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Network Design And Site Exposure Criteria For Selected Noncriteria Air Pollutants

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CONTENTS

Figures iv
Tables v

1. Introduction 1
2. Monitoring Needs for Noncriteria Pollutants 3
   Monitoring objectives 3
   Data needs 3
   Principal uses of data 4
3. Characteristics of Noncriteria Pollutants 8
   Physical and chemical properties 8
   Sources of emissions 8
   Sampling requirements 23
   Airborne toxicity 29
4. Siting Procedures 34
   Representative types of monitoring sites 34
   Overview of siting procedures 35
   Siting procedures for representative spatial scales.. 43
5. References 70

Appendixes

A. Recommended monitoring techniques 72
B. Observation of diurnal variations of selected noncriteria air pollutants 89
C. Meteorological data tabulations available from the National Climatic Data Center 100
D. Chemical profiles 120

FIGURES

Number		Page
1	Site selection procedure	37
2	Source configuration	39
3	Wind rose	40
4	Steps for locating an urban scale site	44
5	Concentration as a function of stability class, computed using HIWAY2 model	50
6	Frequency of 24-hour mean wind directions for Baltimore-Washington International Airport for 1973-1977	53
7	Example of high exposure area	54
8	Steps for locating a neighborhood scale site	56
9	Guideline for estimating impact distance of a point source overlapping an area source	62
10	Steps for locating micro or middle scale sites	64
11	Downwind distance to maximum concentration and maximum relative concentration ($\chi u/Q$) as a function of Pasquill stability class and effective plume height in rural terrain	67
12	Downwind distance to maximum concentration and maximum relative concentration ($\chi u/Q$) as a function of stability class and effective plume height in urban terrain	68

TABLES

Number		Page
1	Selected Noncriteria Pollutants That Need Monitor Siting Guidelines	2
2	Common Uses of Monitoring Data	4
3	Volatility, Reactivity, and Physical State of 43 Selected Noncriteria Air Pollutants	9
4	Sources of Emission of 43 Noncriteria Pollutants	10
5	Ranked Listing of Total Emissions of Selected Noncriteria Air Pollutants	20
6	Classes of Pollutant Sources Applicable to Selected Noncriteria Air Pollutants	24
7	Suggested Analysis Methods for Applicable Sampling Media	26
8	Toxicity of Noncriteria Air Pollutants	30
9	Representative Scales Applicable to Types of Pollutant Sources	36
10	Maximum Distance for Selected Ratios of Monitored Concentration to Source Strength	47
11	Ambient Concentrations and Emission Factors	48
12	Example of the Frequency of Occurrence of Wind Directions for Neutral Atmospheric Stability	52
13	Recommended EPA Models by Source Configuration and Averaging Time	58
14	Identification and Classification of Land Use Types	60

SECTION 1

INTRODUCTION

There is a need for air monitor siting guidelines that are applicable to the noncriteria air pollutants (NCAPs). The increasing need to consider the effects of known or suspected hazards has led Federal, State, and local air pollution control agencies to measure a variety of hazardous NCAPs. This has resulted in many short-term ambient air monitoring studies of NCAPs.

To increase the usefulness of NCAP studies, guidelines on network design and siting criteria are needed. Thus, the objective of this report is to provide monitor siting guidelines for selected NCAPs. A complete list of the pollutants treated in this document is given in Table 1. Most of these pollutants are toxic organic compounds that are priority substances for consideration as primary national health hazards. Seven of the listed pollutants have been identified as hazardous in compliance with Section 112 of the Clean Air Act (CAA).

Ambient monitoring data are needed to determine if the chemical is present in the ambient air and at what concentration, to assess population exposure estimates, and to determine the need for emission controls.

For many of the NCAPs, adequate methods to monitor still need to be developed. Thus, the monitoring activities will be undergoing improvements to the state-of-the-art methodologies initially put to use. The major objective of the monitoring activities is to apply available state-of-the-art techniques in data-gathering programs to observe air quality trends and to characterize noncriteria levels around critical sources and populations.

The monitoring siting criteria cover all NCAPs with the exception of pollutants associated with acid rain and visibility or as a criteria pollutant under Section 108 of CAA. Thus, pollutants such as sulfates, nitrates, inhalable particulates, and other "visibility" pollutants are excluded.

TABLE 1. SELECTED NONCRITERIA POLLUTANTS
THAT NEED MONITOR SITING GUIDELINES

Acetaldehyde	Ethylene oxide
Acrolein	Formaldehyde
Acrylonitrile	Hexachlorocyclopentadiene
Allyl chloride	Maleic anhydride
*Arsenic	Manganese
*Asbestos	*Mercury
*Benzene	Methyl chloroform (1,1,1-trichloroethane)
Benzyl chloride	Methylene chloride (dichloromethane)
*Beryllium	Nickel
Cadmium	Nitrobenzene
Carbon tetrachloride	Nitrosomorpholine
Chlorobenzene	Perchloroethylene (tetrachloroethylene)
Chloroform	Phenol
Chloroprene	Phosgene
Chromium	Polychlorinated biphenyls
o-,m-,p-Cresol	Propylene oxide
p-Dichlorobenzene	*Radionuclides
Dimethylnitrosamine	Toluene
Dioxin	Trichloroethylene
Epichlorohydrin	*Vinyl chloride
Ethylene dichloride	Vinylidene chloride
	o-,m-,p-Xylene

* Listed as hazardous air pollutants under Section 112 of the Clean Air Act.

SECTION 2

MONITORING NEEDS FOR NONCRITERIA POLLUTANTS

MONITORING OBJECTIVES

It is important when planning air monitoring activities to clearly define the objectives to be met by the monitoring data. In general, the objectives of ambient monitoring are the following:

- Measure or characterize urban air quality
- Measure or assess specific source impacts.

If the NCAP data collected satisfy these two objectives, the monitoring program will satisfy all of the needs for ambient data.

DATA NEEDS

The data needed to meet the monitoring objectives will vary in accuracy, frequency of measurement, and spatial density, depending on the nature of the local situation, the nature of the hazard associated with the NCAPs, and the nature of the measurement process. With regard to the nature of the hazard for the 43 pollutants listed in Table 1, there are two classes of hazards, the 7 regulated pollutants already identified by EPA as hazardous substances, and the remaining 36 pollutants that are suspected to be hazardous and that are under consideration for regulation. However, ambient air quality levels that are accepted as hazardous have not been established for either class. Therefore, accuracy and frequency of measurement may be considered secondary to spatial variation. It will be most important to define what areas are affected by the pollutants. This is the data characteristic most closely tied to siting and network design that is the subject of this document.

The spatial variations of air quality levels may be defined by in situ monitoring at fixed sites, by mobile monitoring, by remote monitoring at fixed or mobile sites, or by some combination of the three. In situ monitoring may include in situ analysis or collection of samples by a media for subsequent laboratory analysis. The use of personal samplers to collect samples for laboratory analysis is another way of obtaining spatially variant data that are especially relevant to human exposure estimates. Although there are a number of ways of including spatial variability in the monitoring data, the use of fixed monitoring sites is most common and is the method for which quality control procedures are best established at present. In this document, primary emphasis is given to the use of fixed in situ monitoring sites.

The number of fixed monitoring sites needed to measure spatial variability of NCAPs for one or more monitoring objectives depends very much on the number, type, and magnitude of sources of emissions. Other influencing factors are the topography and meteorology of the local area. Methods of taking these factors into account in planning for the number and location of monitoring sites are described in Section 4.

PRINCIPAL USES OF DATA

Common uses of monitoring data listed in Table 2 were recently cited by the Ad-Hoc Work Group on Air Toxics Monitoring.* These data uses must be borne in mind when planning a monitoring network. There must be agreement between those who will use the data and those who will collect them regarding how many and what locations will meet the data needs. Sometimes this coordination is needed between groups within a single agency. However, more often there must be coordination between parties of different levels of Government or between Government and nongovernment parties. Some concepts regarding how data use relates to monitor siting are discussed below.

TABLE 2. COMMON USES OF MONITORING DATA
(cited by the Ad-Hoc Work Group on Air Toxics Monitoring)

• Determine air quality status and trends
• Develop and review air quality standards
• Determine source-receptor relationships
• Develop and evaluate emission control standards and strategies
• Initiate corrective action in emergency response
• Characterize urban air quality

* November 1983, Second Draft. Long-Term Plan for Toxic Ambient Air Pollutant Monitoring (unpublished). The group consists of representatives from States, EPA Regions, Office of Research and Development, Office of Management Systems and Evaluation, and Office of Air Quality Planning and Standards.

Assess Human Exposure Risk

The relationship of measured ambient concentrations to human health or welfare risks depends on a number of factors regarding time and magnitude of exposure, which may affect how frequently samples are collected and analyzed. However, the most crucial concern from a siting point of view is often that the data represent or be related to the highest ambient concentration. This requires that the right location be sampled at the right time. Another consideration is the number and sensitivity of the exposed population. Children, elderly persons, and sick persons may be more susceptible to lower concentrations than are other people. Therefore, the concentrations to which highly susceptible people are exposed may be as important to health risk assessment as the magnitude and location of the maximum concentration. Site selections are often made to satisfy both needs, i.e., maximum concentration and concentration to which the maximum population or the most susceptible population is exposed.

Determine Air Quality Trends

Air quality trends are important to show whether pollution is getting worse or better and whether regulatory controls are adequate. The single most important siting consideration for trend data is that transient influences not representative of the region be excluded. The shutdown of a nearby plant or the shifts of traffic from a nearby highway are examples of transients that may be undesirable unless they represent the major effects in the region. Typical locations that are good locations for measuring trends are (1) the central business district of a large metropolitan area, (2) the edge of a metropolitan area downwind of the prevailing wind direction, and (3) a dense residential population area. Other types of locations may also be suitable, depending on what the local situation is regarding sources of emissions.

Develop and/or Validate Models

The use of models can greatly increase the amount of information developed regarding air quality levels over that given by a monitoring network. However, the model estimates are limited by the accuracy of the model. Monitoring data can be used to establish the validity of models and to provide a basis for improving models. This is particularly important where local terrain influences are present. The EPA guidance on validating models (e.g., U.S. EPA 1978) requires that monitoring be designed to describe the spatial variation of pollutant concentrations across the area. For each local situation the best selection of sites will depend on meteorology,

topography, and the configuration and characteristics of sources. The following examples are offered of four common types of local situations (U.S. EPA 1982); however, the adequacy of a network for a specific site may be expected to vary from these examples:

- For aerodynamic downwash, consider one or two background monitors plus two to four downwind monitors. The number of downwind monitors should be determined by a consideration of the frequency of the downwash events, the expected magnitude of the impact, and the areal extent of the impact.

- For shoreline conditions, consider one to two background monitors and three to eight downwind monitors. The number of downwind monitors should be determined by considering site characteristics, the magnitude and the areal extent of the predicted impact. It may be necessary to complement the stationary monitoring network with mobile sampling and plume tracking techniques.

- For complex terrain, the air quality monitors should assess the maximum impacts for each averaging period for which an air quality violation is expected to occur. Approximately three to eight monitors should be considered necessary to monitor for each such averaging time. The exact number depends on the magnitude and extent of expected violations. At least two monitors for each contiguous area where violations are expected to occur are necessary except where these areas are large. In this case, more than two monitors could be required. As a guide, a 22-1/2° sector should define the maximum size of a large contiguous area. Based upon meteorological judgment, additional monitors may be required to evaluate the source impact, depending on the complexity of the terrain.

- For urban situations where the concern is particulates and the sources of violations appear to be fugitive and/or reentrained dust, extensive monitoring and receptor models may be needed to accurately assess the problem.

Identify Areas of Effect or Exposure Levels

In order to estimate the area covered by a specific exposure effect, there must be a relatively large number of sampling sites. The number required will depend on the complexity of the local pattern of air quality levels. As a general rule it will be necessary to supplement monitoring data

with modeling estimates. It is desirable that the monitoring data be adequate to identify the shape of the air quality pattern and the areas of sharpest gradient. Remote sampling and mobile sampling can be useful adjuncts to fixed-site monitoring in meeting this data use.

Determine Source Impact Areas

Much of what applies to defining integrated areas of effects over a region can be applied to defining the impact area from a single source. A number of monitoring sites are needed, and monitoring data can be usefully supplemented by modeling data. The monitoring sites will be located in the vicinity of the site, and will be most productive if they are sited in a pattern that is downwind of the prevailing wind direction from the source.

Determine Pollutant Transport and Fate

Many air pollutants are relatively stable in the atmosphere. They are transported out of the source area by the wind, being diluted by turbulent mixing in the process. In most cases, pollutants remain airborne until they are taken up by dry or wet particles and washed out by rainfall. Some pollutants undergo rapid chemical transformations, which makes them less toxic and often more susceptible to removal. In a few cases, pollutants fall out because they are emitted as large particles that are not easily retained as aerosols. Detailed chemical and physical analyses of pollutant samples are useful in defining the fate of transported air pollutants. Monitoring sites can be arranged in downwind lines at convenient distances from major sources or source areas to obtain data that describe pollutant transport fates.

SECTION 3

CHARACTERISTICS OF NONCRITERIA POLLUTANTS

PHYSICAL AND CHEMICAL PROPERTIES

In planning monitoring operations for NCAPs, it is useful to keep physical and chemical properties in mind. For this purpose, Table 3 identifies the 43 pollutants listed in Table 1 in terms of three properties that affect the emissions, transport, and fate of pollutants in the atmosphere. The three properties are volatility, reactivity, and physical state. Standard chemical references may be used to determine more details regarding these and other physical and chemical properties. A number of important characteristics of 26 compounds are listed in Appendix D to this report.

Volatility is related to the difficulty of containing a pollutant during production, handling, transport, storage, use, and disposition. Emission rates are likely to be higher for the more volatile compounds, and sources that use these materials are of concern from an air monitoring point of view. Reactivity relates to how fast the pollutant changes form in the atmosphere due to photochemical and other atmospheric chemical processes. Pollutants with higher reactivity will not travel far from their source before undergoing chemical transformation. The physical state of the compound may be of interest in selecting a sample collection technique. It may also be of interest in identifying handling and storage processes that are of concern as sources of emissions.

SOURCES OF EMISSIONS

An important step in selecting monitoring sites is identifying the nature and location of expected emissions of the pollutants of interest. A summary of emissions for the 43 pollutants identified in Table 1 is given in Table 4 for the following types of sources:

- Production plants
- Industrial user plants
- Sources that emit the pollutant as a byproduct or indirect emission
- Storage, transport, and fugitive sources.

In order to give an overview of the relative importance of these emissions, Table 5 is a ranked listing of total atmospheric emissions of 46 compounds (all from Table 1) in 1978. It may be noted that two of the pollutants in Table 1, namely nitrosomorpholine and dimethylnitrosamine are not commercially produced and not directly emitted to the atmosphere. These

TABLE 3. VOLATILITY, REACTIVITY, AND PHYSICAL STATE OF 43 SELECTED NONCRITERIA AIR POLLUTANTS

	Low reactivity		Medium reactivity			High reactivity		
Volatility	Solid	Liquid	Solid	Liquid	Gas	Solid	Liquid	Gas
High		Methyl chloroform		Vinylidene chloride	Ethylene oxide		Acetaldehyde	Acetaldehyde
		Chloroform		Chloroprene	Formaldehyde		Allyl chloride	Phosgene
		Methylene chloride		Propylene oxide	Vinyl chloride		Acrolein	
Medium	Dichloro-benzene	Benzyl chloride		Dimethyl-nitrosamine			Xylene	
		Carbon tetrachloride		Acrylonitrile				
		Perchloro-ethylene		Chlorobenzene				
		Ethylene dichloride		Toluene				
				Trichloro-ethylene				
				Epichloro-hydrin				
				Nitroso-morpholine				
				Benzene				
Low	Chromium	Hexachloro-cyclopentadiene	Cadmium	Nitro-benzene		Phenol		
	Manganese	Mercury	Cresols	Cresols				
	Polychlor-inated biphenyls	Polychlor-inated biphenyls	Maleic anhydride					
	Nickel		Arsenic					
	Asbestos							
	Beryllium							
	Dioxin							
	Radionuclides (also gas)							

TABLE 4. SOURCES OF EMISSION OF 43 NONCRITERIA POLLUTANTS

Chemical name	Production emissions*	Industrial use emissions*	Byproduct emissions*	Storage, transport, and fugitive emissions*
Acetaldehyde	2.3×10^{-2}% Plants located (1978) in TX (3), PA (1), and LA (1)	Acetic acid production: 0.34% Other processes: 0.46%	Not significant	Production-- Storage: 2.9×10^{-3}% Fugitive: 1.3×10^{-3}% Industrial use-- Storage: 4.2×10^{-2}% Fugitive: 2.2×10^{-2}%
Acrolein	Isolated acrolein: 0.11% Unisolated: 6.2×10^{-3}% Plants located in TX (2) and LA (2)	Acrylic acid: 6.7×10^{-3}% Refined acrolein and glycerin: 1.8×10^{-2}% Methionine and other chemicals: 0.12%	Present in fuel combustion products, wood fires, smoke, and cigarette smoke	No storage emissions
Acrylonitrile	0.03% 6 plants (1980)	93,764 tons/yr Emitted by production of acrylic fibers, nonacrylic fibers, ABS and SAN resins Approximately 35 plants	Monomer residue is released from automobile tires	Unknown
Allyl chloride	0.29% Plants in TX and LA	Epichlorohydrin: 0.33%	N/A	Production-- Storage: 1.4×10^{-2}% Fugitive: 3.0×10^{-2}% (plant equipment leaks)
Arsenic	0.01% Annual production: 70×10^{6} lb	799,000 lb/yr emitted by 325 glass production plants	Copper smelters (1974): 5.9×10^{6} lb/yr Coal burning (369 plants): 1.1×10^{6} lb/yr	Fugitive dust from refining facilities: 0.1%
Asbestos	5.5% from mining and milling 1979 production: 200×10^{6} lb	N/A	1.2×10^{6} lb/yr (from building demolitions and vehicle brake lining wear)	Primary sources: Mine to mill transport Mining waste disposal Landfill areas

(Continued)

*Percentages are amount of chemical throughput that is emitted to the atmosphere.

TABLE 4. (continued)

Chemical name	Production emissions*	Industrial use emissions*	Byproduct emissions*	Storage, transport, and fugitive emissions*
Benzene	0.09% Production (1980): 12×10^9 lb	Primarily from production of ethylbenzene, cumene, cyclohexane: 50×10^3 ton/yr	Motor vehicle refueling: 500 ton/yr Coke ovens, etc.: 20 to 80×10^3 ton/yr Gasoline consumption: 40 to 80×10^3 ton/yr	Transport and storage: 115×10^3 ton/yr Oil spills: 11×10^3 ton/yr
Benzyl chloride	0.05% 4 plants in NJ and IL Production (1978): 115×10^6 lb	Benzyl alcohol: 0.035% Quaternary ammonium compounds (QAC): 0.028% Butyl benzyl phthalate: 0.011% 15 plants in IL, NC, NJ, OH, PA, TX, and WI	N/A	Fugitive-- Production: 9.3×10^{-3}% Benzyl alcohol: 11.0×10^{-3}% QAC: 8.0×10^{-3}% Storage: 4×10^{-3}%
Beryllium	1,100 lb/yr Production (1978): 7.5×10^6 lb	5,500 lb/yr primarily from alloy production 5 plants located in PA (3), OH, and NJ	Coal consumption: 5×10^{-4} lb/ton of coal Oil consumption: 3.5×10^{-4} lb/1,000 gal of oil Gray iron foundries: 4.44×10^{-4} lb/ton of iron	Unknown
Cadmium	17×10^6 produced (1980), including high cadmium content compounds	6×10^6 lb/yr (1975)	Steel blast furnaces: 2×10^6 lb (1975) Copper smelting: 1.3×10^6 lb/yr	Unknown
Carbon tetrachloride	0.31% Production (1981): 717×10^6 lb	Fluorocarbon production: 4.5×10^{-2}%	Solvent applications: approximately 60×10^6 lb	Production-- Storage: 0.21% Fugitive: 4.8×10^{-2}% Fluorocarbon production-- Storage: 4.42×10^{-2}% Fugitive: 1.78×10^{-2}%

(continued)

*Percentages are amount of chemical throughput that is emitted to the atmosphere.

TABLE 4. (continued)

Chemical name	Production emissions*	Industrial use emissions*	Byproduct emissions*	Storage, transport, and fugitive emissions*
Chlorobenzene	0.21% Production (1978): 335 x 10^6 lb emitted from plants in MI, WV, IL, DE, NY, and NY	DDT: 4.0 x 10^{-2}% Nitrochlorobenzene: 0.11% Diphenyl oxide: 7.0 x 10^{-2}%	Used as solvent in cold cleaning operations and in pesticide applications: 100% emissions	Production-- Storage: 4.5 x 10^{-2}% Fugitive: 6.9 x 10^{-2}% Chemical intermediate-- Storage: 0.5 x 10^{-2}% DDT 2.0 x 10^{-2}% nitrochlorobenzene 1.0 x 10^{-2}% diphenyl oxide Fugitive: 0.5 x 10^{-2}% DDT 3.0 x 10^{-2}% nitrochlorobenzene 2.0 x 10^{-2}% diphenyl oxide
Chloroform	6.8 x 10^{-3}% 330 million lb produced (1978) at 7 plants	Fluorocarbon (F-22) production: 0% emissions 8 plants in CA (2), KY (2), MJ (2), IL, and MI	Solvent use: 100% emissions from 7% of production	Fluorocarbon production-- Storage: 0.37% Fugitive: 0.08% Production-- Storage: 8.2 x 10^{-2}% Fugitive: 2.3 x 10^{-2}%
Chloroprene	1.40 x 10^{-2}% (Du Pont) 0.22 x 10^{-2}% (Dunka) Production (1978): 277 x 10^{-6} lb at 3 plants in TX and LA	All production is captively consumed to manufacture polychloroprene (neoprene)	N/A	Production-- Storage: 0.4 x 10^{-3}% Fugitive: 0.1%
Chromium	Negligible domestic mining emissions Refining: 26 million lb/yr (1970) 750 million lb (1980) of chromium and compounds processed in 1980	Steel and alloy production: 1.3 million lb/yr (1970)	Coal and oil combustion, incineration, cement production: 4.7 million lb/yr (1970)	Unknown

(continued)

*Percentages are amount of chemical throughput that is emitted to the atmosphere.

TABLE 4. (continued)

Chemical name	Production emissions*	Industrial use emissions*	Byproduct emissions*	Storage, transport, and fugitive emissions*
o-,m-,p-Cresol	Mixed cresol production and cresylic acid production: 0.19% (1978) Cresol isomer production-- o-Cresol: 0.19% m-Cresol: 0.19% p-Cresol: 0.39%	Phenolic resin: 0.4% Pesticides: 4.0×10^{-2}% BHT/antioxidants: 8.0×10^{-2}% Tricresyl phosphate (TCP): 3.5×10^{-2}% Miscellaneous: 0.1%	Wire enamel solvents: 16.4 million lb/yr Disinfectant cleaning compound: 2.5 million lb/yr Coke oven emissions: 0.048 lb/ton of coke Ore flotation agent: 2.5 million lb/yr	Mixed cresol, cresylic acid, m-cresol, and o-cresol production:-- Storage: 2×10^{-2}% Fugitive: 4×10^{-2}% Others-- p-Cresol: Storage 3×10^{-2}%, Fugitive 8×10^{-2}% Phenolic resin: Storage 5×10^{-2}%, Fugitive 5×10^{-2}% Pesticides/TCP: Storage 5×10^{-3}%, Fugitive 5×10^{-3}% BHT/antioxidants: Storage 1×10^{-2}%, Fugitive 1×10^{-2}%
p-Dichlorobenzene	0.58% 7 plants	Pesticide intermediate: 4.0×10^{-2}%	Space deodorant and moth control: 100% emissions	Pesticide intermediate-- Storage: 0.5×10^{-2}% Fugitive: 0.5×10^{-2}% Production-- Storage: 4.1×10^{-2}% Fugitive: 0.10%
Dimethylnitrosamine	Not currently produced in commercial quantities, but formed from emissions of dimethylamine (DMA) production: 0.13%	Formed from emissions of dimethylamine during production of industrial solvents, lauryl DMA oxide, rubber chemical accelerators, dimethylhydrazine/pesticides: 0.065%	Found as a contaminant during rubber processing and in rocket fuel production and use Contained in formulations of the pesticide 2,3,6-trichlorobenzoic acid and in dimethylhydrazine	Production of DMA-- Storage: 0.02% Fugitive: 0.05% Users of DMA-- Storage: 0.01% Fugitive: 0.025%
Dioxin	Not commercially produced	An impurity resulting from the manufacture of trichlorophenol, 2,4,5-T, and pentachlorophenol: 2.5×10^{-2}% of production volume 10 plants in MI, KA (2), IL (2), PA, CA, MO, AR, and WA	Weed control applications of 2,4,5-T: 6.5 lb/yr (based on 1 ppb in product) Wood preservative use: 42.3 lb/yr From burning: 18.8 lb/yr (based on particulate matter content of 2 ppb)	No data available

(continued)

*Percentages are amount of chemical throughput that is emitted to the atmosphere.

