
Cycling Cyclone Incinerator	Plasma Arc
Electric Pyrolysis	Plasma Dust Process
Fluidized Bed Calciner	Plasma Incinerator
Fluid Wall Reactor	Pyrolyzing Rotary Reactor
High-temperature Slagging Incinerator	Revolving Fluidized Bed
Indirectly-fired Rotary Kiln	Thermal Desorption
Infrared Reactor	Thermolytic Detoxification
Low-temperature Fluidized Bed Reactor	
Microwave Plasma Generator	

There are currently about 40 commercial hazardous waste incineration facilities in addition to transportable and mobile systems in the United States. Transportable systems tend to be larger, requiring up to 60 trailers to complete transport, but are capable of handling five to twenty tons of waste per hour. Mobile systems may be delivered onsite in just a few trailers, but tend to have smaller capacities.[1,2] These systems may be onsite for periods of months or years.

Process breakdown

Figure 1 displays the typical subsystems associated with incineration systems. Emissions may be generated during with waste preparation (fugitives) and combustion (stack). Most existing incinerators have some type of air pollution control device, including quench, scrubbers, absorbers and ESP.

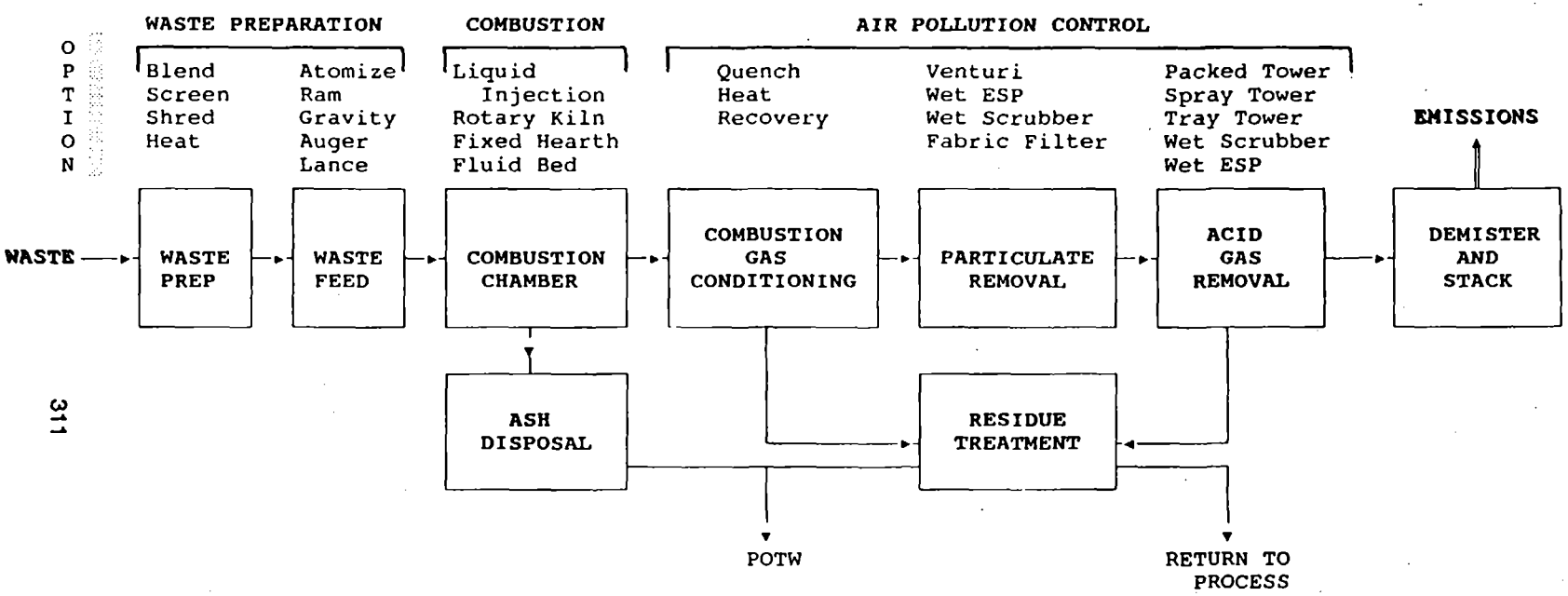

Figure 1. Typical incinerator subsystems and component options.

Reason for considering the category

Innovative waste destruction technologies such as incineration continue to be developed and applied to meet hazardous waste disposal needs. Many mobile and transportable technologies have been developed for application to Superfund sites or wastes. Other incinerators, specifically municipal solid waste incinerators and commercial/industrial solid waste incinerators, are covered in point source inventories. Mobile and transportable onsite systems are not in current SIP or NEDS inventories and these technologies are not covered currently in emissions estimation methodologies. Changes in and expansion of hazardous waste incineration technologies may need to be reflected in future emissions inventories.

Pollutants emitted

Pollutants emitted are waste- and fuel-dependent and may include SO_2, NO_x, VOC, CO, PM, air toxics, metals, acid gases and others.