TABLE 4. (continued)

Chemical name	Production emissions*	Industrial use emissions*	Byproduct emissions*	Storage, transport, and fugitive emissions*
Epichlorohydrin	4.2×10^{-2}% Plants in TX and LA	Epoxy resin production synthetic glycerin production and other chemical production: 0.15%	From epoxy resin use: 8.0×10^{-2}% From use of glycerin and other chemicals: 2.6×10^{-2}%	Production-- Storage: 1.0×10^{-3}% Fugitive: 4.0×10^{-3}%
Ethylene dichloride	5 million metric tons produced (1977) 18 facilities: 0.48% 53.2×10^{6} lb/yr	More than 80% produced is used in synthesis of vinyl chloride monomer and 12-15% used for other chemical synthesis (1977): 5.5×10^{6} lb/yr	Used in gasoline as a lead scavenger: 2.9×10^{6} lb/yr Waste disposal (1977): $<60 \times 10^{6}$ lb/yr Dispersive uses (1977): 11×10^{6} lb/yr	Production (1977)-- Storage: 31.6×10^{6} lb/yr Fugitive: 11.4×10^{6} lb/yr Industrial use (1977)-- Transportation: $<5 \times 10^{6}$ lb/yr
Ethylene oxide	Air oxidation process (5 producers): 5.25×10^{-2}% Oxygen oxidation process (8 producers): 4.7×10^{-2}% 3,640 million lb produced (1978) at 13 plants	Produced and used at same sites Used to make ethylene glycol (EG) polyester, EG antifreeze, surface active agents, ethanolamines, glycol ethers, etc. Production emission estimates include industrial use estimates	N/A	Production by air oxidation process-- Storage: 0.21×10^{-2}% Fugitive: 0.02×10^{-2}% By oxygen oxidation process-- Storage: 0.71×10^{-2}% Fugitive: 0.5×10^{-3}%
Formaldehyde	For silver process: 2.6×10^{-2}% For metal oxide process: 3.9×10^{-2}% 6.4×10^{-9} lb produced (1978) at 53 plants	Urea, melamine, phenolic, and acetal resins: 0.40% Butanediol: 0.20% Pentaerythritol: 0.73% Most others: 0.48%	Automobile emissions: 610 million lb/yr Other indirect emissions are from power plants, incinerators, and petroleum refineries	Production by silver process-- Storage: 0.21×10^{-2}% Fugitive: 0.52×10^{-2}% By metal oxide process-- Storage: 0.41×10^{-2}% Fugitive: 0.81×10^{-2}% Resin and butanediol production-- Storage: 0.5×10^{-3}% Fugitive: 0.5×10^{-3}%
Hexachlorocyclo-pentadiene	0.52% 7 million lb (1978) produced at plants in MI, NY, and TN	Chemical intermediate in manufacture of flame retardants, pesticides: 3.25×10^{-2}% Many of these uses are now banned by EPA and OSHA	No data available	Production-- Storage: 0.08% Fugitive: 0.20% Industrial use-- Storage: 0.5×10^{-2}% Fugitive: 1.25×10^{-2}%

(continued)

*Percentages are amount of chemical throughput that is emitted to the atmosphere.

TABLE 4. (continued)

Chemical name	Production emissions*	Industrial use emissions*	Byproduct emissions*	Storage, transport, and fugitive emissions*
Maleic anhydride	304 million lb/yr produced (1981) at 7 plants 0.85×10^6 lb emitted (1974)	1974 emissions from: Methalic anhydride production (1974): 2.96×10^6 lb Other products: 0.85×10^6 lb	Unknown	Packaging and storage (1974): 0.06×10^6 lb
Manganese	High grade ore no longer mined in the U.S., so mining emissions are assumed to be negligible	Manganese alloy and metal: 0.33% of ferro alloy product Iron and steel production: 0.20×10^{-2}% of iron and steel product Gray iron foundries: 1.5×10^{-2}% of iron product	Electrical power utility plants-- Coal fired: 11×10^3 lb/ton Oil fired: 0.5×10^3 lb/100 gal Coke oven emissions: 2.6×10^{-2} lb/ton coal	No data available
Mercury	Estimated world production (1973) of 10,000 tons, with emissions of the order of 300 tons/yr	Electrolytic production of chlorine	291 million lb/yr (1978) Local emissions from natural sources of mercury Given off during electrolysis of alkali metal salts in zinc recovery Emitted from coal or paper burning, from use of electrical or measuring instruments containing mercury	Emissions from disposal of fluorescent tubes, fever thermometers, etc., and from incinerator sludge estimated at about 185,500 lb/yr (1971)
Methyl chloroform (1,1,1-trichloroethane)	7.2×10^{-2}% 620 million lb (1978) produced at plants in LA (3) and TX (1)	Aerosol formulations and other chemical intermediate uses: 0.06 million lb/yr	Metal degreasing and cleaning operations: 371.2 million lb/yr (at 276,000 units) Solvent/cleaner use: 135 million lb/yr Aerosol use: 30 million lb/yr	Production-- Storage: 0.23% Fugitive: 0.10%

(continued)

*Percentages are amount of chemical throughput that is emitted to the atmosphere.

TABLE 4. (continued)

Chemical name	Production emissions*	Industrial use emissions*	Byproduct emissions*	Storage, transport, and fugitive emissions*
Methylene chloride (dichloromethane)	Methyl chloride process: 2.6×10^{3}% Methane process: 1.4×10^{2}% 525 million lb (1978) produced at 7 plants in LA (2), KS, WV (2), TX, and KY	Paint and varnish remover formulation, aerosol formulation, plastics processing: eventually 100% Chemical intermediate	Metal degreasing solvent: 107.1 million lb/yr (at 122,000 units) Paint and varnish remover: 157.5 million lb/yr Aerosols: 89.3 million lb/yr Plastics: 26.3 million lb/yr	Methylene chloride process-- Storage: 0.246% Fugitive: 0.047% Chloromethane production: Storage: 0.25% Fugitive: 0.05% Methane process-- Storage: 0.102% Fugitive: 0.032%
Nickel	0.81% 27,000 lb/yr produced in 2 plants in U.S. and 188,100 tons.S. imported 100 tons	Iron and steel manufacturing: 1.1×10^{-4}% of iron/steel product Ferro-alloy production: 2.2×10^{-2}% of ferro alloy product Gray-iron foundries: 5.2×10^{-4}% of hot metal product Nonferrous alloys: 1.2×10^{-3}% of product	Coal-fired boilers (per ton)-- Power/industry: 6.6×10^{-4} lb Resident/commerce: 3.0×10^{-4} lb Oil-fired boilers (per 1000 gal)-- Power: 0.30 lb Resident: 0.23 lb Resident/commerce: 0.13 lb Diesel fuel: 0.13 lb/1,000 gal Coke ovens: 1.6×10^{-3} lb/ton coal	No data available
Nitrobenzene	0.8×10^{-3}% 795 million lb produced in 6 plants (1978)	99% nitrobenzene produced is used captively for production of aniline: 0.8×10^{-3}% Chemical intermediate for production of dichloroanilines and dinitrobenzenes: 0.11%	Solvent use in cellulose ether manufacture and in petroleum industry: 100% 6.4 million lb (1978) emitted from 279 refineries	Nitrobenzene and aniline production-- Storage: 0.6×10^{-3}% Fugitive: 3.1×10^{-2}% Chemical intermediate: Storage: 1.5×10^{-2}% Fugitive: 3.0×10^{-2}%
Nitrosomorpholine	Not commercially produced; formed from emissions of morpholine 137,700 lb of morpholine emitted from 2 TX plants (1978)	No reported uses	Contaminant found in dichloromethane, chloroform, morpholine, and in a rubber cross-linked accelerator Morpholine emissions (1978)-- Corrosion inhibitors: 7.5×10^{-6} lb Polishes and waxes: 2.5 10^{-6} lb	N/A

(continued)

*Percentages are amount of chemical throughput that is emitted to the atmosphere.

TABLE 4. (continued)

Chemical name	Production emissions*	Industrial use emissions*	Byproduct emissions*	Storage, transport, and fugitive emissions*
Perchloroethylene (tetrachloro-ethylene)	0.25% 639 million lb produced (1978) in 10 plants	Chemical intermediate, dry cleaning processes, and equipment (1977): 12%	Metal cleaning operations: 104.5×10^6 lb/yr estimated (1978)	85-90% of chemical produced is eventually lost in emissions
Phenol	0.18% 320 million lb produced at 16 plants (1978)	Chemical intermediate: Manufacture of phenol-formaldehyde (phenolic) resins: 3.5×10^{-2}% Caprolactam production: 0.13% Other chemical products: 7.5×10^{-2}%	Miscellaneous uses: 6.8×10^{-2}%	Production-- Storage: 0.3×10^{-2}% Fugitive: 4.1×10^{-2}% Phenolic resin production-- Storage: 0.2×10^{-2}% Fugitive: 1.3×10^{-2}% Caprolactam production: Storage: 0.1×10^{-2}% Fugitive: 1.3×10^{-2}%
Phosgene	None	Toluene diisocyanate (TDI): 0.6×10^{-3}% Polymeric isocyanates: 0.66×10^{-3}%	None	Production (18 sites)-- Storage: None Fugitive: 1.8×10^{-2}% TDI and polymer isocyanate production: None
Polychlorinated biphenyls	No longer produced in the U.S. after 1977 and no imports since 1979; 35 million lb/yr produced prior to 1977	Approximately 1.397 billion lb produced since 1929; only an estimated 61.5 million lb have been destroyed Used in manufacture of capacitors, transformers, and closed electrical systems	Disposal (incineration) of transformers and capacitors containing PCBs at 12 incinerator sites: 30 million lb/yr processed; emissions estimated to be 0.1-0.1%	Spills, leaks, disposal of hydraulic fluids: 3,960-4,950 ton/yr
Propylene oxide	Chlorohydrination process: 7.5×10^{-2}% Peroxidation process: 2.1×10^{-2}% (2 TX sites) 3,215 million lb (1978) produced at 7 plants in TX (4), LA, MI, and KY	Urethane polyol production: 1.3×10^{-2}% Propylene glycol production: 0.28×10^{-2}% Surfactant polyol production: 1.3×10^{-2}% Di- and tripropylene glycol and glycol ethers: 0.28×10^{-2}%	Unknown	Production-- Storage: 0.31×10^{-2}% Fugitive: 0.21×10^{-2}% Urethane polyol and surfactant polyox production-- Storage: 0.01×10^{-2}% Fugitive: 0.01×10^{-2}% Propylene, di- and triglycol production-- Storage: 0% Fugitive: 0.01×10^{-2}%

(continued)

*Percentages are amount of chemical throughput that is emitted to the atmosphere.

TABLE 4. (continued)

Chemical name	Production emissions*	Industrial use emissions*	Byproduct emissions*	Storage, transport, and fugitive emissions*
Radionuclides	Natural sources: gases from the earth's crust and the interaction of cosmic radiation with gases in the atmosphere. Low and intermediate levels are released to the environment. High-level wastes are not released and require isolation for 600-700 years, or thousands of years if alpha emitters are present	Tailings from mining operations are sources of radionuclide emissions. Nuclear reactor operations and nuclear spent fuel processing are principal sources of radioactive gases Other sources: Processing radioactive materials Metallurgical plants Chemical plants	Fossil fuels: Traces of uranium 238 and thorium 226 (1-2 ppm) are given off from coal-ash and oil-burning plants	NRC specifies shipping criteria DOT regulates shipping requirements
Toluene	Production processes-- Catalytic reformate: 0.2×10^{-2}% Pyrolysis gasoline: 1.5×10^{-2}% Coal derived: 5.0×10^{-2}% Styrene byproduct: 0.1×10^{-2}%	Benzoic acid production: 0.1% Benzyl chloride and vinyl toluene: 5.5×10^{-2}% Benzene production and xylene disproportionation: 0.5×10^{-2}%	Gasoline marketing: 38.5 million lb/yr Coke oven operations: 25.7 million lb/yr Paints, coatings: 100%	Catalytic reformate process-- Storage: 0.6×10^{-2}% Fugitive: 0.2×10^{-2}% Other production processes-- Storage: 6.0×10^{-2}% Fugitive: 1.5×10^{-2}% Benzoic acid production-- Storage: 0.4×10^{-3}% Fugitive: 0.1×10^{-3}% Benzyl chloride and vinyl toluene production: Storage: 0.3×10^{-3}% Fugitive: 0.15×10^{-3}% Benzene production and xylene disproportionation-- Storage: 0.1×10^{-3}% Fugitive: 0.05×10^{-3}%
Trichloroethylene	0.51×10^{-3}% 3 plants (1978)	Unknown	Solvent: 100%; 11.6 million lb/yr (1978) Vapor degreasing: 98%; 195.6 million lb/yr (1978) Cold cleaners: 32.9 million lb/yr (1978)	Production-- Storage: 0.81×10^{-3}% Fugitive: 0.75×10^{-3}%

(continued)

*Percentages are amount of chemical throughput that is emitted to the atmosphere.

TABLE 4. (concluded)

Chemical name	Production emissions*	Industrial use emissions*	Byproduct emissions*	Storage, transport, and fugitive emissions*
Vinyl chloride	0.45% 4 billion lb produced (1975)	97% of total produced is used in polymer production 202.4 million lb/yr emitted Polyvinyl chloride production: 4.5%	Unknown	2,000 lb/yr released to sewers in manufacturing process discharge streams
Vinylidene chloride (VDC)	4.5×10^{-2}% estimated (1977) 3.3 million lb (1974)	Production of 1,1,1-trichloethane (not available) Polymer synthesis of polyvinylidene chloride: 1.35 million lb (1974)	Up to 25% used in Saran may be in landfill refuse areas	25%
o-,m-,p-Xylene	Mixed xylene production from catalytic reformate process: 0.3×10^{-2}% From pyrolysis gasoline process: 0.7×10^{-2}% From toluene: 0.5×10^{-2}% Coal derived: 5.0×10^{-2}%	Ethylbenzene (mixed xylenes): 1.0×10^{-2}% Phthalic anhydride (o-xylene): 1.4×10^{-2}% Isophthalic acid (m-xylene): 8.5×10^{-2}% Dimethylterephthalic acid (p-xylene): 1.3×10^{-2}% Terephthalic acid (p-xylene): 0.25%	Mixed xylenes in solvent applications, agricultural pesticides, household products: 100%	Mixed xylene production-- Catalytic reformate: Storage: 0.6×10^{-2}% Fugitive: 0.3×10^{-2}% Pyrolysis gasoline-- Storage: 3.0×10^{-2}% Fugitive: 0.3×10^{-2}% Toluene process-- Storage: 1.0×10^{-2}% Fugitive: 0.5×10^{-2}% Coal derived-- Storage: 6.0×10^{-2}% Fugitive: 1.5×10^{-2}%
	o-Xylene: 0.21%			o-Xylene production-- Storage: 0.8×10^{-2}% Fugitive: 3.8×10^{-2}%
	m-Xylene: 0.16%			m-Xylene production-- Storage: 1.2×10^{-2}% Fugitive: 3.0×10^{-2}%
	p-Xylene: 0.12%			p-Xylene production-- Storage: 1.9×10^{-2}% Fugitive: 2.4×10^{-2}%

*Percentages are amount of chemical throughput that is emitted to the atmosphere.

TABLE 5. RANKED LISTING OF TOTAL EMISSIONS
OF SELECTED NONCRITERIA AIR POLLUTANTS

Chemical	Total emissions* (lb/yr)
Toluene	2,235,842,590
Benzene	1,300,000,000
Methylchloroform	538,730,000
Perchloroethylene	500,000,000
m-Xylene	453,533,940
Methylene chloride	407,700,000
o-Xylene	268,497,360
Trichloroethylene	240,700,000
p-Xylene	239,270,414
Vinyl chloride	220,000,000
Acrylonitrile	190,000,000
Ethylene dichloride	180,000,000
Chlorobenzene	175,376,130
Carbon tetrachloride	65,030,000
p-Dichlorobenzene	49,900,950
Manganese	35,000,000
Formaldehyde	33,000,000
Chloroform	24,040,000

(continued)

* Actual emissions estimated as of 1978.

TABLE 5 (continued)

Chemical	Total emissions* (lb/yr)
Nickel	22,573,640
Chromium	15,000,000
Nitrobenzene	13,040,000
Asbestos	12,200,000
m-Cresol	10,960,000
Morpholinet	10,028,000
Arsenic	9,500,000
p-Cresol	9,124,941
Phenol	6,924,360
Cadmium	6,000,000
Acetaldehyde	4,853,950
Maleic anhydride	4,800,000
o-Cresol	4,504,150
Vinylidene chloride	4,300,000
Radionuclides	4,000,000
Chloroprene	3,523,092
Ethylene oxide	1,991,000
Mercury	1,900,000
Propylene oxide	1,346,160

(continued)

* Actual emissions estimated as of 1978.

† Precursor to atmospheric formation of nitrosomorpholine.

TABLE 5 (continued)

Chemical	Total emissions* (lb/yr)
Allyl chloride	1,110,000
Epichlorohydrin	479,000
Beryllium	357,035
Phosgene	253,176
Dimethylamine†	215,400
Acrolein	102,920
Benzyl chloride	100,271
Hexachlorocyclopentadiene	59,500
Polychlorinated biphenyls	30,020
2,3,7,8 TCDD (dioxin)	84

* Actual emissions estimated as of 1978.

† Precursor to atmospheric formation of dimethylnitrosamine.

compounds are primarily found in the atmosphere as a result of chemical reactions involving the precursors, morpholine and dimethylamine, respectively, which are listed in Table 5.

It may be noted from the description in Table 4 that the large quantities of emissions of the highest ranked pollutants in Table 5 are from many small, widely dispersed sources. Typical examples are the 1.3 billion pounds per year of toluene emitted from motor vehicle exhausts, the 579 million pounds per year of toluene emitted from paint and other coating solvents, and the 371 million pounds per year of methyl chloroform released from metal cleaning operations.

The sources of each pollutant have been characterized into the following four types:

- Well-isolated plant sites having major emissions
- Industry-related sources that may or may not be well isolated from one another
- Sources identified with product use and related to population distribution
- Motor vehicle traffic.

Pollutants falling into each class are listed in Table 6. Some pollutants are listed in more than one class. These groupings will help in planning monitoring networks with respect to each pollutant. Further suggestions for using these classes to define monitor sites are presented in Section 4.

SAMPLING REQUIREMENTS

The sample collection for NCAPs differs from that of criteria pollutants, mainly in the fact that the sampling procedure is not specified as it is with criteria pollutants. Therefore, the analyst must evaluate the currently recommended and the most recently developed procedures to determine how the sample should be collected and analyzed. A list of sampling media and analysis methods for the pollutants addressed in this document is shown in Table 7. The problems encountered when specifying a sampling protocol are many; hence, a logical procedure that considers at least the following points should be followed:

- Media. Unless very expensive equipment is dedicated to field monitoring activities, samples will normally be collected as grab samples and brought to a laboratory for analysis. The media selected to collect each pollutant must have good collection efficiency for the compound(s) of interest, and it must retain and release the compound in

TABLE 6. CLASSES OF POLLUTANT SOURCES APPLICABLE TO SELECTED NONCRITERIA AIR POLLUTANTS

I. Small number of well-isolated plant sites

Dimethylnitrosamine (vicinity of 13 plants emitting dimethylamine, rocket launches)
Allyl chloride (3 plants)
Epichlorohydrin (12 plants)
Acrolein (5 production and 3 user plants)
Ethylene oxide (13 plants)
Hexachlorocyclopentadiene (3 production plants)
PCBs (12 incinerator sites)
Phenol (16 production and 16 user plants)
Phosgene (18 production plants)
Propylene oxide (7 production and 30 user plants)
Acetaldehyde (5 production and 13 user plants)
Benzyl chloride (4 production and 15 user plants)
Chloroprene (3 plants)
Acrylonitrile (5 production and 25 user plants)
Ethylene dichloride (18 production plants)
Vinyl chloride (production and chemical specialty plants)
Maleic anhydride (7 production and many specialty user plants)

II. Emissions related to specific industries and many users

Formaldehyde (wood products, chemical specialties)
Manganese (ferro and silico alloys, power plants, iron and steel plants, foundries)
Nickel (power plant oil combustion)
Nitrobenzene (cellulose ether and petroleum plants)
Beryllium (power plant coal consumption)
Cresols (wire coating plants, coke ovens, mining sites)
Radionuclides (power plant coal consumption)
Chromium (refineries, steel plants, cement plants)
Mercury (power plant coal combustion, incinerators, mercury and zinc refineries)
Cadmium (iron and steel plants, copper and zinc smelters)
Asbestos (production plants, building demolitions)
Arsenic (copper smelters, glass plants, refining plants)
Benzene (petrochemical plants, coke ovens, gasoline refineries)
Vinylidene chloride (chemical specialty plants)

(continued)

TABLE 6 (continued)

III. Emissions related to population density

Dioxin (use of wood preservatives, incinerators)
Formaldehyde (wood products in homes)
Methyl chloroform (degreasing)
Methylene chloride (paint remover, degreasing)
Nitrosomorpholine (vicinity of morpholine emissions, mainly boiler corrosion inhibitors, and polishes and waxes)
Nickel (oil combustion, including diesel)
Toluene (paints and adhesives)
Trichloroethylene (degreasing and cleaning)
Xylenes (adhesives, household products, pesticides)
Carbon tetrachloride (miscellaneous household and commercial products)
Chlorobenzene (cold cleaners, pesticides)
Chloroform (solvent in pharmaceuticals and pesticides)
Cresols (disinfectant/cleaning compounds)
p-Dichlorobenzene (space deodorant, moth control)
Perchloroethylene (dry cleaning, metal cleaning)
Arsenic (coal combustion, pesticide use)
Asbestos (building demolition)

IV. Emissions related to motor vehicle use

Toluene
Xylene
Benzene
Asbestos

TABLE 7. SUGGESTED ANALYSIS METHODS FOR APPLICABLE SAMPLING MEDIA

Organic pollutant	Sample collection media*				
	Tenax-GC	Charcoal	Impinger	PUF**	Other
Acetaldehyde			1		2 (Bubbler reagent)
Acrolein			1		
Acrylonitrile					3 (Canister, mole sieve)
Allyl chloride					3 (Canister, cryogenic)
Benzene	3				
Benzyl chloride	4,5				4,5 (Canister)
Carbon tetrachloride	4,5				4,5 (Canister)
Chlorobenzene	4,5				4,5 (Canister)
Chloroform	5,6				
Chloroprene	4,5				
o-,m-,p-Cresol	4,5		4,5	4,5	
p-Dichlorobenzene	4,6				6 (Cryogenic)
Dimethylnitrosamine	7				7 (Thermosorb-N)
Dioxin					4 (Submicron filter)
Epichlorohydrin	4,5				4,5 (Cryogenic)
Ethylene dichloride					4,5 (Cryogenic)
Ethylene oxide		4,5			4 (Canister)
Formaldehyde			1		2 (Bubbler reagent)
Hexachlorocyclopentadiene	4,5			4,5	6 (Porapak T)
Maleic anhydride					None available
Methyl chloroform	4,5				4,5,6 (Canister)
Methylene chloride					4 (Canister, mole sieve)
Nitrobenzene	4,5				4,5 (Canister)

(continued)

* Analysis method:
1. Spectrophotometric
2. Derivitization, high performance liquid chromatograph
3. Gas chromatograph/flame ionization detector
4. Gas chromatograph/photoionization detector
5. Gas chromatograph/mass spectrometry
6. Gas chromatograph/electron capture detector
7. Gas chromatograph/thermal emission analyzer
8. High performance liquid chromatograph

** Polyurethane foam.

TABLE 7 (continued)

Organic pollutant	Sample collection media*				
	Tenax-GC	Charcoal	Impinger	PUF**	Other
Nitrosomorpholine					8 (Thermosorb-N)
Perchloroethylene	4,5				4,5 (Canister)
Phenol	4,5		5		
Phosgene					Field analysis only, due to instability of compound
PCBs				5,6	6 (Florosil)
Propylene oxide	4,5				4,5 (Cryogenic)
Toluene	4,5				4,5 (Cryogenic)
Trichloroethylene	6				6 (Cryogenic)
Vinyl chloride	4,5				4,5 (Cryogenic)
Vinylidene chloride	4,6				4,6 (Cryogenic)
o-,m-,p-Xylene	4				

Inorganic pollutant	Sample media	
	Hi-vol filter	Other
Arsenic	1	
Beryllium	1	
Cadmium	1	
Chromium	1	
Manganese	1	
Nickel	1	
Asbestos		Microscopy (millipore filter)
Radionuclides		α, β, and γ spectroscopy (millipore filter)
Mercury		Atomic absorption spectrometry (silver wool)

* Analysis method:
1. Spectrophotometric
2. Derivitization, high performance liquid chromatograph
3. Gas chromatograph/flame ionization detector
4. Gas chromatograph/photoionization detector
5. Gas chromatograph/mass spectrometry
6. Gas chromatograph/electron capture detector
7. Gas chromatograph/thermal emission analyzer
8. High performance liquid chromatograph

** Polyurethane foam.

a predictable and reliable way. Cost of the media, sample preparation, and extraction are all necessary considerations when designing a sampling program.

- Procedure. The procedures listed in Table 7 primarily use collection on solid media--either filters, Tenax-GC, or charcoal. Most of the information was extracted from the EPA "Technical Assistance Document for Sampling and Analysis of Toxic Organic Compounds in Ambient Air" (Riggin 1983). A more complete description of the sampling and analytical methods is provided in Appendix A of this document. Table 7 shows columns headed with the various collection media used for organic compounds. Suggested analytical methods for each compound are indicated by numbers that are identified in a footnote. A procedure for each phase of the sampling program must be written out in advance of the sampling activity in order to anticipate how each step is to be done. Phases of the sampling activity include preparation, field sampling, and sample analyses. Procedures must be written to describe media preparation, e.g., preconditioning, assembly (if necessary), sample handling, and analytical procedures to be followed. In addition to sample preparation and handling, a plan is needed for how much air must be sampled to obtain the amount of pollutant necessary to meet the minimum detectable limits of the analytical procedure. The volume of air necessary to sample can be determined by estimating the concentration of the pollutant in the ambient air and calculating what volume of air would contain the amount of pollutant necessary to meet the minimum detectable quantity attributed to the analytic procedure. A margin of safety should be added for less than 100 percent capture efficiency of the media. Consideration must be given to the possibility of collecting too much of a compound in a single sample tube, i.e., so that some of the material in the sample passes through. Considerable study has been directed to the breakthrough volume of Tenax. Breakthrough volume for a variety of volatile organic compounds has been reported by Krost et al. (1982). Estimated detection limits are also given for most of the compounds listed by Krost.

Determination of the volume of air to sample can be shown using the following simple example. Assume that the detection limit for a compound is 15 ng per ml and the compound is extracted into 5 ml of solvent. The sample would need to contain 75 ng of the pollutant in order to be detectable. Assume the concentration of the pollutant in the atmosphere typically ranges from 5 to 25 ng/m^3. The volume of air to be sampled would range from 3 m^3 in areas of high concentration to 15 m^3 in areas where low concentrations exist. If the sample media were only 80 percent effective in capturing the pollutant, the volume of air to be sampled would be increased by 25 percent. Unfortunately, the capture efficiencies of sampling media are not readily available for many of the compounds of interest. It may be necessary to assume collection efficiencies much lower than 80 percent.

AIRBORNE TOXICITY

Table 8 presents recent information on the toxicity of the 43 pollutants listed in Table 1. The reason for providing these data is to assist monitoring planners in setting priorities for selecting monitoring sites oriented to certain pollutants. Sites that measure pollutants for which toxic effects are dubious or for which the expected ambient concentration is low relative to toxic levels, can be assigned a low priority. When funds limit the number of sites that can be set up and the number of samples that can be collected and analyzed, these data may be helpful.

The toxicity effects of greatest concern relate to severe body cell irregularities, including carcinogencity and mutagenicity. For 13 of these compounds, other toxic effects are of concern. Seven of the listed compounds, including arsenic, asbestos, benzene, chromium, nickel, radionuclides, and vinyl chloride, are known carcinogens. Two of these, radionuclides and vinyl chloride, are also mutagens. For all of the others, the evidence on carcinogenicity and mutagenicity varies from completely unknown to probable but uncertain. Two of the compounds, acrolein and phosgene, are known to be not carcinogenic but to have other toxic effects.

TABLE 8. TOXICITY OF NONCRITERIA AIR POLLUTANTS

Pollutant	Carcinogen'city*	Mutagenicity	Other effects
Acetaldehyde	No data	Mutagenic in drosophila; no human data	
Acrolein	Current information indicates acrolein is not a carcinogen or cocarcinogen	Cytotoxic in short-term tests; mutagenic in short-term tests	Potent respiratory irritant at 30-100 ppm
Acrylonitrile	Probably carcinogenic to humans although evidence is limited; sufficient evidence in experimental animals	Sufficient evidence in short-term tests	
Allyl chloride	Inadequate data	Mutagenic in E. coli; no human data	
Arsenic	Sufficient evidence in humans	Increased chromosomal aberrations in exposed humans	
Asbestos	Sufficient evidence in humans	No data	
Benzene	Sufficient evidence in humans	Not mutagenic, but produces chromosomal aberrations in short-term tests (mammalian cells) and in humans	
Benzyl chloride	Inadequate evidence in humans; limited evidence in experimental animals	Mutagenic in short-term tests; no data on humans	
Beryllium	Limited evidence in humans; sufficient evidence in experimental animals	Inadequate evidence	
Cadmium	Limited evidence in humans; sufficient evidence in experimental animals	Inadequate evidence	
Carbon tetrachloride	Inadequate evidence in humans; sufficient evidence in experimental animals	Inadequate evidence	

(continued)

* "Sufficient evidence" of carcinogenicity indicates a causal relationship between the agent and cancer.
"Limited evidence" indicates that a causal interpretation is credible, but that alternative explanations such as chance, bias of review board, or confounding could not adequately be excluded.
"Inadequate evidence" indicates one or more of the following: few pertinent data; available studies showing evidence of association did not exclude change, bias, or confounding; and studies were available that do not show evidence of carcinogenicity.
The classification of any chemical may change as new information becomes available.

TABLE 8 (continued)

Pollutant	Carcinogenicity*	Mutagenicity	Other effects
Chlorobenzene	Inadequate evidence to assess carcinogenic risk	No data	
Chloroform	Inadequate evidence in humans; sufficient evidence in experimental animals	Inadequate evidence	
Chloroprene	Inadequate evidence in humans and experimental animals	Mutagenic in short-term tests; produces chromosomal abnormalities in humans	
Chromium	Sufficient evidence in humans	Cr VI mutagenic in short-term tests; Cr VI produces chromosomal abnormalities in humans	
o-,m-,p-Cresol	No evidence	No evidence	Corrosive to skin and mucous membrane
p-Dichlorobenzine	Inadequate data in humans and animals	Inadequate data	
Dimethylnitrosamine	Sufficient evidence in experimental animals	No data	
Dioxin (TCDD)	Inadequate evidence in humans; sufficient evidence in animals	Inadequate evidence	Extremely high acute toxicity
Epichlorohydrin	Inadequate evidence in humans; sufficient evidence in experimental animals	Mutagenic in short-term tests	Limited evidence of reproductive toxicity
Ethylene dichloride	Carcinogenic in experimental animals; no human data	Mutagenic in short-term tests	
Ethylene oxide	Inadequate evidence in humans and experimental animals	Mutagenic in short-term tests; chromosomal aberrations in exposed workers	
Formaldehyde	Inadequate evidence in humans; sufficient evidence in experimental animals	Mutagenic in short-term tests	
Hexachlocyclo-pentadiene	No data	No data	Potent irritant; burns upon contact with skin
Maleic anhydride	No data	No data	Upper respiratory irritant, eye irritant; with ambient concentrations above 2.5 ppm, extreme acute irritation

(continued)

* "Sufficient evidence" of carcinogenicity indicates a causal relationship between the agent and cancer.
"Limited evidence" indicates that a causal interpretation is credible, but that alternative explanations such as chance, bias of review board, or confounding could not adequately be excluded.
"Inadequate evidence" indicates one or more of the following: few pertinent data; available studies showing evidence of association did not exclude change, bias, or confounding; and studies were available that do not show evidence of carcinogenicity.
The classification of any chemical may change as new information becomes available.

TABLE 8 (continued)

Pollutant	Carcinogenicity*	Mutagenicity	Other effects
Manganese	No data	No data	Manganese poisonings have been associated with mining; chronic disease not fatal; reports of neurological disorders
Mercury	No evidence in humans	No data available on humans	Associated with neurological disorders in humans
Methyl chloroform (1,1,1-trichloroethane)	Inadequate data	Limited data in short-term tests	
Methylene chloride (dichloromethane)	Inadequate evidence in humans and experimental animals	Limited evidence	
Nickel	Sufficient evidence in humans; limited evidence in nickel and certain nickel compounds in humans, but sufficient evidence in experimental animals	Inadequate evidence	
Nitrobenzene	Unknown, but being tested in fiscal year 1983	Unknown, but being tested in fiscal year 1983	A few ml of liquid can be lethal to humans; produces cyanosis and blood disorders
Nitrosomorpholine	Sufficient data in experimental animals	No data	
Perchloroethylene (tetrachloroethylene)	Inadequate evidence in humans; limited evidence in experimental animals	Inadequate evidence	
Phenol	No data	No data	Marked corrosive effect on any tissue; can cause severe eye damage and blindness; skin contact causes severe burns
Phosgene	No known carcinogenic effects		Extremely toxic gas; can cause death by suffocation or heart failure
Polychlorinated biphenyl	Inadequate evidence in humans; sufficient evidence in experimental animals	Inadequate evidence	

(continued)

* "Sufficient evidence" of carcinogenicity indicates a causal relationship between the agent and cancer.
"Limited evidence" indicates that a causal interpretation is credible, but that alternative explanations such as chance, bias of review board, or confounding could not adequately be excluded.
"Inadequate evidence" indicates one or more of the following: few pertinent data; available studies showing evidence of association did not exclude change, bias, or confounding; and studies were available that do not show evidence of carcinogenicity.
The classification of any chemical may change as new information becomes available.

TABLE 8 (continued)

Pollutant	Carcinogenicity*	Mutagenicity	Other effects
Propylene oxide	Inadequate evidence in humans and experimental animals	No data	Adverse effects to humans; injury to eyes and skin
Radionuclides	Increased risk of lung cancer, leukemias, and other cancers, depending on lifetime dose rates and biological half-lifes of specific radionuclides	Genetic damage to persons directly exposed and also their progeny, causing genetic impairment of live-born offspring or fetal death	
Toluene (ortho)	Inadequate evidence in humans; sufficient evidence in experimental animals	Sufficient evidence in short-term tests; no human data available; no increase in chromosome aberrations	Central nervous system
Trichloroethylene	Inadequate evidence in humans; limited evidence in experimental animals	Inadequate evidence in short-term tests; no data on humans	
Vinyl chloride	Sufficient evidence in humans	Sufficient evidence in humans	
Vinylidene chloride	Inadequate evidence in humans; limited evidence in experimental animals	Sufficient evidence in short-term tests; no data available in humans	
o-,m-,p-Xylene	No evidence	No evidence	Vapor causes irritation of eyes, nose, and throat; exposure to high concentrations causes reversible kidney and liver damage

* "Sufficient evidence" of carcinogenicity indicates a causal relationship between the agent and cancer.
"Limited evidence" indicates that a causal interpretation is credible, but that alternative explanations such as chance, bias of review board, or confounding could not adequately be excluded.
"Inadequate evidence" indicates one or more of the following: few pertinent data; available studies showing evidence of association did not exclude change, bias, or confounding; and studies were available that do not show evidence of carcinogenicity.
The classification of any chemical may change as new information becomes available.

SECTION 4

SITING PROCEDURES

To assist in selecting monitoring sites, specific procedures have been developed for different scales of air quality representativeness. A description follows of what scales of representativeness may occur, how to identify what scales of representativeness are applicable to a specific area of monitoring responsibility, and some recommended guidelines for locating monitors for each scale.

REPRESENTATIVE TYPES OF MONITORING SITES

Spatial Scales of Representative Air Quality Levels

Because the air quality measured at a single site is based on a sample of air from a very small volume, it is useful to know over how large an area this value can be considered representative. The concept of representative spatial scale is used to designate this area. The spatial scale of representativeness means the physical dimensions of the area within which a monitoring station is located that pollutant concentrations are reasonably similar.* The following five scales are defined in Appendix D of Part 58, Title 40 of the Code of Federal Regulations:

- Microscale--defines the concentrations in air volumes associated with area dimensions ranging from several meters up to about 100 m.
- Middle Scale--defines the concentration typical of areas up to several city blocks in size with dimensions ranging from about 100 m to 0.5 km.
- Neighborhood Scale--defines concentrations within some extended areas of the city that have relatively uniform land use with dimensions in the range of 0.5 to 4.0 km.
- Urban Scale--defines the overall citywide conditions with dimensions on the order of 4 to 50 km. This scale would usually require more than one site for definition.
- Regional Scale--defines usually a rural area of reasonably homogeneous geography and extends from tens to hundreds of kilometers.

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* Similar means extreme concentrations are within 25% of the mean for the area. If larger values occur, the area would need to be subdivided until this similarity criterion is met.

Relevant Representative Spatial Scales

As described above, the spatial scales of representativeness depend on the spatial variability of air quality levels. Observable physical properties that primarily determine air quality levels are the sources, air movements, and atmospheric transformation and depletion processes. In Section 3, there are data and methods to characterize data that may be used to estimate these determinants of air quality. Experience suggests that a good emission inventory is the most useful single factor in estimating air quality levels. Additional needed information includes a climatological summary of the combined influences of wind direction, wind speed, and atmospheric stability and an estimate of rapid removal processes (e.g., coarse particulate matter settles out of the air quickly, and highly reactive chemicals transform to other substances quickly).

In each monitoring area, the locations and emission rates of sources for each pollutant of concern need to be identified as well as possible. Table 4 may provide some help in identifying sources, and Table 6 suggests prototypes of source configurations that are most likely to be associated with the 43 pollutants with which this report is primarily concerned. It would be convenient to link source configurations to representative air quality configurations. However, this requires that the meteorology of different areas of the country be relatively consistent. A review of annual surface wind roses in the Climatic Atlas of the United States (U.S. Department of Commerce 1968) shows this is not the case because patterns of wind direction are highly variable across the country. The next best alternative is to devise a methodology for selecting monitoring sites that takes the local air quality pattern into account. A methodology has been developed for representative spatial scales. The air quality pattern will be related to the source pattern. The scale of interest with respect to a source pattern will depend on the monitoring objectives and may vary from determining the maximum effect to determining the maximum area within which a measurable impact can be detected. Table 9 suggests the range of representative scales that are of interest with respect to each of four types of source configurations. Because, for the pollutants of interest in this study, we are generally concerned with ground-level sources, there will always be a microscale area of maximum air quality level near or within the source configuration of primary concern. The extent to which larger scale air quality effects are also of interest will vary with the monitoring objectives.

OVERVIEW OF SITING PROCEDURES

A general method for selecting sampling sites is outlined in Figure 1. This procedure is applicable to all the representative spatial scales. The The monitoring agency must be able to present a strong argument that the data collected represent the real concentration pattern or exposure potential. Sampling locations will be selected to fulfill the monitoring agency's information needs, such as maximum concentration, frequency distribution of the typical concentrations, spatial variations of the concentration,

TABLE 9. REPRESENTATIVE SCALES APPLICABLE TO TYPES OF POLLUTANT SOURCES

Type of source	Representative scales
Isolated plant	Micro to neighborhood
Small area	Micro to neighborhood
Large area	Micro to urban
Traffic	Micro to urban

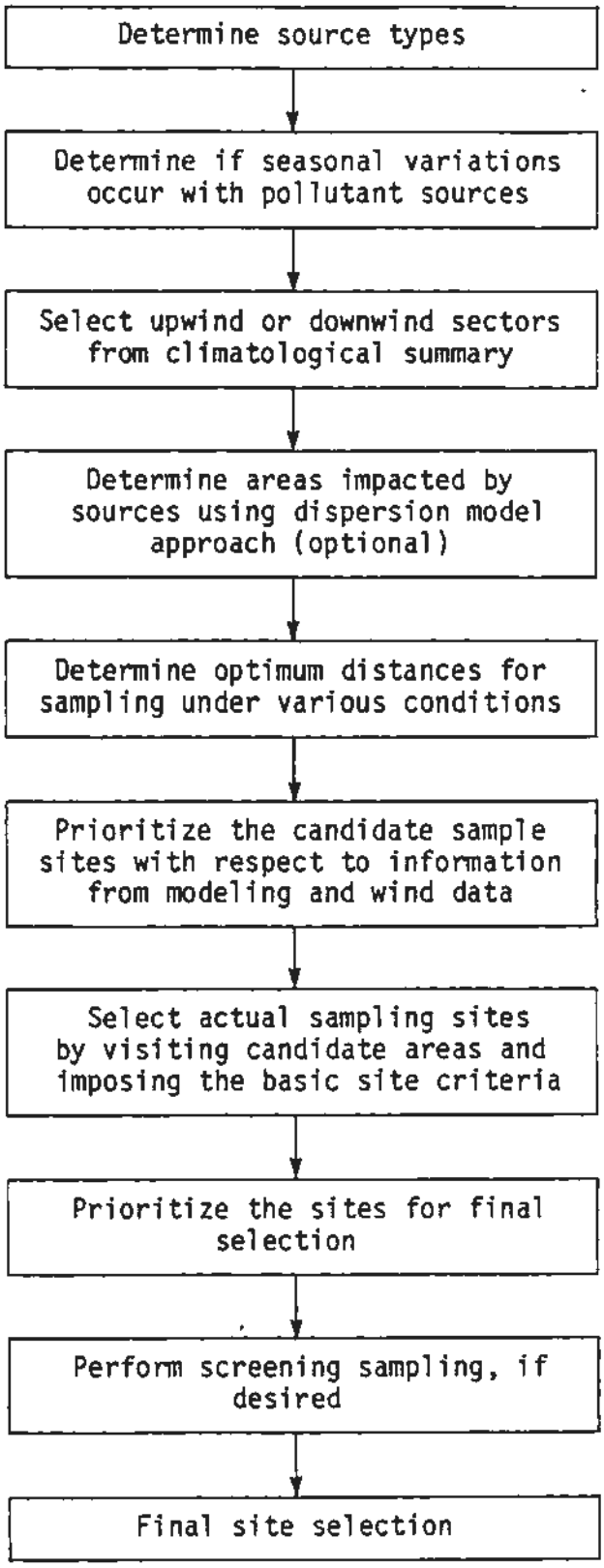


Figure 1. Site selection procedure.

etc. The objectives of the sampling activity must be clearly stated so the sampling strategy and locations can be selected to collect the most relevant information.

The first step in the site selection procedure is to determine sources. The logic that this step requires is depicted in Figure 2. The type of sources that will be encountered and their locations are combined with meteorological information in the next step of the procedure. A representative climatological wind summary is needed. A wind rose (see Figure 3) readily shows the prevalent wind directions and most frequent wind speed. From the wind data, the logical sectors for downwind (impact) or upwind (background) sites can be determined.

Dispersion modeling is a good way to analyze the available source and meteorological data in an objective manner to identify areas of relatively good and poor air quality. Model results may be used to define distances from sources to find maximum concentrations or the most frequently impacted areas, which is the next step in the procedure. Site selection can be narrowed down to zones within the sectors favored by wind direction and to zones within those sectors that will be impacted by emissions as indicated by modeling. A preliminary prioritization of candidate sites can be made based on the modeling information. However, the candidate areas should be viewed before final evaluation. A semifinal ranking of all locations can be finalized after preliminary or screening sampling has been performed.

The site selection procedure described above is appropriate to all sources in a general way but is most appropriate to sources that may be defined as point sources or small area sources. Depending on the spatial scale of the monitoring problem, an area source can be considered as a point source if the monitoring location is far enough downwind (e.g., on the order of 5 to 10 times the diameter of the area source). Monitoring area sources may require sampling sites along the perimeter of a well-defined small area source or sampling within the perimeter of a large area source.

The following criteria are recommended guidelines in the final site selection step:

- Locate the sampler in an area that has unobstructed air flow, especially in the direction of any recognized sources of the materials being sampled. Turbulence and eddys from obstructions will cause nonrepresentative results. The distance between the obstruction and the sampler should not be closer than two times the height of the obstruction.

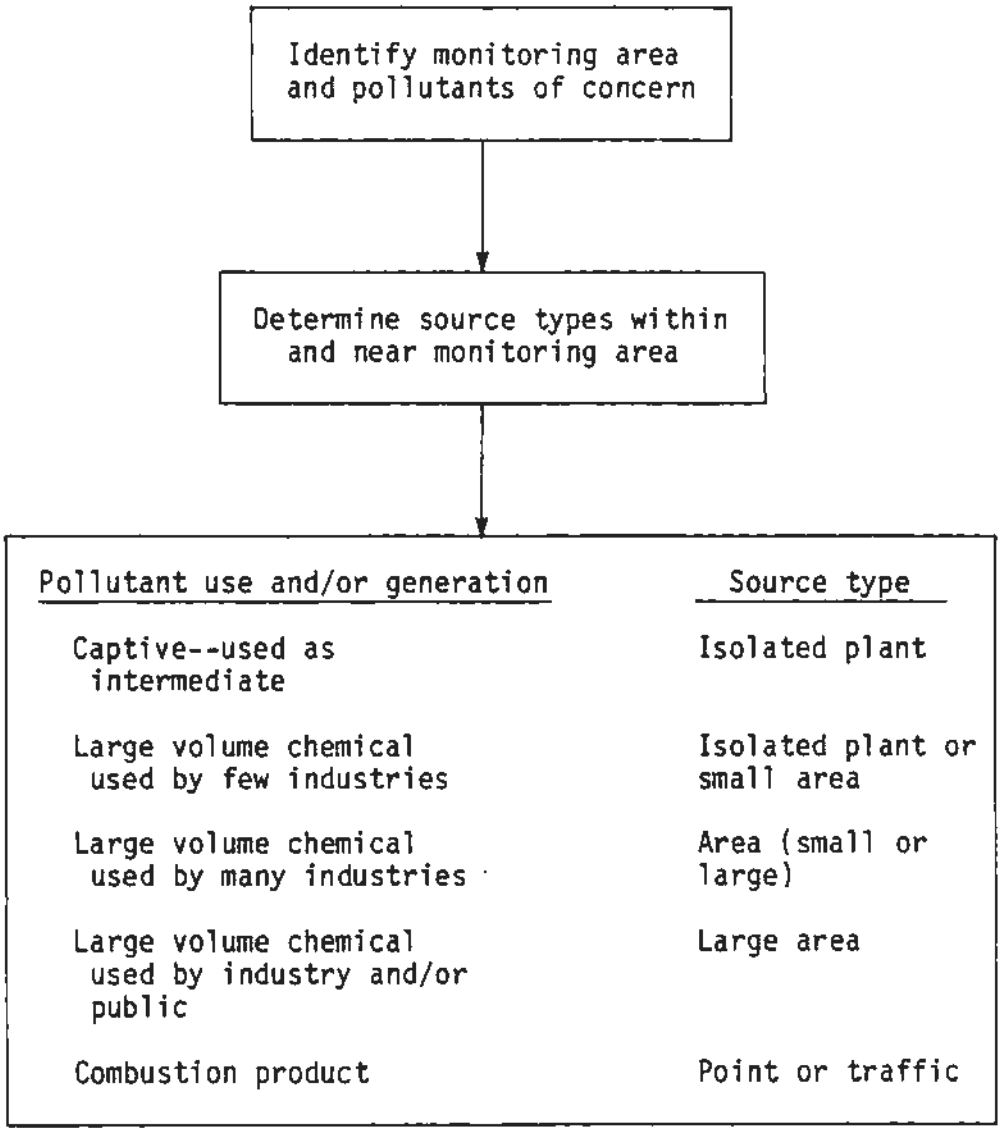


Figure 2. Source configuration.

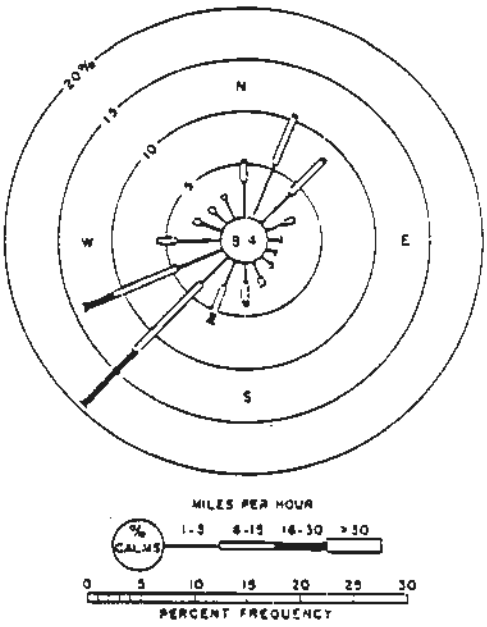


Figure 3. Wind rose.

- Avoid locations that will be unduly influenced by nearby sources or activities.

- Avoid locations where reactive surfaces may cause chemical changes in the air sampled.

- Be aware of micrometeorological influences due to nearby hills, bodies of water, valley drainage flow patterns, etc.

- Place the intake probe at a representative height. The guidance given for criteria pollutants is for probe height to be 3 to 15 m above ground level, as near to building height as possible but not where a building is an obstruction or the equipment is easily vandalized.

- The probe should extend at least 2 m from a supporting structure; if located on a building, it must be mounted on the windward side.

Monitoring site selection criteria should be the same in most regards whether the site will be used for a fixed station or for the nonfixed (mobile) site. Uniformity among the sites should be achieved to the greatest degree possible. Descriptions should be prepared for all sampling sites. The description, at a minimum, should include the type of ground surface; the direction, distance, and approximate height to any obstruction to airflow; and the direction and distance to any local pollutant sources (actual or potential). Photographs of the site are valuable for analysts who will not have firsthand knowledge of the site.

Monitoring Point and Isolated Area Sources

Once an isolated source of interest is identified, the preferred sampling locations are selected based on climatological data and perhaps dispersion modeling information. Representative wind data for an isolated area is especially important for plants that are built in a coastal area. Many of the chemical plants that are of concern for noncriteria air pollutants are built along the Gulf Coast where sea-breeze effects will be an important factor in sample site selection. An experienced meteorologist's advice will be necessary to interpret available data and to select the most suitable locations for downwind sampling. Accessibility to the desired locations may be a determining factor for final site selection; therefore, site visits will be necessary in order to ensure that monitoring is practical in the selected area.

For stack emissions, the sites should be selected to indicate the locations of ground impacts of the maximum concentrations. For area sources normally at or near ground level and that have no buoyancy, the maximum concentration will occur within a few meters of the downwind boundary of the source; therefore, sampling sites should be along the perimeter of the area source. If elevated point sources are combined with ground-level releases in the source configuration, dispersion modeling is recommended to indicate where the combined impact will cause the maximum concentration. A number of samples will be necessary in order to be confident that the small plume from a small source will impact the sampler. The dimensions of the area source will dictate how many samplers will be necessary to represent the maximum pollutant concentration. Judgment based on experience and knowledge of the character of the source will provide guidance on the number of samplers to place. If the source is not well characterized, more samples must be obtained. Also, if only one or a few isolated sources are present, the likelihood of the source impacting each sampling site is small; hence, more samplers are required. For pollutants that are very reactive, the downwind distance from the source should be kept to a minimum to avoid degradation of the pollutant due to chemical reactions.