Estimate of the pollutant levels

Emissions from current hazardous waste incineration practices and projection of future emissions trends are difficult to define. Current RCRA standards call for 99.99 percent destruction and removal efficiency (DRE) for principal organic waste constituents. The most recent survey indicates 300 million tons of hazardous waste are generated annually, although only a small fraction (perhaps three million tons) is incinerated.[2] Precise wastestream information is not available due to the intermittent basis on which wastes are handled and the generic nature of some EPA standard waste codes. Substances include solvents, paints, motor oils, agricultural chemicals, contaminated soils, etc.

Typical uncontrolled emissions for PM and VOC range from 0.3 to 15 g/hour (PM) and 0.065 to 325 mg/hour (VOC).[9]

Point/area source cutoff

Mobile and transportable units are expected to emit less than ten TPY and should be included in the area source inventory. Commercial (fixed) facilities, if properly operated, will also emit less than ten TPY and should be considered as area sources.

Level of detail of information available

Emissions test results for each incinerator or incinerator type

Estimates of amounts and types of hazardous waste treated by incineration

Level of detail required by users

Incinerator population by type and location (county)

Emissions per incinerator type and wastestream type

Wastestream volumes and content

Emission factor requirements

Emissions per amount of waste burned by waste type

Regional, seasonal or temporal characteristics

None

Urban or rural characteristics

No special urban or rural characteristics

Methodology

Emissions from hazardous waste incinerators may be tracked through point source inventories. Commercial operations can be identified through state permits. Although many of the sites are temporary, they may be identified through either the Superfund program or state permitting agencies. Emissions can then be estimated by defining emission factors and activity levels for the different technologies employed. However, based on available trial burn data, the emissions generated from properly run incinerators are expected to be very small to meet RCRA, Toxic Substances Control Act (TSCA), Comprehensive Environmental Response, Compensation and Liability Act of 1980 (Superfund) (CERCLA) and/or state permit regulations. Emissions of some toxic species may still be of interest for modeling applications and risk analysis.

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WASTE OIL DISPOSAL

Definition/description of category and activity

Estimates of waste oil generation range from 4.3 billion liters (1.1 billion gallons) annually to 9.8 billion liters in 1980.[1] Waste oil categories include industrial process oils (e.g., hydraulic oils, lubricants, etc.) and motor vehicle crankcase oils. Historically, most studies have focused on disposal of crankcase oils. Federal regulations for hazardous waste disposal (used oil is considered a hazardous waste under RCRA) have become increasingly strict and encourage the recycling of used oil. It is often more economical for industries to handle oil recycling or combustion internally rather than dispose of it. Waste oil may be stored or disposed of in a variety of ways. Figure 1 illustrates the breakdown of use, disposal and unknown fate of the estimated 4.3 billion liters of waste oil generated each year in the United States.[2]

Process breakdown

Air pollutants from waste oil disposal may enter the atmosphere as a result of evaporation of oil used as a dust suppressant or combustion of waste oil in boilers, kilns, diesel engines and waste oil heaters. Because of the dangers associated with the ultimate fate of waste oil used as a dust suppressant (e.g., runoff into streams and lakes and possible seepage into ground water), this use of waste oil is not encouraged. However, it is practiced by waste oil collectors, local government agencies and private industries nationwide. An estimated 92 percent of the waste oil is used for combustion.[2] In addition, waste oil may be stored for periods of time in underground storage tanks, above-ground storage tanks (AGSTs) and oil drums. These containers may leak due to problems with ancillary equipment (e.g., pipes, pumps, valves, etc.), tank failure, vandalism, fire, explosions, natural disasters and operational error (overflow). Waste oil may be contaminated with PCBs and other toxics; additives such as sodium nitrite, ethanolamines, phenol, halogenated and aromatic solvents; metalworking substances; and heavy metals, such as lead and cadmium, which may be released when the oil is burned. These substances may be of concern for air toxics depending on the concentrations at which they are released from waste oil combustion.

The ultimate fate of waste oil exposed to air is a function of the type and composition of the oil, the type of exposure and climatic conditions. The environmental impacts of pollutants emitted when waste oil is combusted depend on the composition of the waste oil, the number of sources burning waste oil, the stack heights, meteorological conditions, the type of combustion and the extent of use of emissions control equipment.

Reason for considering the category

Although some waste oil combustion in industrial boilers may be included in current point source inventories, coverage is not likely to be complete. Other methods of waste oil disposal are not accounted for in current area source methodologies.