Monitoring Large Area Sources

Characterizing the air quality resulting from a large number of small sources will be less difficult due to a higher probability of finding the areas of maximum impact. As with all site selection activities, the first steps are to characterize the sources of the pollutant as best as it can be done, and identify areas with the highest likelihood of maximum impact using climatological wind data and dispersion modeling. Special attention is needed to select sites that offer the most potential for adverse impact, e.g., maximum concentration or maximum population exposure. One problem is evaluating the frequency and magnitude of the pollutant emissions. The source with the highest emission rate and the greatest potential for adverse impact is a good starting point. Locations that have the potential to be affected by multiple sources, i.e., locations on the downwind edge of a large source area, are important. Which of these two types of locations will experience higher maximum concentrations or more frequent exposure to the pollutants may depend on the duration of the exposure time that is of concern.

Monitoring Irregular and Widespread Small Emissions

Pollutants used in small quantities by the general public or industries will require long-term sampling programs at locations where exposure may be a matter of special concern. Characterizing the exposure potential requires knowledge of when and where the pollutant will be generated or emitted so that a minimum of unnecessary sampling is done. The best judgment must be made of where and when to sample at sites that conform to good siting criteria with respect to the expected sources. With the probability of the pollutant occuring in a low concentration, the sites selected should avoid areas where high concentrations of other compounds may interfere with the analysis of the pollutant specifically being sought.

Pollutants that are frequently used in small quantities by industry and the public will be nearly ubiquitous. Site selection will depend upon the resources available to carry out the sampling program. Sampling sites should be placed in as many locations as necessary to describe the population exposure. Sampling sites selected should be within populated areas and afford the most representative site that can be obtained over a neighborhood or urban scale area.

SITING PROCEDURES FOR REPRESENTATIVE SPATIAL SCALES

In the preceding section, it was recommended that spatial scales of interest to a specific area of concern be defined by considering types of source configurations and monitoring objectives. Procedures for selecting monitoring sites are presented for the following scales of sites:

- Urban scale
- Neighborhood scale
- Microscale or middle scale.

Urban Scale Sites

A methodology for selecting sites that represent urban scale air-quality levels is presented in Figure 4. In general the method consists of identifying the largest area with which effects of interest may occur, eliminating areas that are not representative of urban scale effects, and emphasizing areas that are representative of high concentrations over widespread areas.

The first step is to assemble data. Seven specific types of data that will be useful are listed in Figure 4. Because urban scale effects are of interest, emissions are possible over a large area and from many sources. The locations and emission rates of sources need to be identified. If a local compilation is not available and cannot be made, information from the following sources may be helpful:

- EPA data bases (e.g., NEDS and NESHAPS)
- State emission inventory
- New source registration/application files
- Table 4 of this report
- EPA reports (e.g., Suta 1979).

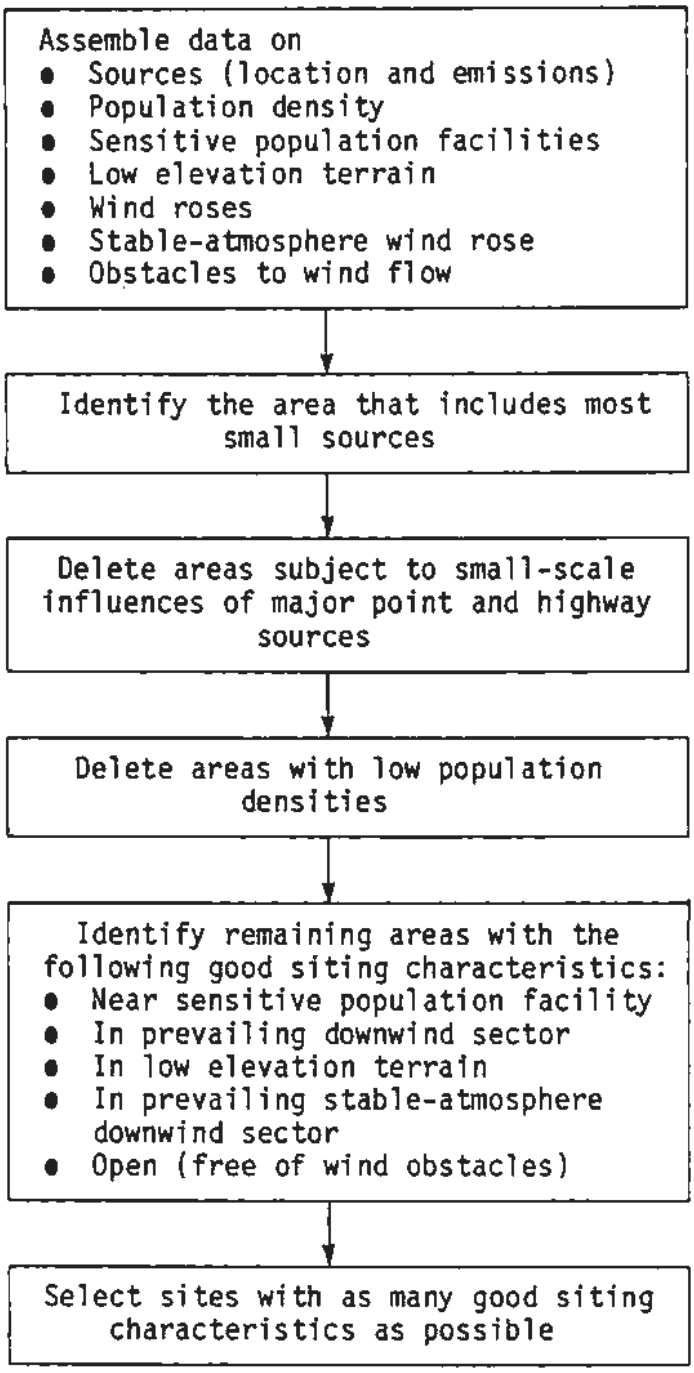


Figure 4. Steps for locating an urban scale site.

Data on population density can be determined from land-use maps available from local urban planning agencies, zoning commissions, and similar types of organizations. U.S. Census data of population densities in small sub-tracts will also be helpful, but it does not reflect the daytime population distribution. The locations of sensitive population facilities (e.g., hospitals, nursing homes, day care centers, elementary schools) can be located using telephone yellow pages if they are not identified on local maps.

Topographical maps are valuable for showing the locations of low-lying and elevated terrain. The information assembled can be conveniently summarized using either topographical (e.g., U.S. Geological Survey maps) or land-use maps.

Information on wind flow is best obtained from wind roses (i.e., a graphical display showing the frequency of occurrence of wind directions). If possible, wind roses for the occurrence of stable atmospheric conditions and light wind speeds should be obtained in addition to a local annual wind rose for surface winds. These are available from the National Climatic Data Center (NCDC) in Asheville, North Carolina, or they may be compiled from an available source of local wind observations. Before wind data not obtained from a National Weather Service (NWS) station is used, a meteorologist should be consulted to determine whether the measured winds are representative of pollution transport over the urban scale area. In fact, a meteorologist should be consulted on the representativeness of any wind data for the scale or location of interest.

Because buildings, trees, and prominent terrain can obstruct air flow, the locations of such air flow obstructions need to be noted in selecting monitoring sites. Aerial photographs and visual inspections of areas to be monitored are usually adequate to identify unsuitable sites.

After data relevant to characterizing the air quality pattern is assembled, an analysis can be made of representative and nonrepresentative monitoring locations. A characteristic of the sources when an urban scale effect is representative is many small sources over a large area. If there are one or more predominantly large sources, there may not be a well-defined urban scale effect. In this case, neighborhood and small-scale siting are more appropriate.

The area surrounding most of the small sources that make up the large source area should be delineated as the first step of the analysis. If this area is less than about 5 km in diameter, urban scale air-quality levels will occur outside the source area. Otherwise, an appropriate urban scale monitoring site should be sought within the source area.

Additional steps should be taken to identify locations that have either desirable or undesirable representation characteristics. Locations close to major sources (e.g., high-traffic roadway or relevant processing

plants) are to be avoided. Locations in deserted areas and areas that are entered infrequently day or night do not demonstrate population exposure hazards and are to be avoided. Desirable location characteristics include high population density (day and/or night); sensitive populations (e.g., hospitals, child day care centers, retirement homes, etc.); susceptible to air pollution episodes (e.g., low lying; downwind of the source area during stable, light wind conditions); and free of prominent building and terrain influences.

A useful guide to selecting desirable sites is to mark areas for each desirable and undesirable characteristic on a map that also shows the source area. Areas that have the most desirable siting characteristics and no undesirable characteristics can be easily designated. These areas can be further reviewed by visual inspection and by mobile or temporary monitoring.

The following guidelines are offered to help identify desirable and undesirable monitoring areas:

Ground-Level Stationary Source Influence--

There are no absolute rules as to how far away the emissions from a stationary source are significant. One limitation is the detection-sensing threshold of available monitoring techniques. Another limitation is the horizontal gradient of concentrations, because once the gradient approaches the gradient of ambient concentrations, the effects of the source are no longer detectable. Through the use of optimum sample collection media and analytical instruments, detection-sensing thresholds need not be a limitation. Recommended monitoring techniques for many of the NCAPs of interest are given in Appendix A. As an example, a detection threshold of 5 ng/m^3 means that a source strength of 0.1 mg/sec (about one third of an ounce per day, or less than 10 g, per day) is detectable within a 130-m wide swath at a distance of 1 km from the source (i.e., assuming neutral stability and a 2 m/sec wind speed blowing from the source toward the sampler for an hour). The variations in ambient concentrations that can be expected in urban areas are shown by the data collected by Singh et al. (1982). For convenient reference, these observations are presented in Appendix B. For toluene, hour-to-hour variations are shown to be as great as 20 $\mu g/m^3$. For most other pollutants, the hour-to-hour variations are more typically 2 $\mu g/m^3$ or less. Table 10 shows maximum distances from sources that a contribution can be measured for given ratios of the source contribution to the source strength. In many cases the ratio of ambient variations to source strength will not be known, but 10^{-4} may be a reasonable expectation. Based on the results in Table 10, locations within 1.3 km of such stationary sources will not represent urban scale air quality during the night. The data in Table 10 suggest that the distance to which a source can have a significant impact on ambient concentrations is highly variable and can be quite large. The data in Table 11 may be used to help estimate ambient concentration variations and source strengths that need to be considered for many of the pollutants of concern. By inspection of the data shown in Appendix B, it appears 10 to 20 percent of the mean of the

TABLE 10. MAXIMUM DISTANCE FOR SELECTED RATIOS OF MONITORED CONCENTRATION TO SOURCE STRENGTH

Ratio of monitored concentration to source strength (s/m^3)	Distance (km) for stability class*		
	C	D	E
10^{-3}	0.14	0.2	0.3
$3x10^{-4}$	0.3	0.4	0.7
10^{-4}	0.5	0.8	1.3
$3x10^{-5}$	0.9	1.8	2.8
10^{-5}	1.7	3.7	6.1

* Assumes wind speed of 2 m/s. Based on data in Workbook of Atmospheric Dispersion Estimates (Turner 1970).

TABLE 11. AMBIENT CONCENTRATIONS AND EMISSION FACTORS

Pollutant	Observed urban concentrations* (ng/m^3)	Typical emission factors†
Benzene	4800-15000	0.13 g/mi from motor vehicles§
Methylene chloride	1400-6300	1.8 lb/yr per person
Chloroform	0-730	Production 0.11%; solvent use 100% (7% of product)
Carbon tetrachloride	820-1700	Production 0.22%; solvent use 100% (8% of product)
Methyl chloroform	1500-5500	100.0% most degreasing and solvent uses
Vinylidene chloride	11-30	Unknown
Trichloroethylene	250-1800	87 lb/day from open top vapor degreasing operations
Perchloroethylene	1100-4800	1.6 lb/yr per person for dry cleaning, 12 lb/day from vapor degreasing operations
Chlorobenzene	510-4100	0.32% production, 0.04 g/s at cold cleaning operations
p-Dichlorobenzene	0-1600	0.72% production, 0.22 lb/yr per person
Formaldehyde	0-3300	0.48% of usage
Phosgene	120-130	0.018% production
Acrolein	9200-21000	0.11% production
Nitrobenzene	0-460	2.8% of cellulose production, 1 $lb/10^3$ bbl crude oil capacity
Dimethylnitrosamine	25-28	0.2% of dimethylamine production
Toluene	17000-57000	0.38 g/mi from motor vehicles, 3.7 lb/yr per person from solvents
o-Xylene	2800-10000	0.6 lb/yr per person from solvents, 0.035 g/mi from motor vehicles
m-,p-Xylene	6100-23000	1.6 lb/yr per person from solvents, 0.074 g/mi from motor vehicles
Phenols	120-120	0.22% production

* 25th and 75th percentiles of compiled observations (Brodzinsky 1982).
† From EPA, OAQPS compilation entitled "Human Exposures to Atmospheric Concentrations of Selected Chemicals" (Systems Applications, Inc., 1980).
§ Assumes benzene is one-third of toluene emission rate (Bucon, Macko, and Toback 1978)

observed range is a reasonable estimate of expected hour-to-hour variations in ambient concentrations. Data observed at urban locations for each of the pollutants listed in Table 11 are also available (e.g., see Brodzinsky et al. 1982).

Mobile Source Influence--

Mobile source emissions are by nature less concentrated than stationary source emissions, because they are spread over a line rather than emitted from a single point. As a result, the concentrations of pollutants from mobile sources are lower and decrease less rapidly with distance. Both these effects result in a more homogeneous effect on urban scale air quality at distances closer to highways than to stationary sources. Figure 5 shows how concentrations vary downwind of a typical high-traffic urban highway. The values shown are representative effects of toluene emissions from automobiles, as computed by the EPA HIWAY2 model. These results suggest that 150 m from the highway, the gradient of concentrations from the highway emissions has become nearly flat and thus spatially homogeneous. As a further guideline, the concentration with travel distance from a line source was examined for a range of typical meteorological conditions. The ratio of the minimum concentration of interest to the estimated highway emission rate was used to determine how far from the highway an urban scale monitor must be located. In most cases, 0.5 km from the most dense traffic roads will be an adequate distance for an urban scale site.

Population Density--

Data from the most recent U.S. Census can be used to identify high density residential areas. Land-use and zoning maps prepared by metropolitan planning commissions are good sources of nonresidential, high-population access areas and remote areas with very low population access. The types and forms of census data available for a specific area can be determined by contacting the Bureau of the Census (Data User Service Division, Customer Services (Publications), Washington, D.C. 20233).

Sensitive Population Facilities--

Sensitive population facilities can be located by consulting common references such as local directories and public service organizations. The number of people accommodated and the hours of operation may also be of interest, as well as location of each facility, because this additional information is easily acquired.

Prevailing Downwind Sector--

Next to an emission inventory, a climatological summary of wind directions is the most useful information for selecting monitoring sites. The frequency of occurrence of wind direction on an annual basis or for any specific time period or special condition (e.g., by atmospheric stability

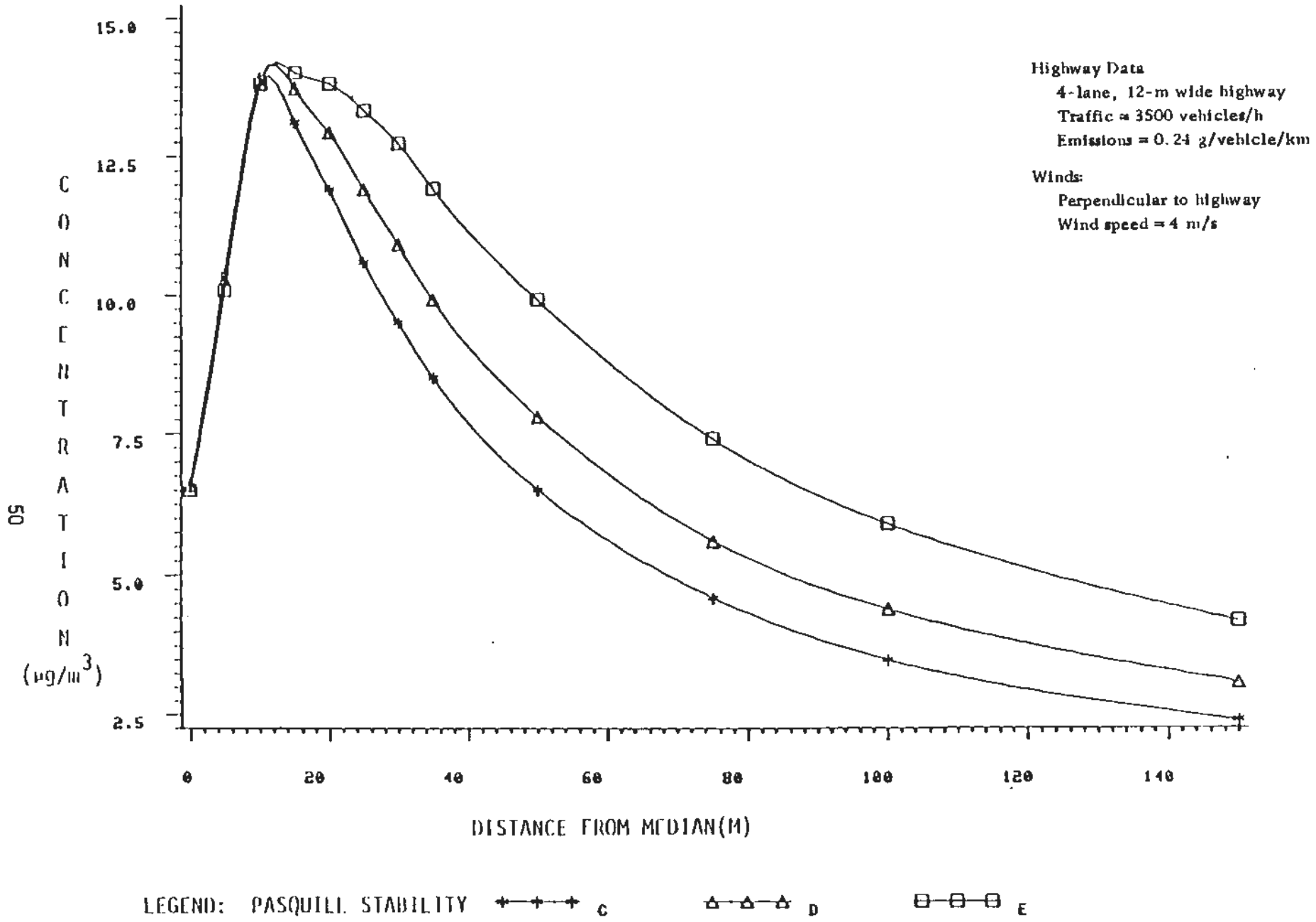


Figure 5. Concentration as a function of stability class, computed using HIWAY2 model.

class) can be tabulated from hourly observations or obtained from the National Climatic Data Center for National Weather Service observing stations. The stability data from NCDC are particularly convenient for this purpose. Table 12 shows an example of the type of data that can be requested. In this example, the relative frequency of occurrence of 16 wind direction classes are given for six wind speed classes and Pasquill class D stability (i.e., as defined by Turner 1964 for standard NWS observations). For NWS data observations collected since 1964, the wind direction can be tabulated by 10° intervals instead of 16 compass point classes. If air quality observations are based on samples collected for 24 hours, a more useful tabulation of wind data is the frequency of occurrence of classes of 24-hour resultant wind directions (see Figure 6). It is a good idea to limit the resultant wind tabulation to days that the wind direction is reasonably persistent as defined by a wind persistence indicator, calculated by taking the ratio of the resultant to the 24-hour arithmetic mean wind speed. In Figure 6 the data are limited to days with a wind persistence indicator of 0.85 or greater.

A tabulation in the format of Table 12, including all stabilities, is recommended to identify the prevailing downwind direction for 1-hour sampling periods. Figure 7 illustrates how the prevailing wind direction and the identified source area may be combined to define the prevailing downwind sector of the source area. The first step is to determine by visual inspection the longest trajectory line across the source area that is parallel to the prevailing wind. In this example, 75 percent of this distance is chosen as a high-exposure distance. All locations that have an upwind trajectory of at least this length are identified as the high-exposure areas.

Prevailing Stable Light Downwind Sector--

The preceding discussion places emphasis on finding a frequently exposed monitoring site. Another area of concern is that exposed to the highest concentrations regardless of frequency. For ground-level sources, this will be periods of low wind speed and a stable atmosphere. Under these conditions, the pollutant remains in the vicinity of its source or slowly drifts with the circulation created by the thermodynamic influence of the city on the otherwise stagnant air. The prevailing wind direction during a stable atmosphere (Pasquill classes E and F) and light wind speeds (i.e., less than 2 m/s) can be determined using a data tabulation such as the one shown in Table 12 for E and F stability combined. It is interesting to note that, for the distribution in Table 12 under the column for the totals of all wind speeds, northwest is the prevailing wind direction. However, for the 0 to 3 knot wind speed column, southeast is the prevailing wind direction.

TABLE 12. EXAMPLE OF THE FREQUENCY OF OCCURRENCE OF WIND DIRECTIONS FOR NEUTRAL ATMOSPHERIC STABILITY

ANNUAL RELATIVE FREQUENCY DISTRIBUTION STATION: 14910 ALEXANDRIA, MINN 52-54 24 095

	SPEED (KTS)*						
DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.001073	0.002133	0.008721	0.008988	0.002590	0.001485	0.024990
NNE	0.001045	0.001600	0.005636	0.007084	0.002780	0.000728	0.018868
NE	0.001243	0.003085	0.008340	0.004760	0.001523	0.000571	0.019523
ENE	0.000634	0.002171	0.007693	0.010092	0.003694	0.002437	0.026722
E	0.001045	0.002361	0.008873	0.008988	0.003466	0.001523	0.026256
ESE	0.001341	0.004189	0.016909	0.022012	0.004189	0.000647	0.049288
SE	0.002921	0.004532	0.017160	0.020413	0.003009	0.000331	0.048355
SSE	0.001820	0.002628	0.016681	0.024107	0.005332	0.000952	0.051519
S	0.001472	0.002095	0.009369	0.019575	0.004951	0.000647	0.038108
SSW	0.000717	0.001447	0.008074	0.019004	0.003808	0.000533	0.033583
SW	0.001544	0.001942	0.007617	0.009102	0.002018	0.000724	0.022947
WSW	0.000526	0.001638	0.004646	0.006465	0.001904	0.000647	0.016026
W	0.000941	0.001904	0.007883	0.013862	0.005256	0.002018	0.031865
WNW	0.000751	0.001333	0.014586	0.034770	0.017825	0.010473	0.079738
NW	0.002140	0.003389	0.016376	0.035960	0.019270	0.006741	0.086876
NNW	0.000856	0.011425	0.011425	0.020565	0.009064	0.002552	0.047052
TOTAL	0.020070	0.039036	0.169929	0.258946	0.090677	0.033057	

RELATIVE FREQUENCY OF OCCURRENCE OF D STABILITY = 0.621715

RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH D STABILITY = 0.002932

* Multiply by 0.51 to determine speed in m/s.

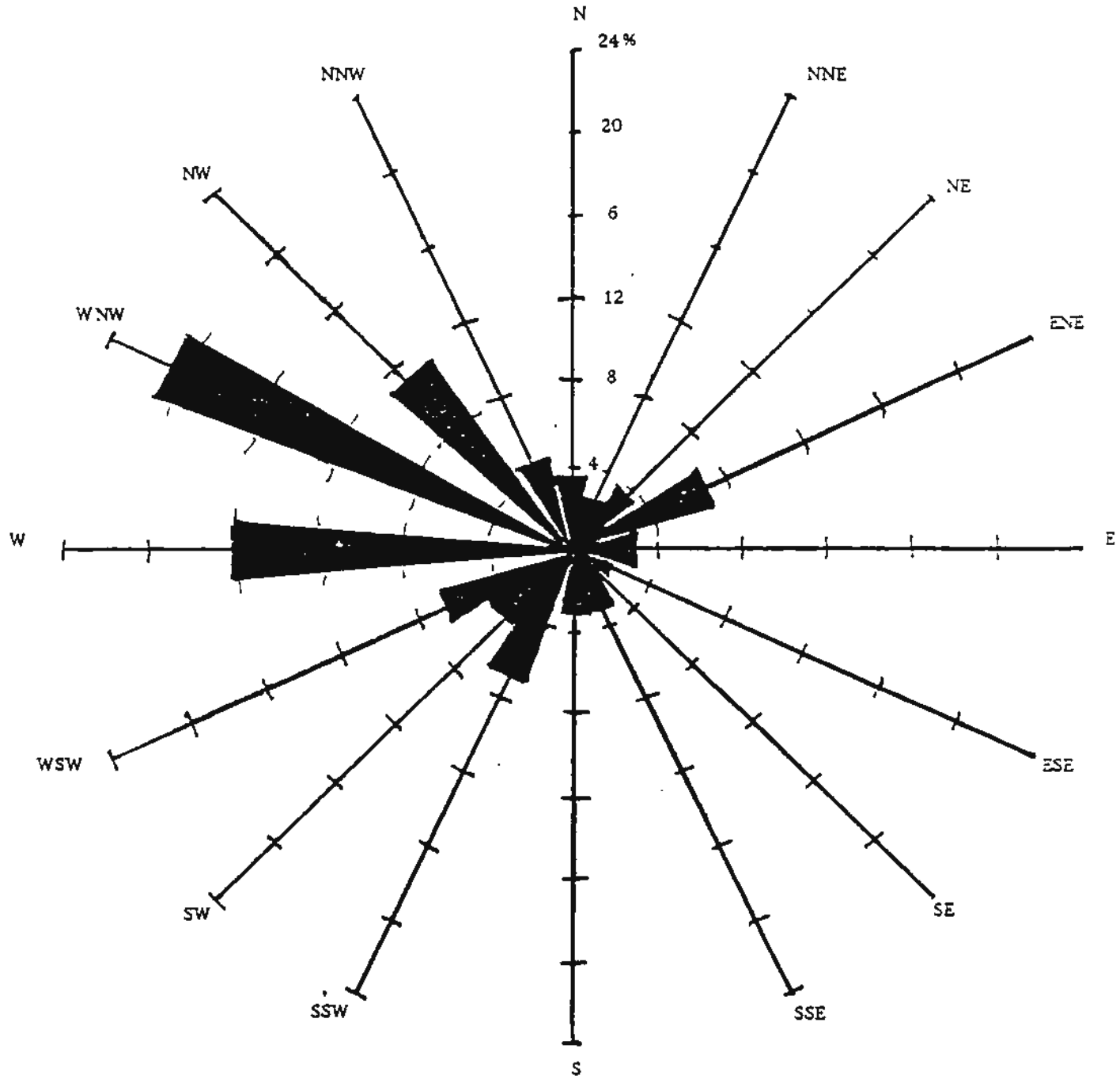


Figure 6. Frequency of 24-hour mean wind directions for Baltimore-Washington International Airport for 1973-1977 (wind persistence indicator greater than 0.85).

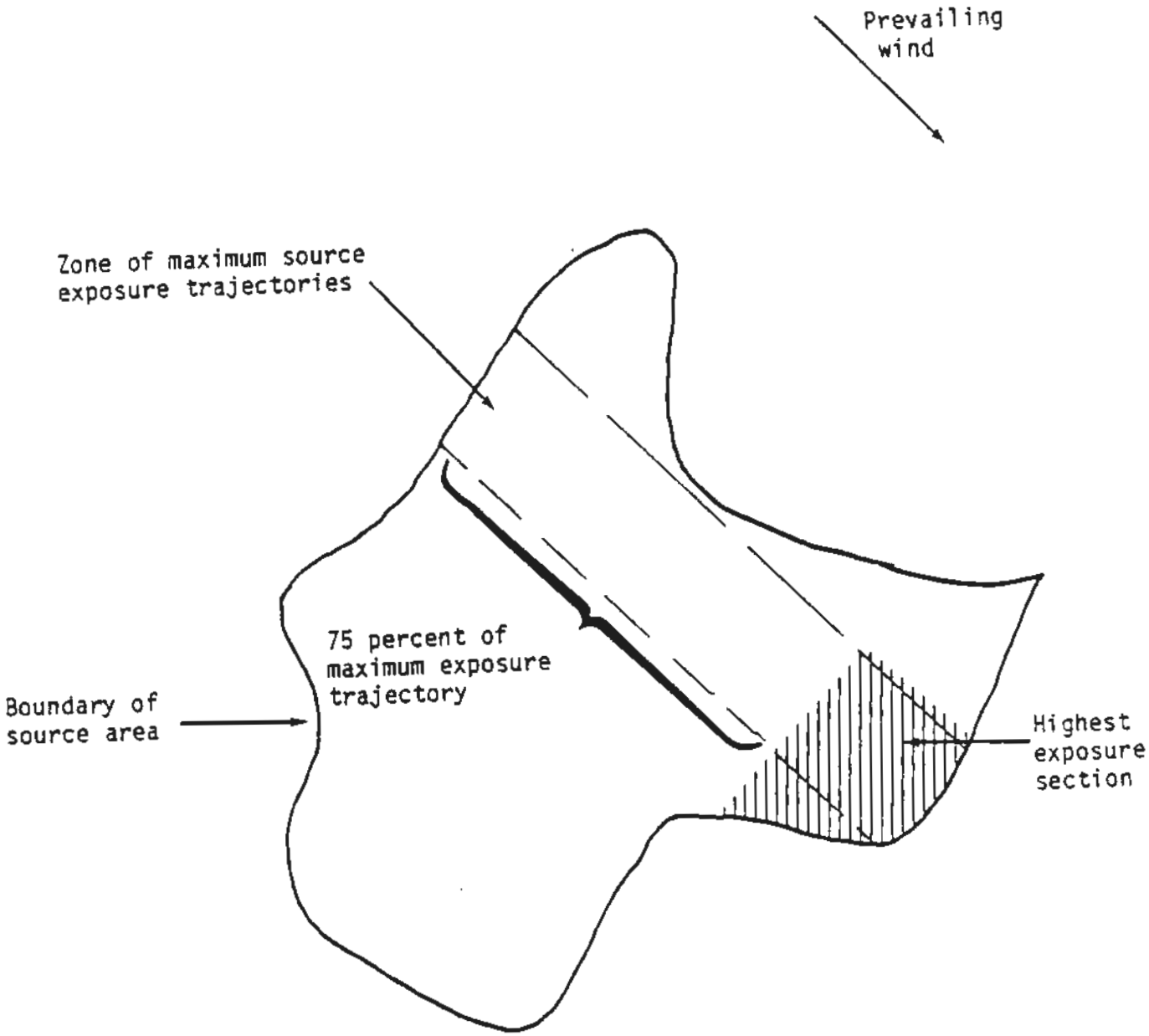


Figure 7. Example of high exposure area.

The procedure illustrated in Figure 7 may be repeated for the prevailing direction under stable light wind conditions. However, if there is a high frequency of reported calm winds, it is recommended that the downwind section be extended to include the center of the source area.

In identifying the prevailing wind direction during light wind conditions, it is important that the meteorological observations be representative of the source area. If the source area is on one side of a large metropolitan area, wind observations from an airport on the opposite side may be misleading. If representative wind data are not available, it would be best to consider the center of the source as the primary exposure area for stagnant air situations. Low-lying terrain is also subject to high pollution during stagnant meteorological conditions.

Low Terrain Areas--

Just as the organization of building structures can influence the flow of air that is stagnant, so can the shape of the terrain. This can be a problem at night when air close to the ground cools rapidly. Cooler air is more dense and will readily displace warmer air at a lower elevation. This leads to nocturnal drainage flows and embedded drainage plumes. As a result, the low point in a source area or the side of a source area to which the air drains will be an area of relatively high nighttime air pollution. These areas can be best identified by examining a topographical map that shows low lying areas and the locations to which air overlying the source area can be expected to drain.

Open Areas--

Locations that are shielded from the general ambient flow by steep bluffs, by buildings, or by trees are poor sampling locations because they frequently are representative of a very small local area that is cleaner or dirtier than a more open area. Open areas that are free of obstructions can best be identified from land-use maps and from visual inspection of the general area to be monitored.

Neighborhood Scale Sites

A methodology for selecting neighborhood scale monitoring sites is shown in Figure 8. Situations in which neighborhood scale air quality effects are of interest occur for an urban area within or around which there are well-defined sources that consist of either small areas of many industrial or commercial operations or large integrated plant sites. The methodology consists of characterizing significant variations in the air quality pattern and the density of population exposed to air quality. Areas of poor, medium, and good air quality and the nature of the overall population exposure threat can be identified by monitoring a range of different neighborhoods. The methodology provides a systematic way of assembling and evaluating information in order to plan a useful monitoring network.

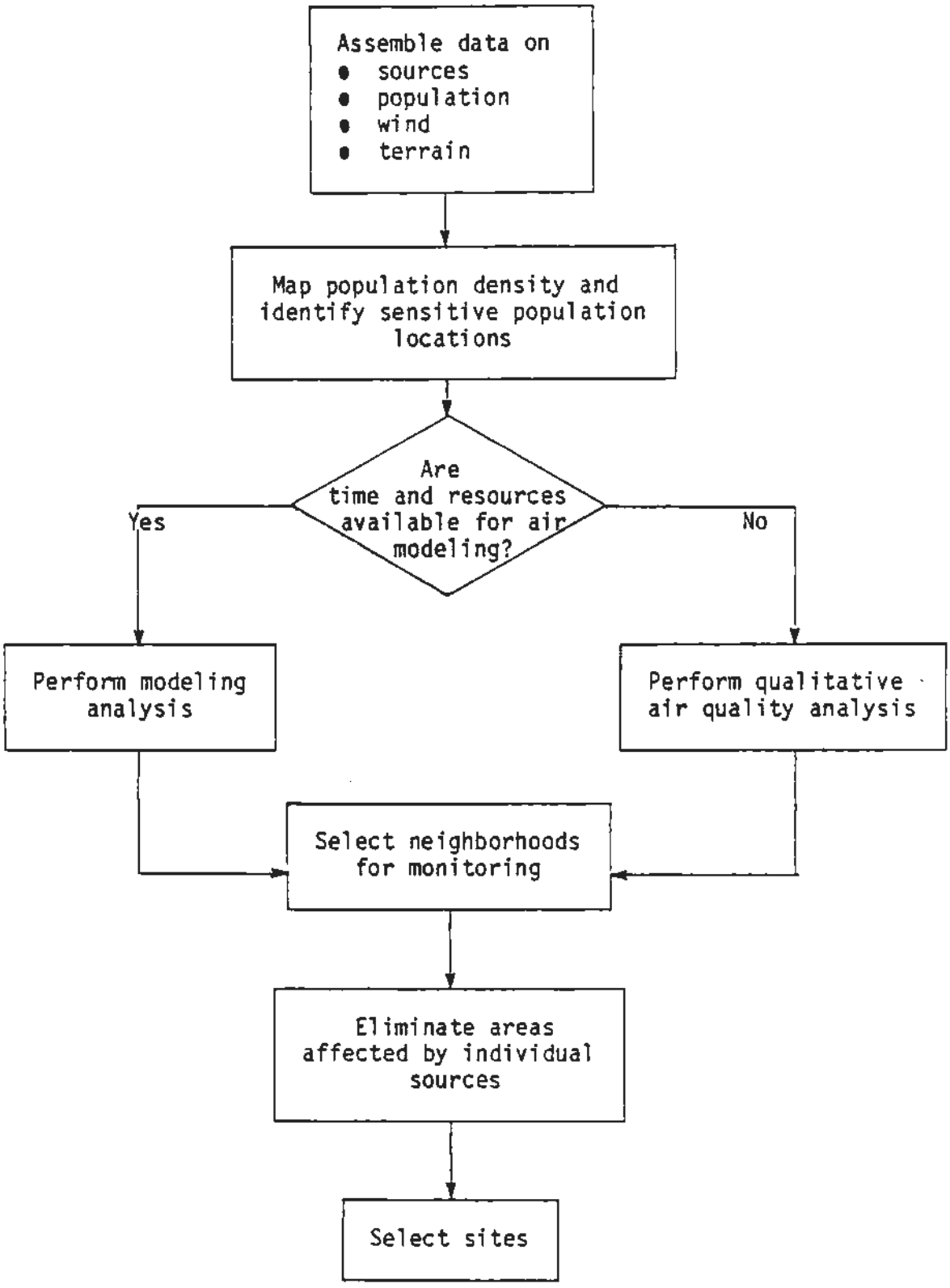


Figure 8. Steps for locating a neighborhood scale site.

The first step in the analysis is to assemble data on sources, population, wind, and terrain. Relevant data were cited in the preceding discussion of urban scale sites.

The second step recommended in Figure 8 is to map the population density and to identify the locations of sensitive population facilities. U.S. Census sub-tract data for urban areas, land-use maps from urban planning agencies, and land-use statistics (e.g., floor space, number of employees, business volume) from tax collection and other relevant agencies are sources of data for defining the population density. It is recommended that the available data be used to divide the monitoring area into high, medium, and low population areas for both day and nighttime periods. For most uses of monitoring data, this is an adequate spatial distinction. Of all the available data, Census data are the most easily related to spatial distribution. It is recommended that population densities based on Census data best represent the nighttime population distribution. Areas of high residential population density should be modified for daytime distribution estimates to include locations with high employment and major shopping centers. It is a relatively simple matter to plot the available data on residential population densities on a map and to divide the monitoring area into zones of low, medium, and high population density. The zones can be modified on a second map to include areas of high employment and major shopping when these activities lie outside the high population zone. These zones should be used as a guide in selecting neighborhoods to include in the complete monitoring network.

The locations of sensitive population facilities should also be noted on a map. Suggestions for identifying and locating sensitive population facilities are given in the preceding section.

The next step is to determine the expected spatial distribution of air quality levels. One way to characterize air quality levels over the monitoring areas of concern is to perform an air quality simulation using one of the standard mathematical models. If one is reasonably confident about the location and emission rates of the sources, if representative meteorological data are available for the area, and if the area is free of major terrain complexities, computer modeling will provide a convenient and comprehensive analysis of the distribution of air quality levels over the area of interest. Models recommended for different source configurations and different averaging periods are shown in Table 13. It should be noted that when multiple pollutants are being considered, a separate model run is needed for each pollutant with different sources or with a different distribution of emissions from the sources. Results from a single simulation are applicable to all pollutants that have the same sources and that have emission rates among the sources that are equal or proportional. For guidance on the use of models and the preparation of input data, consult the Guideline on Air Quality Models (U.S. EPA 1978) and the Regional Workshop on Air Quality Modeling--A Summary Report (U.S. EPA 1982).

TABLE 13. RECOMMENDED EPA MODELS BY SOURCE CONFIGURATION AND AVERAGING TIME*

Monitoring station	Averaging time	
	Annual mean	Maximum 1 to 24 hour
General urban area		
- area and point sources	CDM	RAM
- with complex sources	ISC	ISC
Urban area with single or multiple major source(s)	CDM	RAM
Single source with terrain height below stack top† (complex source)	CRSTER	CRSTER (ISC)
Single source near terrain above stack top§	COMPLEX I or VALLEY	VALLEY or COMPLEX I

* Available in EPA UNAMAP System (Version 5).

† For multiple sources where it is not appropriate to consider the emissions as located at a single point, the MPTER model is appropriate.

§ COMPLEX I and VALLEY are considered screening techniques. For regulatory purposes, COMPLEX I should be used only with onsite meteorological data as input.

These models treat inert pollutants but provide useful approximations for reactive pollutants also. Application of models for reactive pollutants is a special study requiring a specialist in chemically reactive models, more sophisticated computer modeling, and special input data preparation. This level of detail is not usually required for siting studies.

A large metropolitan area may be characterized by well over 1000 different neighborhoods. Although mathematical modeling is the most satisfactory way to classify the air quality potential of neighborhoods, it is also possible to classify neighborhoods in a more qualitative fashion by examining the locations and magnitudes of sources in relation to wind direction frequencies and topographical influences. This approach amounts to using the data needed in a modeling study in a more qualitative manner. Estimates of emissions must be prepared for all areas of the city. One method is to divide the city into homogeneous subareas, each about the size of a neighborhood (i.e., 0.5 to 4 km in diameter). A land-use map prepared by local zoning or urban planning agencies may be suitable for this purpose. If a suitable land-use map is not available, one may be prepared by interpreting aerial photographs and other available sources of information. Table 14 suggests a land-use classification scheme (after Auer 1978) that may be used to guide the preparation of a land-use map. Of course, any large point source of each pollutant of concern should be analyzed separately. The data presented in Section 3 may help to identify which neighborhoods emit which pollutants, and provide a basis for determining an emission rate. However, for many NCAPs, new and better information on sources and emission rates is being assembled as part of EPA's continuing review of potentially hazardous pollutants. Regional offices should be consulted for references to the most current information on each pollutant of interest. An extensive compilation of emission rates and sources of emissions for most of the NCAPs listed in Table 1 was published in a recent EPA study of human exposure estimates (Systems Applications, Inc., 1980 and Suta 1979).

The frequency of occurrence of wind directions must also be determined. These data are available from the National Climatic Data Center for all metropolitan areas. It is necessary to identify only the location that is most representative of the areas to be monitored. Appendix C contains a list of readily available data summaries.

The locations of major topographical features must also be identified relative to the source areas. The following topographical features are of interest:

- Central business district boundary
- Urban development boundary
- Undeveloped area boundaries (including parks, wooded areas, open areas, etc.)
- Major bodies of water
- Terrain elevation contours.

TABLE 14. IDENTIFICATION AND CLASSIFICATION OF LAND USE TYPES (AFTER AUER 1978)

Type	Use and structures	Vegetation
I1	Heavy Industrial	
	Major chemical, steel, and fabrication industries; generally 3- to 5-story buildings, flat roofs	Grass and tree growth extremely rare; <5% vegetation
I2	Light-Moderate Industrial	
	Rail yards, truck depots, warehouses, industrial parks, minor fabrications; generally 1- to 3-story buildings, flat roofs	Very limited grass, trees almost totally absent; <5% vegetation
C1	Commercial	
	Office and apartment buildings, hotels; >10-story heights, flat roofs	Limited grass and trees; <15% vegetation
R1	Common Residential	
	Single-family dwellings with normal easements; generally single-story, pitched-roof structures; frequent driveways	Abundant grass lawns and light to moderately wooded; >70% vegetation
R2	Compact Residential	
	Single- and some multiple-family dwellings with close spacing; generally <2-story, pitched-roof structures; garages (via alley), no driveways	Limited lawn sizes and shade trees; <30% vegetation
R3	Compact Residential	
	Old multifamily dwellings with close (<2 m) lateral separation; generally 2-story, flat-roof structures; garages (via alley) and ashpits; no driveways	Limited lawn sizes, old established shade trees; <35% vegetation
R4	Estate Residential	
	Expansive family dwellings on multiacre tracts	Abundant grass lawns and lightly wooded; >95% vegetation
A1	Metropolitan Natural	
	Major municipal, state, or Federal parks, golf courses, cemeteries, campuses; occasional single-story structures	Nearly total grass and lightly wooded; >95% vegetation
A2	Agricultural Rural	Local crops (e.g., corn, soybeans); >95% vegetation
A3	Undeveloped	
	Uncultivated; wasteland	Mostly wild grasses and weeds, lightly wooded; >90% vegetation

The number of neighborhood scale monitoring sites to be selected will depend on the monitoring objectives, the number of pollutants of concern, and the resources available. However, neighborhoods can be categorized as high, low, or medium with respect to concentrations of each pollutant, by using the information described above. The following guidelines are recommended:

1. High concentration neighborhoods

   - Neighborhoods with highest emission density, i.e., mass emitted per unit area
   - Neighborhoods downwind of prevailing wind from the area with highest emission density, particularly one with a relatively high emission density
   - Neighborhood at the downwind end of the longest trajectory over areas with significant emissions.

2. Low concentration neighborhoods

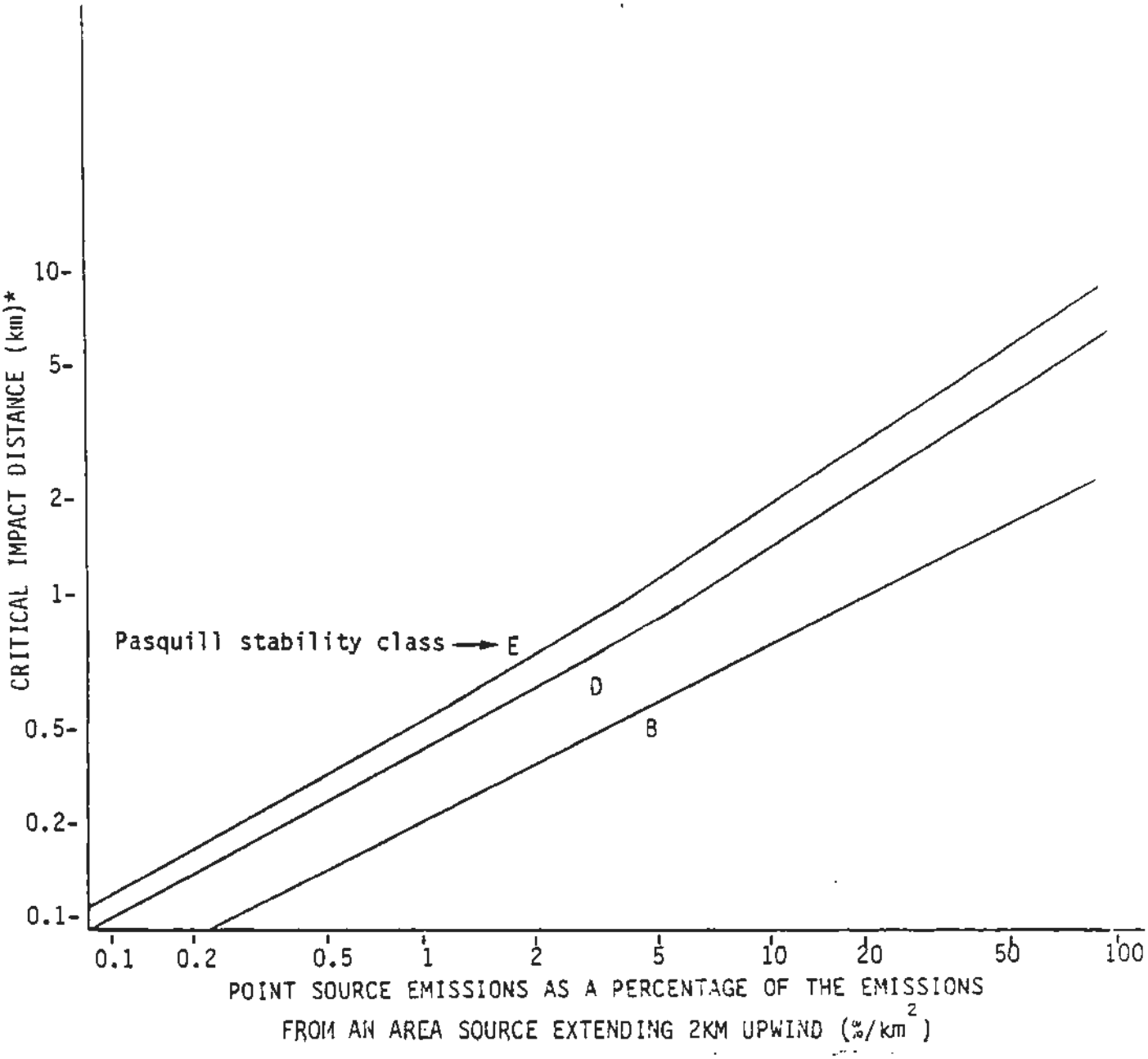
   - Neighborhoods with lowest emission density
   - Prevailing upwind side of areas with significant emissions.

3. Medium concentration neighborhoods

   - Between high and low concentration neighborhoods
   - Adjacent to high concentration neighborhoods
   - Neighborhoods with sensitive population, high population density, or major projected growth.

In determining prevailing downwind and upwind directions, the available data on wind direction frequencies should be modified to account for the influence of topographical features. A meteorologist should be consulted on how to estimate topographical influences.

A specific site within a selected neighborhood should be free of the influence of individual sources, or the measurements will not represent the neighborhood scale. Figure 9 provides an aid in determining how far away a ground-level point source can influence a monitor. Elevated stacks would have significantly less influence. To use the graph, an estimate is made of the general or area source emissions from a square kilometer in the vicinity of potential monitoring sites. The plotted lines in Figure 9 show the distance beyond which a point source will contribute less than 10 percent of the ambient concentration due to nearby area sources that



* This is the distance from a ground-level point source beyond which the ambient concentration contribution is less than 10% of the concentration from a 2 km along-wind area source.

Figure 9. Guideline for estimating impact distance of a point source overlapping an area source.

extend 2 km upwind of the receptor, as a percentage of the area source emission density. Plotted lines are presented for three Pasquill stability classes in order to show how variable the estimates could be in a 1-hour steady wind condition. It is recommended that the D stability graph be used as a guide in determining how far to locate monitors from a nearby point source. It may be seen that large sources will influence monitors 6 km or more away. If it is necessary to locate a monitor closer than the suggested impact distance from a point source, it is recommended that a site be selected in a direction from the source that has a low frequency of occurrence, as shown from wind direction data.

Microscale or Middle Scale Sites

When measuring air quality concentrations that represent the microscale or the middle scale, one is generally dealing with the influence of specific nearby sources, such as a large plant or a highway. There are two points that are of concern: (1) the point of maximum impact due to contributions from the source alone and (2) the point of worst air-quality level due to the combined impact of the source and contributions from all other sources. In selecting these points, there are a number of factors related to the nature of the source, the meteorology, and the topography of the area that need to be taken into account. Figure 10 presents a systematic, step-by-step procedure for selecting monitoring sites.

The first step is to assemble relevant data on sources, meteorology, and terrain. The following data are recommended:

- Source
  - Emission, including annual and maximum hourly rates and diurnal variations
  - Effective height of source plume, including rise due to heat and momentum of exhaust gas
  - Areal extent of source emission area
  - Source owner's property boundaries.
- Meteorology
  - Frequency statistics for joint occurrence of wind direction and atmospheric stability classes
  - Wind direction frequencies.
- Terrain
  - Topographical map showing terrain elevations, water bodies, developed areas.