GENERATION

LITERS	GALLONS	PERCENT OF TOTAL
4350	1150	100

USE AND DISPOSAL

	LITERS	GALLONS	PERCENT OF TOTAL
TOTAL	3200	850	74
BURNING	1900-2500	500-660	43-57
ROAD OILING	190-380	50-100	4-9
LAND DISPOSAL/ DUMPING	950-1100	250-300	22-26
LUBE OIL	340-380	90-100	8-9
OTHER	190-380	50-100	4-9

NOT RECEIVED

LITERS	GALLONS	PERCENT OF TOTAL
1100	300	26

ALL VALUES IN MILLIONS OF LITERS AND MILLIONS OF GALLONS

Figure 1. Quantities of waste oil generated annually and their uses and disposal.[2]

Pollutants emitted

Air pollutants emitted due to the evaporation of waste oil will consist largely of VOC species. Combustion of waste oil will produce SO_2, NO_x, CO, CO_2, VOC, PM and some toxic materials and heavy metals. It is estimated that about 50 percent of the metals present in the waste oil will be released to the atmosphere during combustion.[2]

Estimate of pollutant levels

Assuming that 1.1 billion gallons of waste oil are generated yearly and that 50 percent of this waste oil is used as fuel, TSP emissions are calculated (using the *AP-42* emission factor for TSP) as follows:

$$(1.1 \times 10^9 \text{ gallons})(.50)(61 \text{ lbs TSP}/10^3 \text{ gals oil})(0.005 \text{ ash}) = 167{,}750 \text{ lbs}$$

or 84 TPY TSP
(from combustion only)

In addition, *AP-42* provides an emission factor for lead from waste oil combustion of 42 pounds multiplied by the weight percent of lead in the waste oil per 1,000 gallons combusted.[3] In a study by EPA and Battelle-Columbus Laboratories, gaseous emissions from combustion in waste oil heaters were similar to conventional distillate (No. 2) oil combustion emissions.[4] NO_x and SO_x emissions were higher than conventional distillate oil combustion due to higher fuel nitrogen and sulfur concentrations. NO_x emissions from waste oil combustion were about twice as high as NO_x emissions from combustion of No. 2 oil and SO_x emissions were about four times as high. Particulate emissions were also significantly higher. Of the waste oil not used for combustion, some is stored for recycling or disposal, some is used as a dust suppressant and some is reprocessed. No evaporative emission factor for waste oil was found. Estimates of emission factors for oil spills may be modified to develop waste oil emission factors.

Point/area source cutoff

Waste oil combustion in industrial boilers could most easily be accounted for in the point source inventory. However, unless the release of waste oil from oil storage occurs at a source otherwise counted as a point source and the leak is substantial, oil leaks are not included in the point source inventory. Waste oil used as a dust suppressant would be considered an area source due to its dispersed nature.

Level of detail of information available

The NRC collects data concerning any type of releases to the environment. Over fifty percent of the information reported to the NRC concerns spills and releases of fuel oil and some may involve waste oil.[5] The type of fuel may be specified by the person filing the report. The NRC requests information on the address/location of the spill and the date, if known. Attempts are being made to include the county location also. Monthly and yearly summary statistics are also tabulated. No estimate of the percentage of spills covered by the NRC is available; however, personnel at the NRC commented that many more reports are filed in the summer than in the winter.

National information on the storage and combustion of used industrial and engine crankcase oils seems to be relatively easy to obtain or estimate. This information could be allocated to the county level based on industrial statistics and motor vehicle registration information.

Level of detail required by users

For the purposes of the SIP and NEDS inventories, emissions will need to be estimated on the county level. The amount of waste oil generated, the use of the waste oil (e.g., combustion, dust suppression and waste oil storage) and the location of the waste oil in each county are needed.

Emission factor requirements

Emission factors are needed to describe the evaporation of volatile oils from dirt and gravel road surfaces as well as concrete pads or asphalt areas where AGSTs may be located. Combustion emission factors for lead and particulate matter are available in *AP-42*. SO_2, NO_x, CO_2, VOC and CO emission factors may be derived from existing distillate or residual oil combustion emission factors.

Regional, seasonal or temporal characteristics

Combustion in waste oil heaters occurs predominantly in the winter when automotive repair shops heat mechanics' bays with that waste oil. Other forms of waste oil combustion (e.g., industrial) should occur independent of season, but occur in more industrialized areas. Waste oil use for dust suppression occurs most commonly in rural areas.

Urban or rural characteristics

The use of waste oil as a dust suppressant is probably more prevalent in rural areas and in areas where there is a concentration of mining, logging, construction or agricultural activities. These industries produce significant quantities of waste oil and often apply the oil to their own roads. Other uses of waste oil (e.g., waste oil combustion and waste oil storage) are not expected to have distinctly urban or rural characteristics.

Methodology

To determine county-level estimates of pollutants from waste oil disposal, this category should be subdivided into the following three activities: the combustion of waste oil; the use of waste oil as a dust suppressant; and the storage of waste oil. National estimates of waste oil generated can be allocated to the county level based on industrial employment and motor vehicle registration data. These county-level estimates can then be divided into the estimated use fractions (e.g., percent combusted, percent applied to dirt/gravel roads, percent stored, other) and the emissions associated with the various uses calculated. For example, *AP-42* provides emission factors for particulate matter and lead from waste oil combustion and emission factors for other pollutant species from combustion could be estimated from distillate or residual oil combustion. Rough estimates based on laboratory simulations are available which describe the rate of evaporation of hydrocarbons from a surface. More research should be focused on obtaining evaporation emission factors.

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