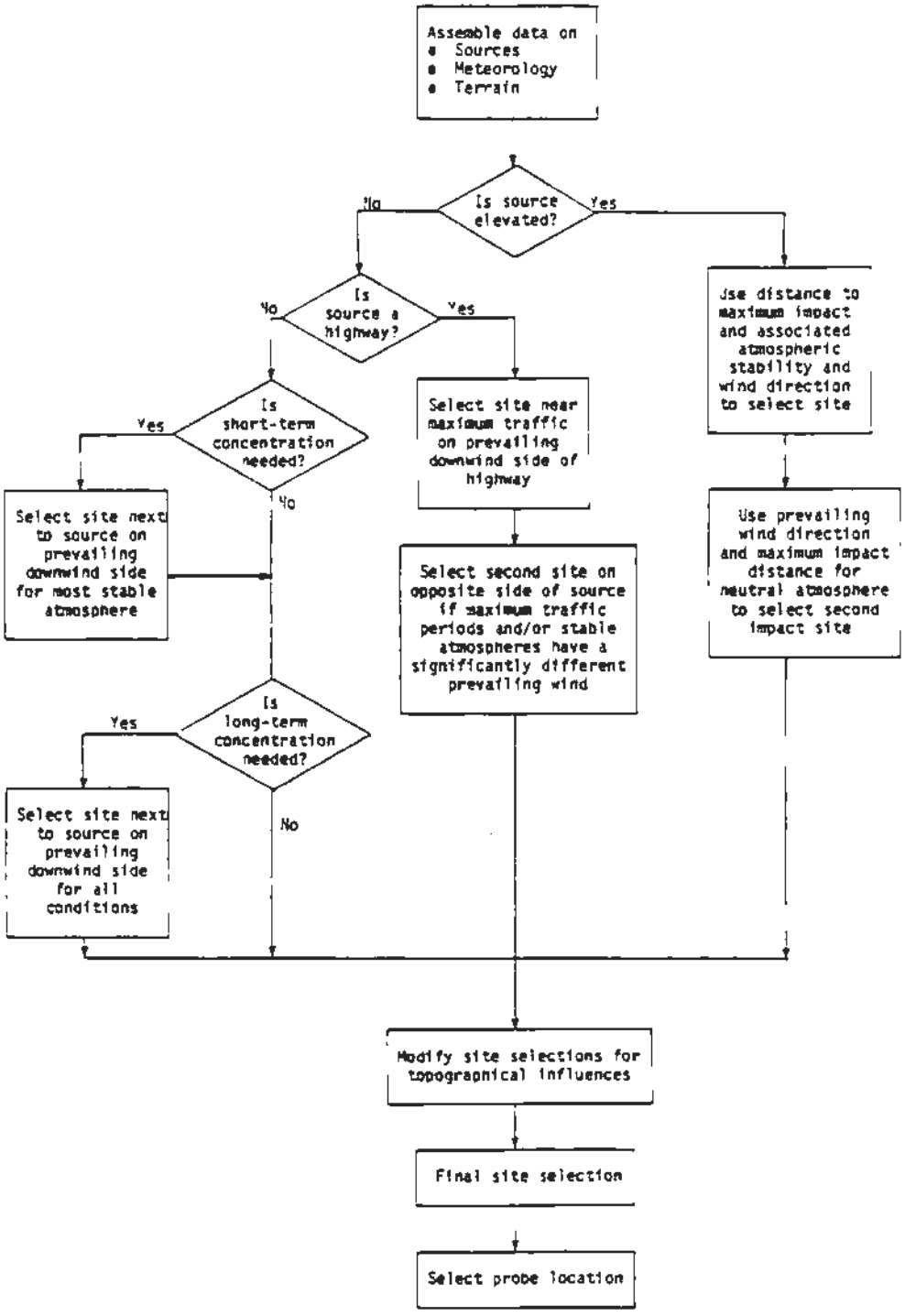


Figure 10. Steps for locating micro or middle scale sites.

The maximum impact of ground-level emissions occurs close to the source. Site selection considerations for monitoring the influence of elevated sources, usually well marked by stacks, are more complex. Ground level emissions will be associated with either a plant site or a highway. To monitor the maximum impact of a ground-level source, it is necessary to get as close to the source as possible and still be in a zone of concern because of the exposure hazard to the public. The major factor to take into account is the wind direction. However, only periods in which emissions occur and during which the emissions are least diluted due to atmospheric turbulence need to be considered.

When considering NCAP emissions from point sources, until exposure time standards are set, it may be necessary to consider both long-term and short-term mean concentrations. The meteorology of the area may be such that the maximum long-term and short-term impacts occur at different locations. An air quality simulation model may be used to identify the locations of maximum impact. The impacts can be assessed using the CRSTER or the ISC models. (See the preceding discussion for recommendations and references regarding the use of these models.) As a quick alternative to modeling, one can use routine meteorological data summaries to select sites. The following guidelines are recommended for selecting the location of the maximum short-term impact:

1. Determine most stable atmospheric class associated with periods of high emissions. If emission rate has no diurnal variations, select most stable class (Pasquill class F for rural areas, class E for urban areas).

2. Determine wind direction with greatest frequency of occurrence for selected stability.

3. Select location close to source fence line and downwind of source in direction of most frequent wind transport for selected stability.

For the location of maximum long-term impact, the following guidelines are recommended:

1. Determine the climatologically prevailing wind direction (highest frequency of occurrence annually). Day and nighttime summaries are available and should be used for sources that have primarily day or nighttime emissions.

2. Select location close to source fence line and downwind of source in direction of prevailing wind.

When considering NCAP emissions from highways, it is desirable to account for possible correlations between diurnal variations in emissions and wind direction. If two sampling sites can be allocated to the source, one could place a site on either side of the area of maximum traffic flow. If only one site is to be used, it is important that the site be on the side that is downwind of the highway most frequently during periods of maximum traffic. If peak traffic occurs from 7:00 a.m. to 8:00 a.m. and from 5:00 p.m. to 6:00 p.m., the frequency of wind directions during very stable and very unstable conditions should be excluded. It is recommended that the most frequent wind direction for Pasquill stability classes C, D, and E be used to determine on which side of the highway to locate a monitoring site. The monitoring site should be located as close to the highway as is practical for monitoring gaseous pollutants or pollutants collected using size selective intakes. If standard hi-vols are to be used, the siting guidelines for distance from roadways given in 40 CFR 58 for TSP monitoring, should be followed.

For elevated sources, the distance to the zone of maximum impact and the effect of meteorological conditions on its location must be taken in account in selecting a site for monitoring the maximum impact of the source. The use of air quality simulation models, such as CRSTER and ISC, is the recommended way of determining the locations of maximum short-term and long-term contributions to ambient concentrations. These models will take the effect of variations in wind speed and atmospheric stability into account in estimating the degree of plume rise, as well as the direction of travel and dilution of the plume by turbulence. The models provide a comprehensive analysis of the effects of hourly variations in meteorological conditions of the patterns of air-quality effects. This provides the best estimate of where the maximum short-term and long-term concentrations will occur. An alternative is to take the following short-cut steps using the graphs in Figures 11 and 12 to select the location of maximum short-term concentration:

1. Use "Procedure for Evaluating Air Quality Impact of New Sources" (U.S. EPA 1977, pp. 4-7 to 4-9) or other equivalent procedures to estimate effective source height for each stability class with significant emissions.

2. Use Figure 11 or 12 to determine stability condition and downwind distance that give maximum concentration.

3. Use climatological data to determine wind direction with greatest frequency of occurrence for selected stability condition.

4. Select site in the downwind direction of most frequent wind for selected stability, at distance of maximum concentration (Step 2).

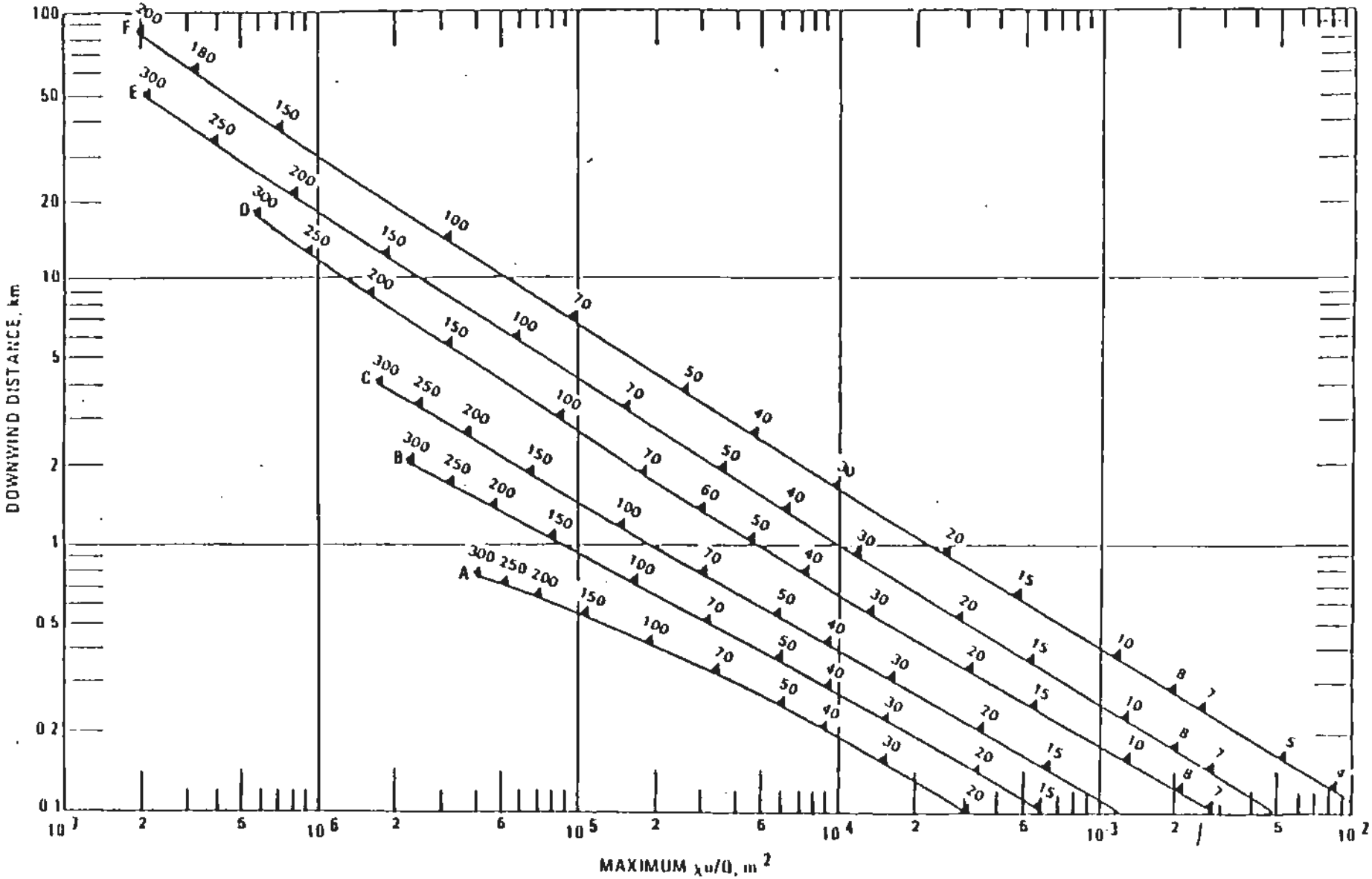


Figure 11. Downwind distance to maximum concentration and maximum relative concentration ($\chi u/Q$) as a function of Pasquill stability class and effective plume height in rural terrain (after Turner 1970).

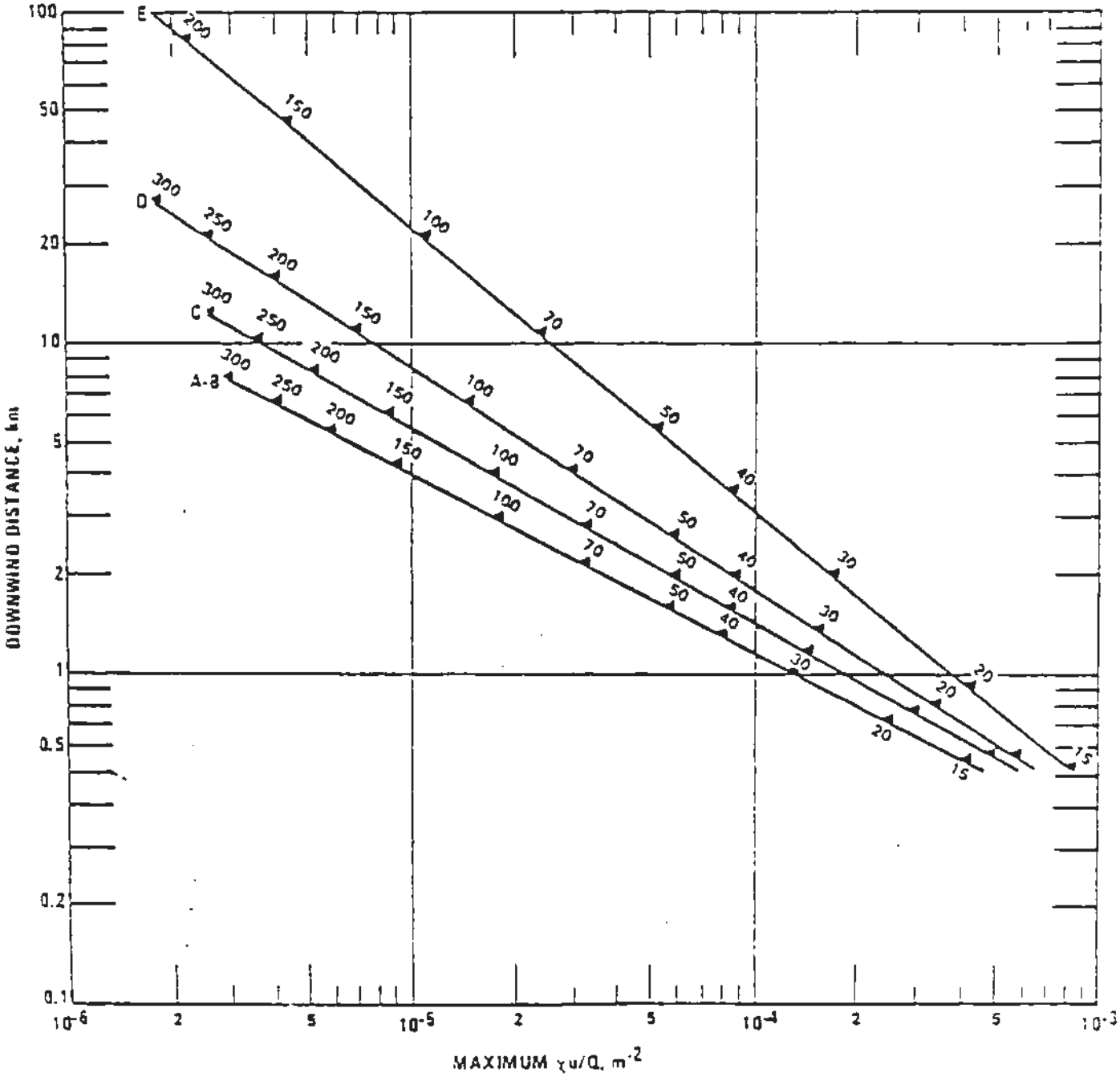


Figure 12. Downwind distance to maximum concentration and maximum relative concentration ($\chi u/Q$) as a function of stability class and effective plume height in urban terrain (U.S. EPA 1977).

The following steps are an alternative for selecting a long-term monitoring site, if modeling cannot be performed:

1. Determine effective source height for neutral stability using the EPA guidelines (U.S. EPA 1977).

2. Use Figure 11 or 12 to determine the distance to the maximum impact for neutral stability (class D).

3. Select a site in the downwind direction of the prevailing wind (all stabilities combined) at the distance of maximum neutral stability impact.

The monitoring locations selected by the above procedures should be reviewed and possibly revised by taking topographical effects into account. This is particularly true in areas of complex terrain and where the meteorological data were not observed in the vicinity of the source. However, a meteorologist should be consulted before making any significant change in site selections. The following topographical influences should be considered:

- Complex terrain results in air flow being channeled by valleys, drained near steep terrain slopes, and modified by mountain-valley circulation effects.

- Large water bodies induce air to flow toward land during the day and toward water at night.

- Urban developments induce air to flow toward city centers.

Finally, in selecting specific probe locations in the vicinity of a selected monitoring location, the guidelines presented in the preceding section should be followed.

SECTION 5

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APPENDIX A

RECOMMENDED MONITORING TECHNIQUES

This appendix consists of Tables 17 and 18 extracted from EPA Technical Assistance Document (TAD) (EPA-600/4-83-027). Table A-1 lists the most widely used sampling and analysis methods for ambient air monitoring. A discussion of the methods (also taken from the TAD) describes a logical grouping of compounds that can be analyzed by the suggested methods. Table A-2 is a list of 31 toxic organic air pollutants and the recommended sampling and analytical methods from Table A-1.

Methods A-F (Table A-1) represent sampling and analysis approaches for volatile hydrocarbons and halogenated hydrocarbons with boiling points less than 200° C. The simplest approach (Method A) involves direct injection of a gas sample onto a GC/FID or other detection system and is useful for compounds more volatile than benzene. Higher boiling compounds can be determined in some cases, although condensation onto the container surface is a more significant problem as volatility decreases. Use of sensitive and/or selective detectors such as ECD for halocarbons and PID for aromatics (19) or certain olefins can be of great value.

Method B involves cryogenic concentration of a whole air sample. Preferably this approach is used as a field method so as to avoid sample transport and storage problems, although laboratory analysis has been used successfully (5). This approach is more time consuming but also much more sensitive than the direct GC injection approach and can be used at the part per trillion level in favorable cases (e.g., using GC/ECD or PID). Compounds in the C_2-C_{10} volatility range can be determined using cryogenic trapping. A limited volume of air (<500 ml) can be sampled since condensed moisture will plug the trap if greater air volumes are collected.

Methods C and D involve the sampling of ~ 20 liters of air using Tenax (a porous polymer adsorbent), thermal desorption of the adsorbed components, and GC or GC/MS analysis. Method C is more comonly used and involves direct desorption of the Tenax-adsorbed components onto the GC or GC/MS system. Method D involves desorption of the components into an evacuated canister and subsequent analysis of the canister contents. Method D offers the advantage of replicate analysis of a single sample, but is somewhat less sensitive than the former approach. Adsorptive losses of higher boiling compounds onto the canister surface is another potential problem. An advantage of the Tenax approach, relative to cryogenic trapping, is that water and other inorganic atmospheric components are not retained. Storage of the organic components in the resin-adsorbed state also tends to circumvent problems with adsorption on container surfaces.

TABLE A-1. SUMMARY OF SAMPLING AND ANALYTICAL METHODS FOR ORGANIC COMPOUNDS IN AMBIENT AIR

Method Designation	Compounds Determined	Sampling and Analysis Approach	Detection Limit	Accuracy	Precision	Relative Cost: Instrument	Relative Cost: Time/Materials	References	Limitations	Comments
Hydrocarbons										
A. ASTM D1870	C_1-C_5 Hydrocarbons	Direct gas injection onto GC/FID	0.01 ppmv	--	±10%	Low	Low	2,19	Losses due to surface adsorption may occur in some cases, especially for less volatile compounds.	GC/MS can be used for component identification. GC/FID is useful for screening.
B. --	C_2-C_{10} Hydrocarbons and other nonpolar organics with B.P. ~100 to 175°C	Whole air collection in canister (cryogenic concentration); GC/FID analysis	0.1 ppbv (100 mL sample)	--	±10%	Moderate	Moderate	5,24	Storage times greater than a week are not recommended. Reactive and water soluble compounds are not readily analyzed.	GC/MS can be used for component identification. If possible, a field GC/FID should be used to avoid sample storage problems.
C. --	C_6-C_{12} Hydrocarbons and other nonpolar organics with B.P. 60-200°C	Adsorption on Tenax; thermal desorption GC/MS analysis	[illegible] ppbv (25 liter sample)	[illegible]	±20 %RSD	High	Moderate	7	Blank levels usually limit sensitivity. Artifacts due to reactive components (e.g. O_3, NO_2) can be a problem. Sample can be analyzed only once.	GC/FID can be used to reduce analysis cost, if component identification is not required.
D. --	C_6-C_{12} Hydrocarbons and other nonpolar organics with B.P. 60-200°C	Adsorption on Tenax; thermal desorption into canisters; GC/FID or GC/MS analysis	0.01-5 ppbv (20 liter sample)	80-100%	±70%	Moderate to high, depending on GC detector	Moderate	6	Carbon tetrachloride gives poor recovery; precision due to adsorption onto metal surface. Blanks and artifact problems same as above	Sample can be analyzed 1-4 times, thus allowing GC/FID quantification and GC/MS identification
E. ASTM D3686/ D3687 or NIOSH PECAM [2]	Nonpolar volatiles (B.P. 0-150°C)	Adsorption on charcoal; desorption with CS_2; analysis by GC/FID	0.1-1 ppbv (10 liter sample)	--	±10%	Low	Low	1,2	Sensitivity much poorer than for thermal desorption approaches.	Charcoal adsorbs highly volatile compounds more efficiently than Tenax.

TABLE A-1. (Continued)

Method Designation	Compounds Determined	Sampling and Analysis Approach	Detection Limit	Accuracy	Precision	Relative Cost: Instrument	Relative Cost: Time/Materials	References	Limitations	Comments
F. --	Nonpolar volatiles (B.P. 0-100°C)	Adsorption on carbon molecular sieves; thermal desorption into canister; analysis by GC/FID or GC/MS	0.01-1 ppbv (low liter sample)	80-100%	±20%	Moderate to high, depending on GC detector	Moderate	4	High temperature (350°C) required for desorption may decompose labile compounds.	See Method D.
G. NIOSH PECAM 206	PAH	Collection of particulate matter on high volume filter; ultrasonic extraction with cyclohexane/silica powder; analysis by normal phase HPLC	3 ng/m^3 (1500 m^3 sample)	95%	±5%	Moderate	Moderate	1	PAHs more volatile than benzo(a)pyrene may be lost by volatilization during the sampling period. Approaches similar to reference 40 may be required for such compounds.	PAH and other particle bound components may be determined using GC/MS.
Halogenated Hydrocarbons										
Methods A-F can be used for volatile halogenated hydrocarbons as well, except that GC/ECD should be used in place of GC/FID in most cases.										
H. --	PCBs, PCNs, organochlorine pesticides, and other semivolatile organics (B.P. 110-450°C)	Adsorption on solid adsorbent such as polyurethane foam (PUF), XAD-2, or Chromosorb 102); solvent desorption; GC/ECD, GC/MS, or GC/FID analysis	3 ng/m^3 (1500 m^3 sample)	60-100%	±20%	Moderate to high, depending on GC detector	Moderate	8 Lower volume approaches (41,42,50)	--	Similar approaches using low volume sampling trains may be more useful for detecting higher levels (1-10 ug/m^3). Hydrocarbons with boiling points >140°C (>C_8) can be determined.

TABLE A-1. (Continued)

Method Designation	Compounds Determined	Sampling and Analysis Approach	Detection Limit	Accuracy	Precision	Relative Cost: Instrument	Relative Cost: Time/Materials	References	Limitations	Comments
1. —	Tetrachlorodibenzodioxins	Collection on high volume filter; extraction (Soxhlet) with methylene chloride; column chromatographic cleanup; high resolution GC/MS analysis	~1 pg/m^3 (1500 m^3 sample)	--	±10-20%	Very high	High	15	TCDDs occur primarily in the particle bound state, but backup adsorption approaches such as reference 40 may be required to ensure no loss occurs through volatilization.	TCDD is highly toxic, hence the need for high sensitivity. These analyses are generally conducted in a special laboratory equipped to handle such materials.
Oxygenated Neutral Compounds										
J. —	Aldehydes	Collection in dinitrophenyl hydrazine (DNPH); solvent extraction of DNPH derivatives; reversed phase HPLC analysis	1-5 ppbv (60 liter sample)	60-100%	±20%	Low	Moderate	6	Blank levels of aldehydes (particularly formaldehyde) will usually determine the detection limit. Reagents must be carefully prepared to avoid significant contamination.	Analysis within 24 hours is recommended.
K. —	Aldehydes (C_1-C_3)	Collection in 1% sodium bisulfite impinger; determine formaldehyde using chromotropic acid, acetoin using mercuric chloride-hexylresorcinol and C_2-C_5 aliphatic aldehyde by GC/FID	10-30 ppbv (assume 120 liter sample)	--	±10-20%	Low	Moderate	3	High levels of phenols, ethylene, and propylene cause negative interference with formaldehyde determination.	--

TABLE A-1. (Continued)

Method Designation	Compounds Determined	Sampling and Analysis Approach	Detection Limit	Accuracy	Precision	Relative Cost: Instrument	Relative Cost: Time/Materials	References	Limitations	Comments
L. NIOSH P&CAM 556, 558, 559, 560, 562-564	Alcohols (C_1-C_5)	Adsorption on charcoal; desorption with CS_2 with 1% dissolved alcohol; GC/FID analysis	100-1000 ppm	--	≤5-10%	Low	Low	1,23	Humidity level must not be sufficient to allow condensation in tube. Sensitivity is inadequate for most ambient air monitoring purposes.	Direct analysis in the field using GC/FID (as in Method A) should provide 1-10 ppm sensitivity.
Miscellaneous Neutral Compounds										
M. --	Nitrosamines	Adsorption on Thermosorb N; desorption with acetone; GC/thermal energy or GC/MS analysis	25 ng/m^3 (300 liter sample)	85-100%	≤10%	High	Moderate	18	Thermal energy analyzer is a nitrosamine specific detector and is rather expensive ($50-60K). GC/HPD may be a less expensive alternative in many situations.	Thermosorb N is a special adsorbant from Thermo Electron Corporation.
Sulfur, Phosphorus, and Nitrogen Compounds										
Most compounds in these classes can be determined using Methods A-F or N, depending on volatility characteristics, except that selective detectors may be used (e.g. GC/FPD for S or P compounds, GC/AFD for N or P compounds, etc.) in place of GC/FID.										
Basic Compounds										
N. NIOSH P&CAM 277	Aliphatic Amines (C_1 to C_6)	Adsorption on silica gel; elution with acid; neutralization; GC/FID analysis	500 ppbv (10 liter sample)	--	≤3-5%	Low	Low	1	Sensitivity may not be adequate for ambient air monitoring	GC/HPD can be used to obtain better sensitivity (see method below).

TABLE A-1. (Continued)

Method Designation	Compounds Determined	Sampling and Analysis Approach	Detection Limit	Accuracy	Precision	Relative Cost: Instrument	Relative Cost: Time/Materials	References	Limitations	Comments
O. --	Aliphatic Amines (C_1-C_4)	Adsorption of alkali treated Porasil A; thermal desorption GC/NPD analysis	1-5 ppbv (60 liter sample)	80-100%	±5-10%	Moderate	Moderate	11	Requires careful conditioning of GC system to obtain adequate performance	--
P. NIOSH P&CAM 168	Aromatic Amines	Adsorption on silica gel; eluting with ethanol, GC/FID analysis	100 ppbv (100 liter sample)	--	±10%	Low	Low	1	High humidity levels reduce adsorption capacity.	Sensitivity could be improved using GC/NPD. HPLC can also be used (46).
Q. --	Aromatic Amines	Adsorption on Tenax GC, thermal desorption GC/FID or GC/NPD analysis	1 ppbv (100 liter sample)	--	--	Low	Moderate	12	Desorption of high boiling compounds is not complete.	Solvent desorption approaches may be more effective in some cases.

Nitrogen Heterocyclics

These compounds can be determined by the methods described for hydrocarbons and halogenated hydrocarbons, depending on volatility, except GC/NPD or HPLC detection of these compounds may be required. Polar GC phases (e.g. Carbowax 20 M) should be used in most cases.

TABLE A-2. SUMMARY OF SAMPLING AND ANALYSIS METHODS FOR SELECTED TOXIC ORGANIC COMPOUNDS

Compound	Most Appropriate Methods From Table A-1	Specific References	Comments
Acetaldehyde	J,K	3,6	Compound very unstable, requires immediate analysis or derivatization.
Acrolein	J,K	3	Compound very unstable, required immediate analysis or derivatization.
Acrylonitrile	B,F	1	NIOSH Method S156 uses methanol as desorption solvent. GC/NPD will give improved sensitivity.
Allyl Chloride	B,E,F	1	Compound is too volatile to allow use of Tenax/thermal desorption approach. NIOSH Method S116 uses benzene solvent desorption with GC/FID analysis.
Benzyl Chloride	B,C or D	7	Cryogenic trapping or Tenax adsorption appear to be the best approaches. Adsorption on XAD-2 may also be useful. GC/PID is a useful determinative method.
Carbon Tetrachloride	B,C or D	7	Cryogenic trapping or Tenax adsorption appear to be the best approaches. Storage of samples in contact with stainless steel surfaces can result in rapid loss of this compound. GC/ECD is a useful method.

TABLE A-2. (Continued)

Compound	Most Appropriate Methods From Table A-1	Specific References	Comments
Chlorobenzene	B,C or D	4,7,17	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/PID is a useful method.
Chloroform	B,C or D	4,7	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/ECD is a useful determinative method.
Chloroprene	B,C or D	--	Cryogenic trapping or Tenax adsorption appear to be the best approaches, although very little data is available. GC/PID is a useful determinative method.
o-,m-,p-Cresol	C,S,H (low volume)	3,21	Either collection in sodium hydroxide impinger, Tenax adsorption, or resin adsorption/solvent extraction can be used. GC/PID is a useful determinative method.
p-Dichlorobenzene	B,C or D	7,17	Cryogenic trapping or Tenax adsorption appear to be the best approaches. Resin adsorption/solvent desorption approaches can be used. GC/ECD or PID are useful determinative methods.
Dimethylnitrosamine	M	16	Adsorption on Thermosorb N/thermal desorption appears to be the best approach. GC/NPD may provide sufficient selectivity in many cases.
Epichlorohydrin	B,C or D	7	Relatively little ambient air data are available in the literature. Cryogenic trapping or Tenax adsorption appear to be viable approaches.

TABLE A-2. (Continued)

Compound	Most Appropriate Methods From Table A-1	Specific References	Comments
Ethylene dichloride	B,C or D	4,7	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/ECD is a useful determinative method.
Ethylene Oxide	A,B,E	1	Compound too volatile to use Tenax adsorption. Cryogenic trapping is probably the best approach.
Formaldehyde	J,K	3,6	Compound very reactive. Requires immediate analysis or stabilization.
Hexachlorocyclopenta-diene	C or D,H (low volume approach)	20	Very little data available for this compound in ambient air.
Maleic Anhydride	--	--	No suitable methods could be found.
Methyl Chloroform	B,C or D	7	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/ECD is a useful determinative method.
Methylene Chloride	B,F	4	Cryogenic trapping, appears to be the most useful approach. This compound is not retained well by Tenax or other polymeric adsorbents. Adsorption on carbon molecular sieves in place of Tenax is a useful approach. Laboratory contamination with methylene chloride is a common problem.
Nitrobenzene	B,C or D	4	Tenax adsorption is probably the best approach. GC/ECD, PID, or NPD are useful determinative methods.

TABLE A-2. (Continued)

Compound	Most Appropriate Methods From Table A-1	Specific References	Comments
Nitrosomorpholine	M	22	See Dimethylnitrosamine. HPLC may be useful in place of GC for this compound.
Perchloroethylene	B,C or D	4,7	Cryogenic trapping or Tenax adsorption appear to be the most useful approaches. GC/ECD is a useful determinative method.
Phenol	C or S	3,6	Trapping in basic impinger solution or Tenax adsorption appear to be the best approaches. GC/PID is a useful determinative method.
Phosgene	--	18	This compound is highly unstable and hence field determination is desirable. A manual colorimetric method using 4-nitrobenzyl-pyridine appears to be the best approach for routine analysis (detection limit ~0.05 ppm for 25 liter sample).
PCBs	H	8	Adsorption of XAD-2 or polyurethane foam followed by solvent extraction and GC/ECD analysis appear to be the best approaches. PCB formulations are composed of many individual compounds and the method of quantification required careful consideration.
Propylene Oxide	B,C or D	7	Cryogenic trapping or Tenax adsorption appear to be the best approaches, although the Tenax approach should be used with caution because of the low breakthrough volume for this compound.

TABLE A-2. (Continued)

Compound	Most Appropriate Methods From Table A-1	Specific References	Comments
Toluene	B,C or D	4,5,7,9,19	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/PID is a useful determinative technique.
Trichloroethylene	B,C or D	4,7	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/ECD is a useful determinative technique.
Vinylidine Chloride (1,1-dichloroethane)	B,C or D	4,7	Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/ECD is a useful determinative technique.
o-,m-,p-Xylene	B,C or D	4,5,7,9,19	Cryogenic trapping or Tenax adsorption appear to be the best approaches. Adsorption on XAD-2 and solvent extraction is also possible. GC/PID is a useful determinative method.

Major disadvantages of the Tenax adsorption approach is the potential for artifact formation (e.g., by interaction of ozone with the resin) and/or contamination. These factors tend to increase the background (blank) levels relative to cryogenic trapping, thereby adversely affecting the detection limit. The widely varying retention volumes for organic compounds on Tenax requires careful consideration for each monitoring situation. A recent report describes the Tenax adsorption process and gives retention volume data for many organic compounds of interest (25).

Methods E and F involve adsorption of volatile, nonpolar compounds on carbon based adsorbents followed by solvent extraction or thermal desorption and GC or GC/MS analysis. Method E, adsorption of charcoal followed by extraction with CS_2 or other solvents, is the basis for many of the NIOSH methods. Unfortunately this approach is not sufficiently sensitive for most ambient air monitoring programs, although the use of selective detectors can improve sensitivity for certain compounds.

Method F has been used to some extent for ambient air monitoring of vinyl chloride and other volatile compounds. This method is similar to Method D, except that carbon molecular sieves are used in place of Tenax. Direct thermal desorption/GC analysis (analogous to Method C) could be employed for carbon molecular sieves as well. A major advantage of this approach is the strong retention of vinyl chloride and other highly volatile materials. However, the high temperatures required for thermal desorption from carbon based adsorbents can lead to degradation of strongly adsorbed, nonvolatile and/or polar materials.

Methods G, H, and I represent approaches useful for the determination of semivolatile or nonvolatile compounds (i.e., boiling points greater than 140° C). Method G, while referenced as a PAH analysis method, is readily adapted for the determination of many nonvolatile materials adsorbed on atmospheric particulate material. Method I is referenced as a separate method for tetrachloro-dibenzodioxins (TCDDs) which are currently of great environmental concern. Highly specific cleanup and GC/MS steps are used to gain selectivity for TCDDs using the method.

Method H represents as useful approach for PCBs, PCNs, organo-chlorine pesticides and other semivolatile compounds which can occur in both the particle and vapor state. Such compounds are not retained using conventional high volume filtration techniques hence adsorbents such as XAD-2 or polyurethane foam (PUF) must be used in back of the filtration device. The semivolatile components are then recovered from the adsorbent by solvent extraction. Tenax is less useful than XAD-2 or PUFs in this method since many solvents will partially dissolve Tenax.

The remaining methods in Table A-1 represent specialized techniques for selected groups of compounds. Methods J and K are used for determination of volatile aldehydes (C_1 to C_6). Method J involves formation of the DNPH derivatives of the various aldehydes followed by reversed phase HPLC analysis, whereas Method K captures the aldehydes as bisulfite addition products and then employs a variety of colorimetric and GC analytical procedures for the individual aldehydes. Method J should generally be used if a wide variety of aldehydes are to be determined or if interferences with the colorimetric methods are likely to be encountered. The determination of formaldehyde using chromatropic acid, as in Method J, is a simple procedure and is very useful for screening purposes, although negative and positive interferences can occur.

Detection of alcohols in ambient air has not been of widespread interest and no sensitive methods exist. Method L refers to a group of NIOSH methods employing carbon adsorption and solvent desorption/GC analysis. These methods are not useful below 100 ppm. Alcohols are not retained on porous polymer adsorbents such as Tenax and are likely to decompose if carbon adsorption/thermal desorption approaches are attempted. An analytical method involving silylation of alcohols followed by cryogenic trapping of the silylated derivative (as in Method B) has been reported (23).

Nitrosamines are of considerable environmental significance because of the toxicological hazard and potential for formation in various combustion sources. Method M refers to an approach involving collection of the nitrosamine on a specially treated nylon adsorbent (thermosorb/N) and subsequent analysis using GC with MS or thermal energy (TEA) detectors. The latter detector is relatively specific for nitrosamines (16). Since both MS and TEA are relatively expensive detectors, the less expensive GC/NPD approach may preferable in relatively "clean" environments in which ultimate selectivity is not necessary. Thermosorb/N minimizes the formation of nitrosamines on solid adsorbents during sampling, which has proven to be a problem on Tenax under certain sampling conditions.

Methods N-Q represent the best available methods for determining aliphatic and aromatic amines. Nitrogen heterocycles containing no other polar functional groups can usually be determined by one or more of the methods described earlier for hydrocarbons, using nitrogen selective detectors. Methods N and P represent NIOSH procedures for determining aliphatic and aromatic amines, respectively. These methods involve adsorption of the compounds on silica gel, elution with acid and GC/FID analysis. The adsorption of water reduces the capacity of the silica gel and limits the practical sampling volume. Therefore, these methods cannot determine low ppb levels of amines, although use of GC/NPD should increase the sensitivity somewhat. HPLC with fluorescence, electrochemical, or UV detection (13) can improve the detection limit for aromatic amines.

Method O involves determination of volatile aliphatic amines (C_1-C_4) by adsorption on alkali-treated silica (Porasil A) followed by thermal desorption and GC/NPD analysis. This method is reported to achieve 1-5 ppb sensitivity if the GC system is carefully conditioned (11). Method Q is a similar approach using Tenax/thermal desorption for aromatic amines. However, the thermal instability of many aromatic amines must be considered and may limit the usefulness of this approach.

Relatively few analytical methods are available for determining acidic compounds (with the exception of phenols) in ambient air. Phenol itself and possibly cresols can be determined using a Tenax adsorption approach such as Method D. Higher boiling phenols can be determined using a resin adsorption/solvent extraction approach such as Method H. Method S represents a standard method for phenols wherein the compounds are collected in a dilute sodium hydroxide impinger and then steam distilled and analyzed by GC/FID or GC/MS. Less volatile phenols can be analyzed (without steam distillation) by HPLC with fluorescence, UV or electrochemical detection.

Volatile carboxylic acids such as a formic and acetic acid can be determined (Method R) by collection in a dilute sodium carbonate impinger followed by ion chromatographic (IC) analysis (10). IC is a special form of ion exchange HPLC wherein conductance detection is employed (mobile phase buffer is removed prior to detection using a stripper column).

Suitable methods for determining sulfonic acids in air have not been reported. However, collection in an aqueous impinger followed by HPLC analysis (14) appears to be a viable approach.

In order to provide the reader with some useful examples of appropriate methodology, Table A-2 lists a group of toxic organic compounds of concern in ambient air monitoring programs. The most appropriate methods for determining these compounds, specific literature references, and additional analytical considerations are presented in Table A-2. This information should be used as guidance and will not be accurate for every monitoring situation.

The majority of the compounds in Table A-2 represent hydrocarbons, volatile halogenated hydrocarbons, or semivolatile halogenated hydrocarbons which can be determined using conventional cryogenic trapping, Tenax adsorption/thermal desorption, or resin adsorption/solvent extraction approaches. A few compounds (e.g., acrylonitrile, allyl chloride, ethylene oxide) are too volatile to be captured on Tenax and require use of carbon adsorbents or cryogenic trapping. Several of the compounds can be determined using the procedures for aldehydes (e.g., formaldehyde, acetaldehyde, acrolein).

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APPENDIX B

OBSERVATION OF DIURNAL VARIATIONS OF
SELECTED NONCRITERIA AIR POLLUTANTS

Data are presented for the following NCAP:*

Figure	Pollutant
B-1	Benzene
B-2	Carbon tetrachloride
B-3	Chlorobenzene
B-4	Chloroform
B-5	Methyl chloroform
B-6	Methylene chloride
B-7	Perchloroethylene
B-8	Toluene
B-9	Tricholorethylene
B-10	m-,p-Xylene

* Reported by: Singh, H.B., L.J. Salas, R.E. Stiles, and H. Shigeishi. 1982. Measurements of Hazardous Organic Chemicals in the Ambient Atmosphere. SRI International, Menlo Park, CA.

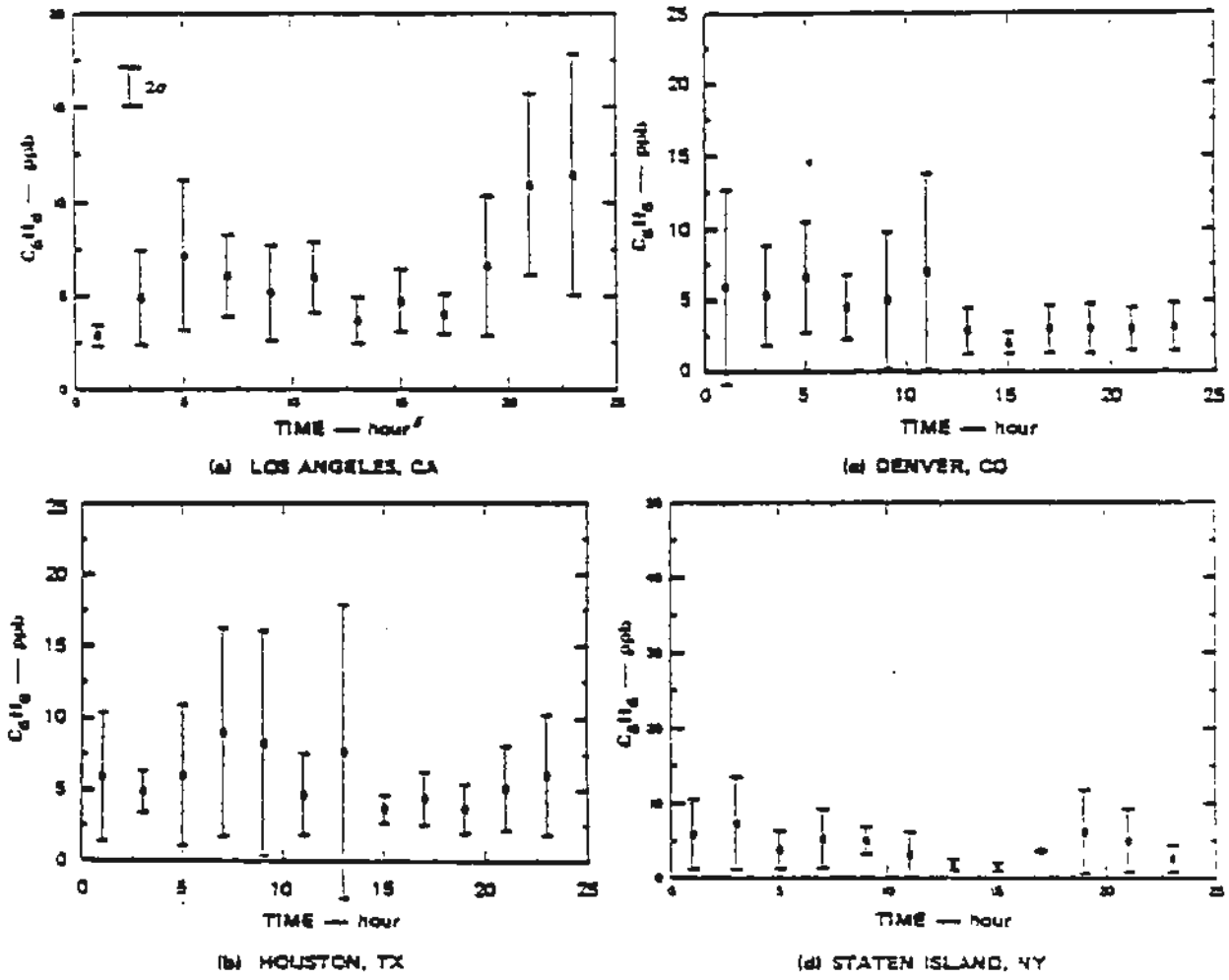

Figure B-1. Mean diurnal variation of benzene.

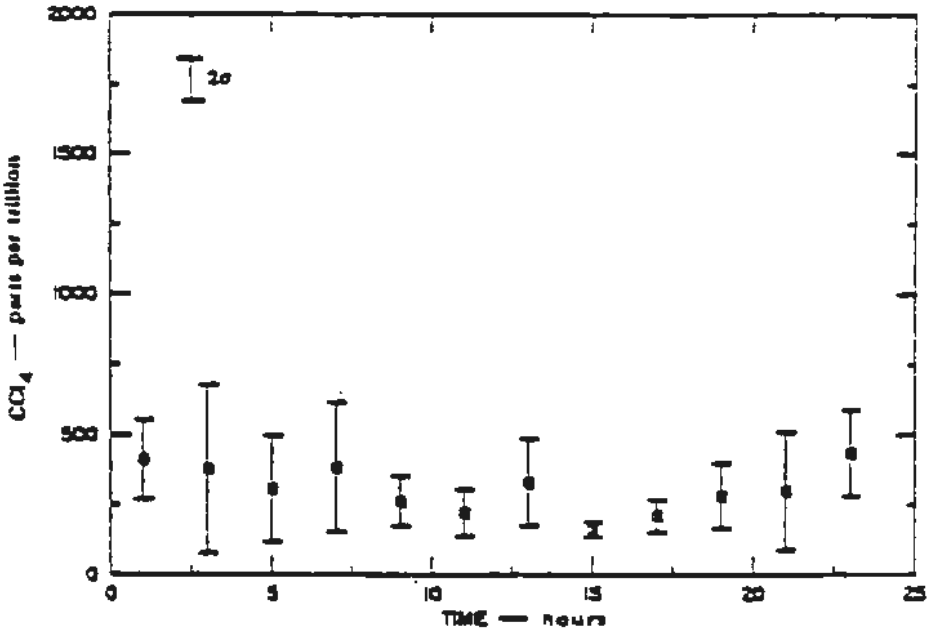

Figure B-2. Mean diurnal variation of carbon tetrachloride at Staten Island, NY.

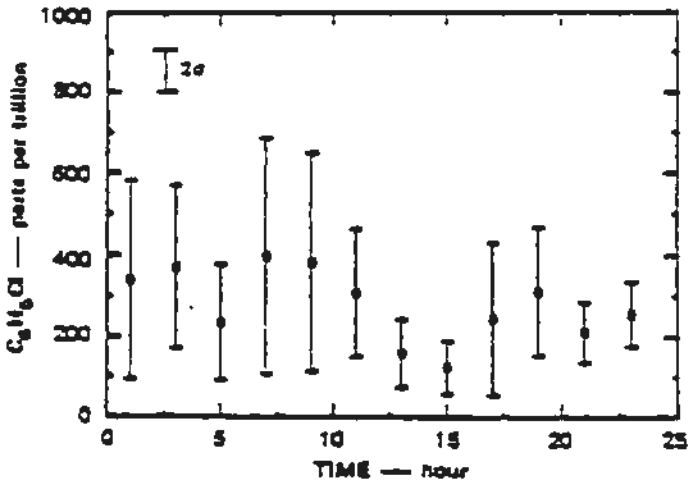

Figure B-3. Mean diurnal variation of chlorobenzene at Denver, CO.

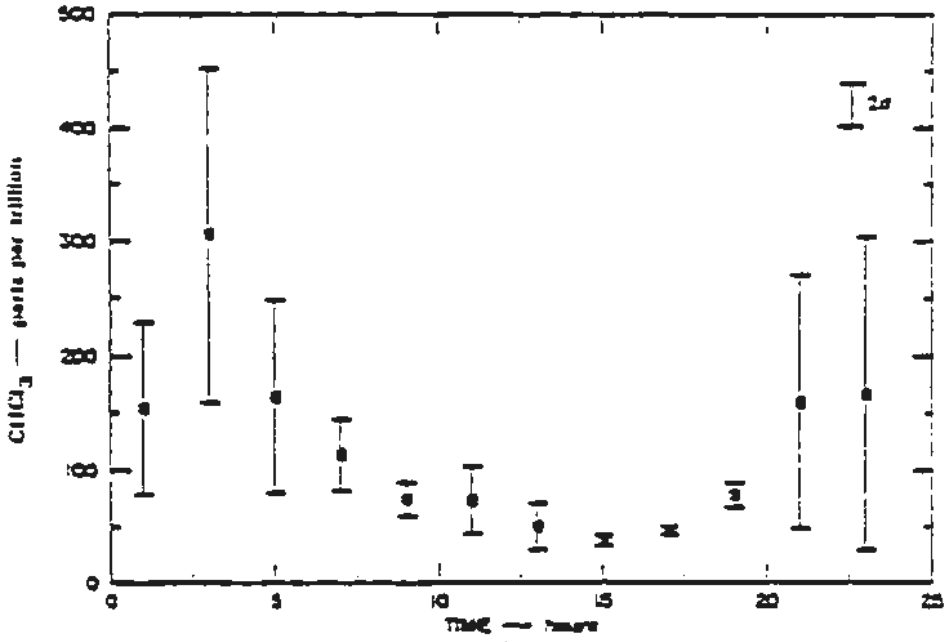

Figure B-4. Mean diurnal variation of chloroform at Phoenix, AZ.

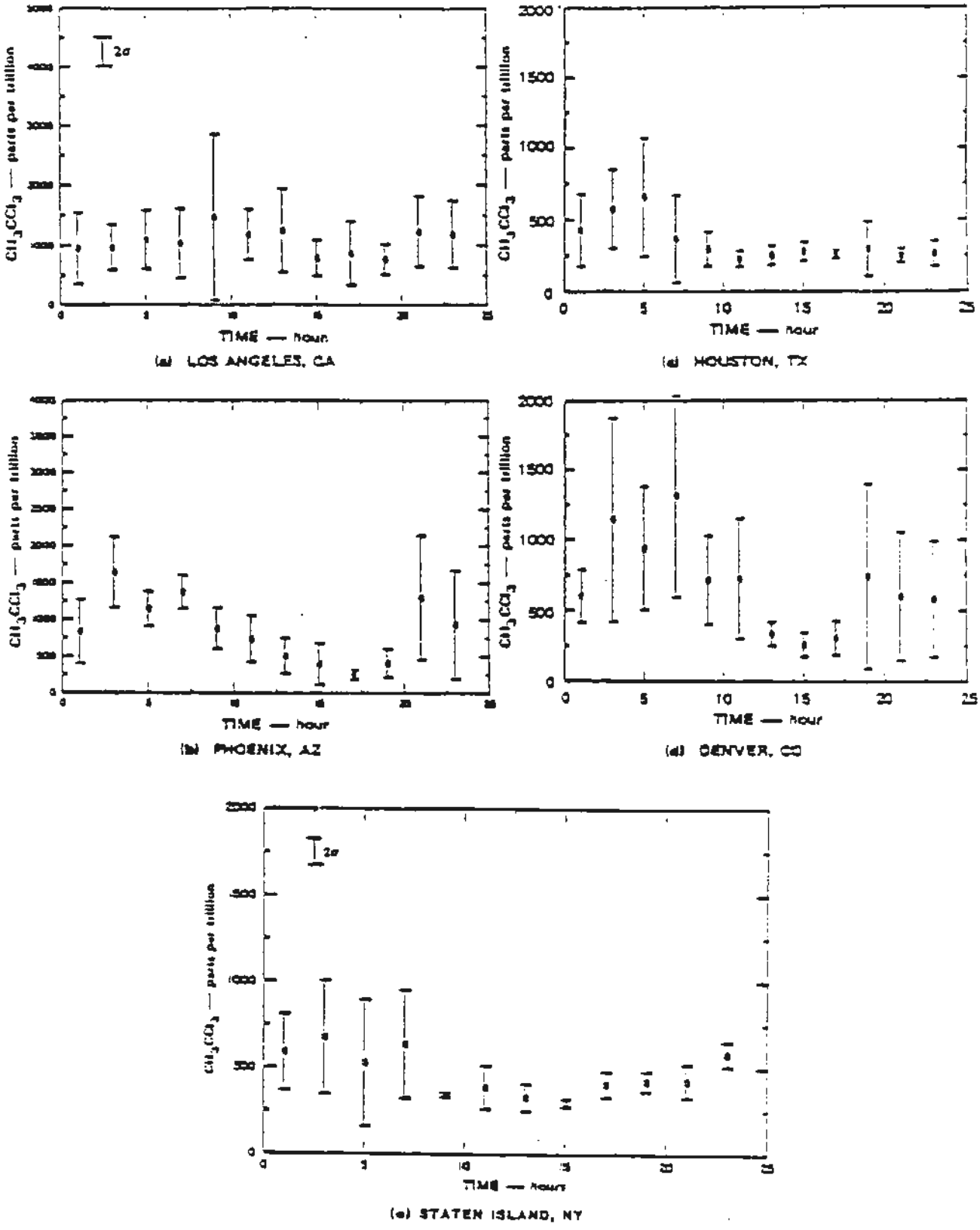

Figure B-5. Mean diurnal variation of methyl chloroform.

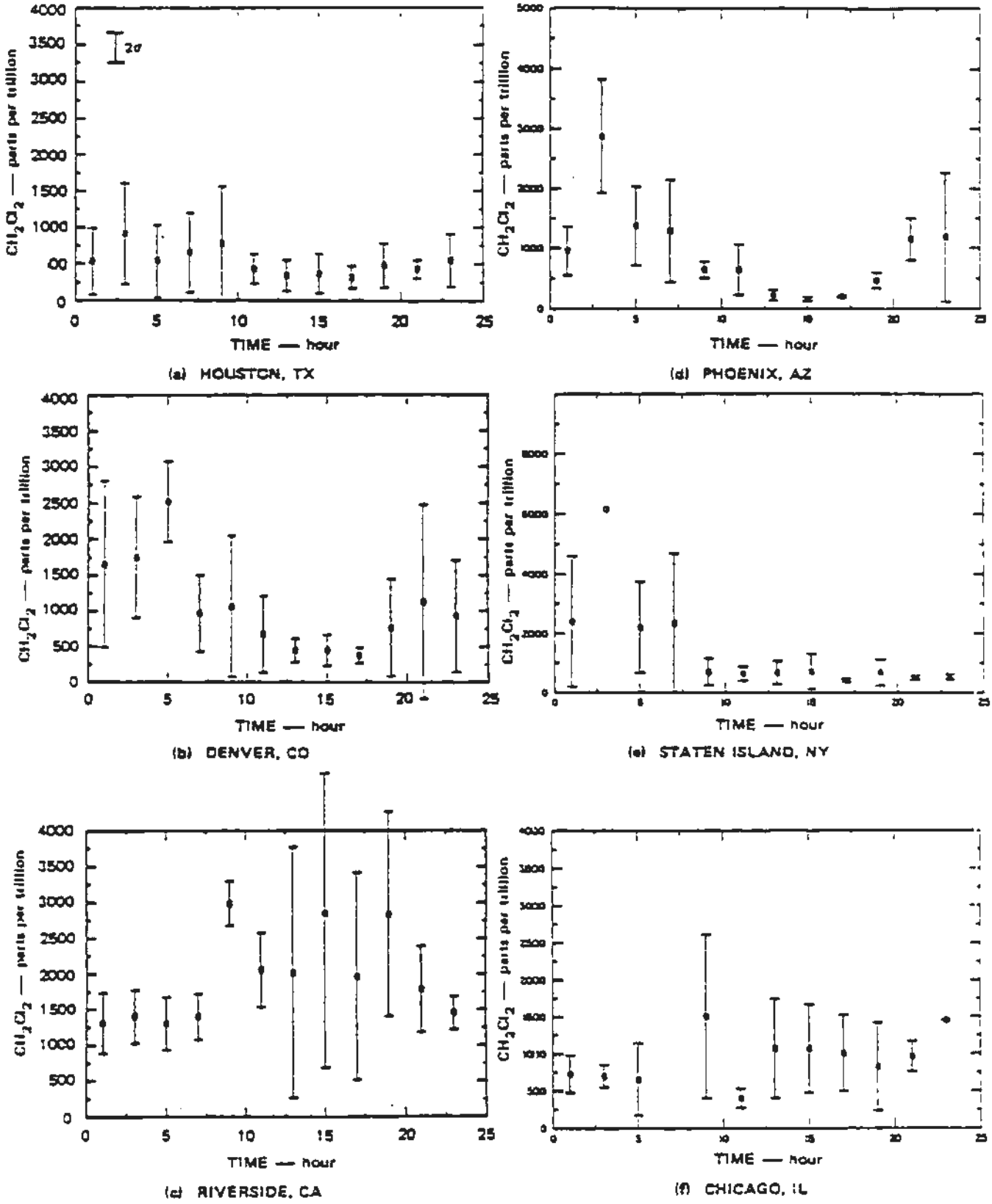

Figure B-6. Mean diurnal variation of methylene chloride.

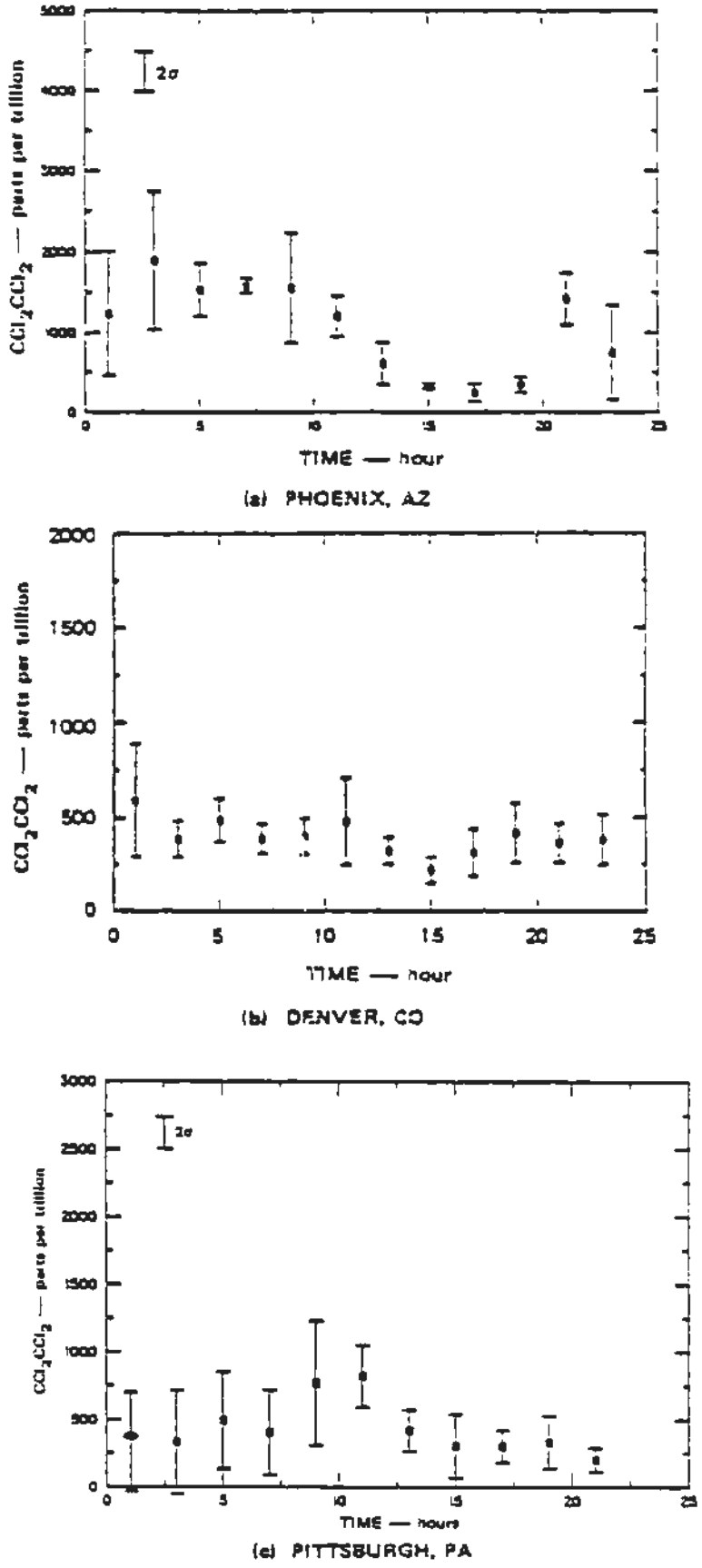

Figure B-7. Mean diurnal variation of perchloroethylene.

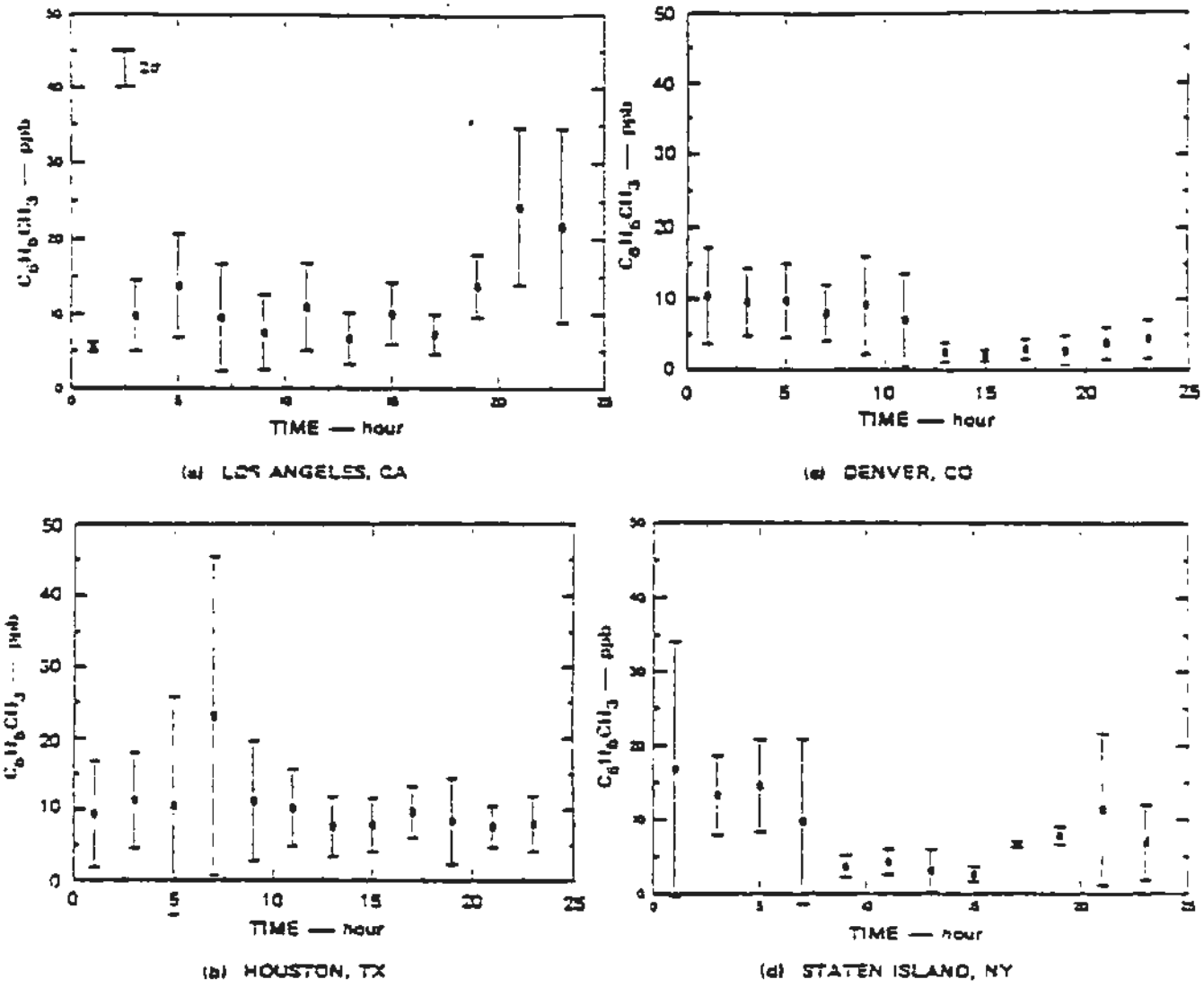

Figure B-8. Mean diurnal variation of toluene.

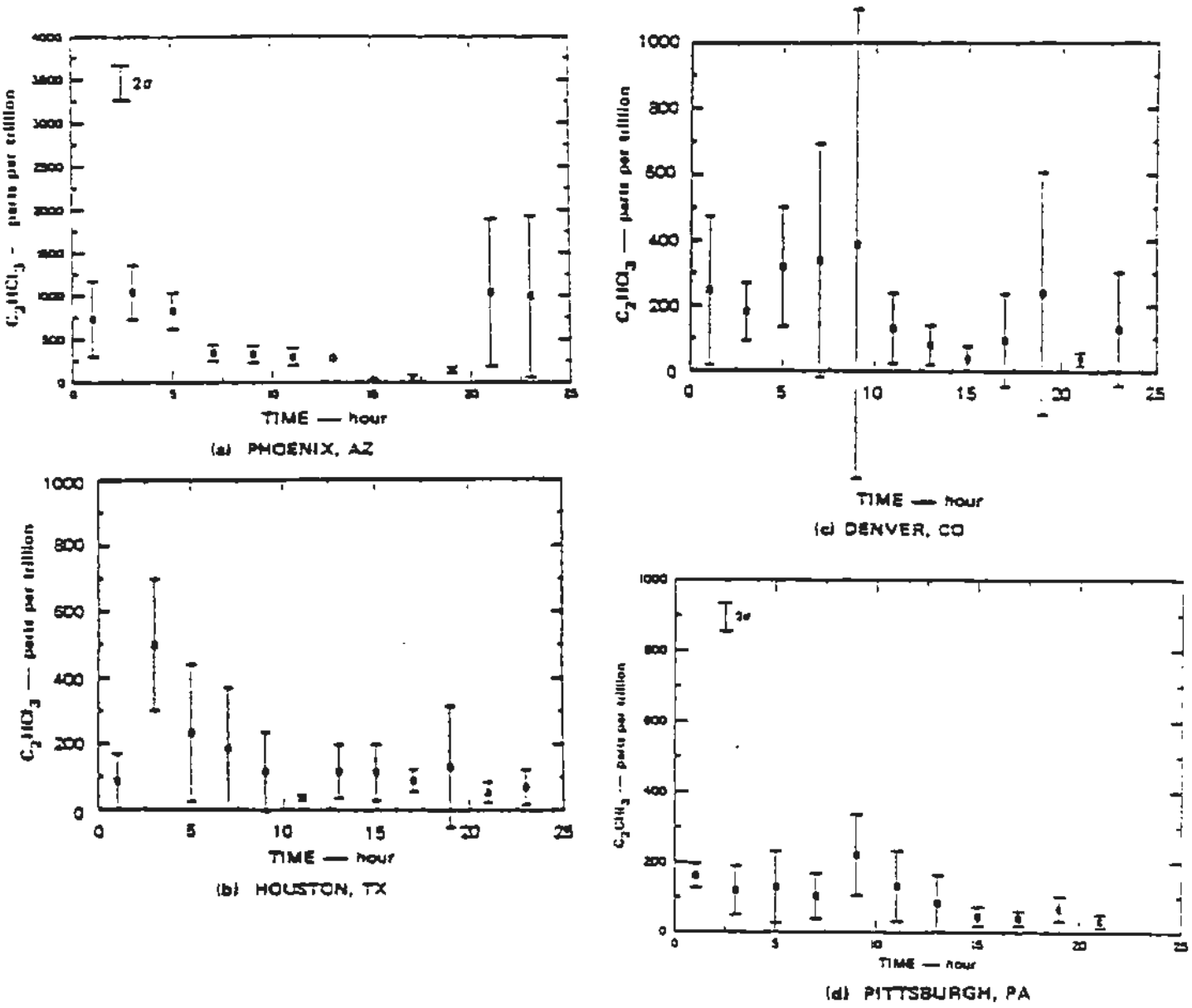

Figure B-9. Mean diurnal variation of trichloroethylene.

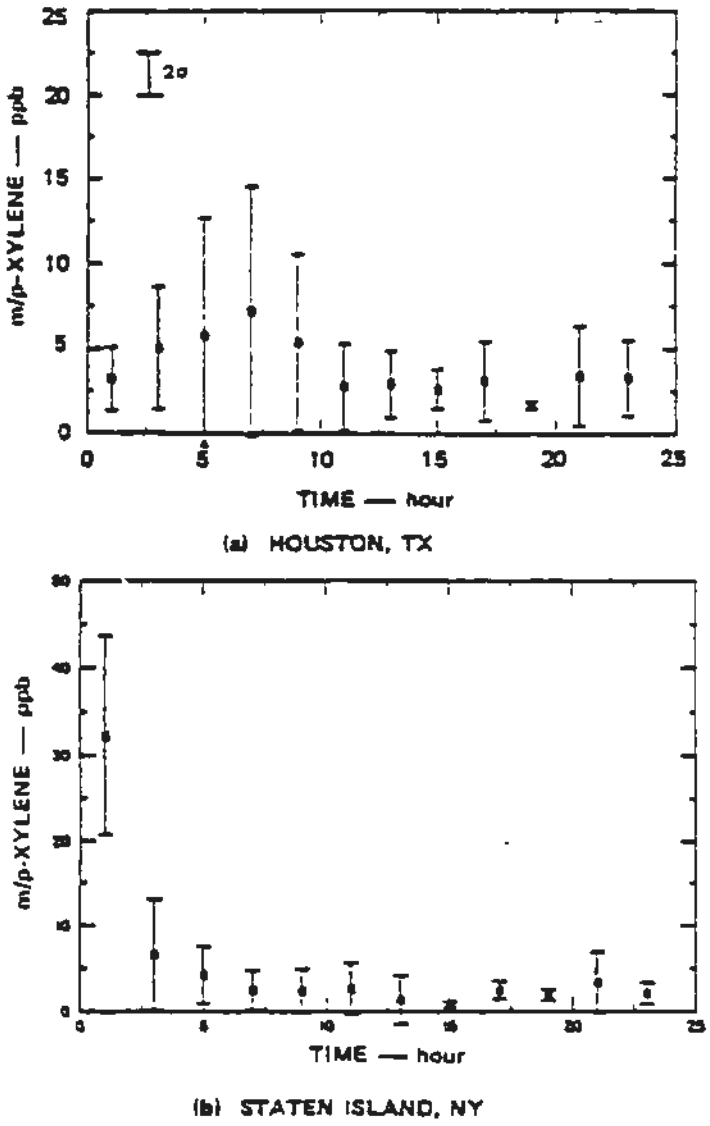

Figure B-10. Mean diurnal variation of m-,p-Xylene.

APPENDIX C

METEOROLOGICAL DATA TABULATIONS AVAILABLE FROM THE NATIONAL CLIMATIC DATA CENTER

Cities for which Stability Array (STAR) data tabulations are available are listed alphabetically by date and by city within a state.* Additional tabulations may be available since this compilation. For assistance on orders contact:

Director
National Climatic Data Center
Federal Building
Asheville, North Carolina 28801

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* From: Changery, M.J., W.J. Hodge, and J.V. Ramsdell. 1977. Index--Summarized Wind Data. BNWL-2220 WIND-11 UC-60, U.S. Department of Commerce, National Climatic Data Center, Asheville, NC.

C.-1. EXPLANATION OF ENTRIES

CITY is the city or town name for the location at which the original observations were taken. It may also be the name of a military installation.

NAME-TYPE is usually the airport or field name and/or service which operated the station. If these had changed during the period summarized, the name and/or service valid for the longest portion of the summary is used. A few stations may have no identifying information.

Under NAME, commonly used abbreviations are:

APT	-	Airport
ATL	-	Air Terminal
BD	-	Building
CAP	-	County Airport
CO	-	County
FLD	-	Field
GEN	-	General
GTR	-	Greater
INL	-	International
MAP	-	Municipal Airport
MEM	-	Memorial
METRO	-	Metropolitan
MN	-	Municipal
RGL	-	Regional
TERM	-	Terminal

Under TYPE, commonly used abbreviations are:

AAB	-	Army Air Base
AAF	-	Army Air Field
AAFB	-	Auxiliary Air Force Base
AEPG	-	Army Energy Proving Ground
AF	-	Air Force
AFB	-	Air Force Base
AFS	-	Air Force Station
ANGB	-	Air National Guard Base
ASC	-	Army Signal Corp
CAA	-	Civil Aeronautics Administration
FAA	-	Federal Aviation Administration
FSS	-	Flight Service Station
LAWR	-	Limited Airways Weather Reporting (Station)
MCAF	-	Marine Corps Air Facility
MCAS	-	Marine Corps Air Station
NAAF	-	Naval Auxiliary Air Facility
NAAS	-	Naval Auxiliary Air Station
NAF	-	Naval Air Facility
NAS	-	Naval Air Station
NAU	-	Naval Air Unit
NF	-	Naval Facility
NS	-	Naval Station
PG	-	Proving Ground
SAWR	-	Supplementary Airways Weather Reporting (Station)
WBAS	-	Weather Bureau Airport Station
WBO	-	Weather Bureau Office

ST is a two-letter code identifying each of the fifty states.

WBAN # refers to the five-digit number identifying stations operated by United States Weather Services (civilian and military) currently or in the past. A few stations have had no number assigned.

WMO # refers to the five-digit block and station numbers assigned to U. S. stations as authorized by the World Meteorological Organization. Many stations with a WBAN # will have no corresponding WMO number.

LAT, LONG are the latitude and longitude of the station in degrees and minutes. If the station changed coordinates during the period summarized, the location reflects the site with the longest record.

ELEV is the elevation (above sea level) of the station in meters. Reported station elevation was used if the barometric height above sea level was not available. If an elevation change occurred during the period summarized, the elevation reflects the station height for the longest period of record.

PERIOD OF RECORD is the first and last month-year of the summarized period. As an example, 01 38 - 12 44 is read as January 1938 through December 1944.

SUMMARY TYPE identifies each summary according to its format. Each format is similar to one of the 16 types presented in detail beginning on page I-13.

SUMM FREQ is the summary frequency or the time period in which the summarized data are presented. Abbreviations used are:

M - Monthly. Data for each calendar month combined and presented on a monthly basis.

S - Seasonal. Data for the months December through February of the period of record are combined into a winter season, summarized and presented on a seasonal basis. The months March-May, June-August, and September-November are similarly summarized.

A - Annual. All data for the period summarized together.

MA - Monthly and Annual.

SA - Seasonal and Annual.

MS - Monthly and Seasonal.

MSA - Monthly, Seasonal, and Annual.

IYM - Individual Year-Month. Data are presented for individual months of record.

SP - Special Period. The special period presented is described further in the given summary's Tab #/Remarks column.

TAB #/REMARKS column contains additional identifying or explanatory information. Many of the summaries produced by the Climatic Center and Air Weather Service for a specific project are identified by a tabulation number. A "T" followed by a 4 or 5 digit number identifies a summary produced by the NCC. Similarly, a "TCL" with a number indicates an AWS summary. Not all summaries can be so identified. This number is provided as an aid in requesting a specific tabulation.

Numbers following or in place of a tabulation number refer to remarks listed beginning on page I-9. These remarks are provided if additional information describing a summary is necessary. Examples are summaries with data for hourly or 3-hour periods, specified hours only, combined stations, etc.

C-2. REMARKS

This is a list of descriptive remarks coded by number in the Tab #/Remarks column of the index. Numbers missing were not used.

1. Broken period
2. 3-hourly groups
3. Day-night
4. 0600-1800 LST only
5. 10-12 observations per day, all daylight hours
6. By hours 00, 03, 06, 09, 12, 15, 18, 21 LST
7. See microfilm for broken periods and format
8. Includes flying weather conditions
9. Part "C" only
10. Hours 0600-1200 LST only
11. May-November only
12. Broken period - pre-11/45 data from Point Hope (Stn #26601)
13. Broken period by hourly groups
14. Less 12/59
15. Pre-1939 data from Tin City (Stn #26634)
16. Less 12/70
17. 0500-1600 LST only
18. 2-13 observations daily
19. 0700-1900 LST only
20. Combined data for Douglas AAF (Stn #23001) for 11/42-11/45 and Douglas Apt (Stn #93026) for 11/48-12/54
21. Part "A" only by hourly groups - combined data for Kingman CAA (Stn #93167) for 01/34-12/41 and Kingman AAF (Stn #23108) for 03/43-06/45
22. For hours 0800, 1400, 1700 LST only
23. Direction and speed by visibility, relative humidity $\geq$ 90% and/or precipitation, and relative humidity $\geq$ 90% and no precipitation - August, October, and December only
24. Part "A" only
25. By 2-hourly groups
26. Daylight hours only
27. September-December only
28. By hourly groups
29. For 0900-1600 and 1700-0800 LST
30. Period 01/37-03/38 for Indio (Stn #03105)
31. Precipitation-wind tabulation for April-October
32. By day and night hours on microfilm
33. Periods: July 15-31, August 1-15 for 1000 and 1400 LST
34. No data for 27 months
35. See Edwards AFB
36. Some data from Paso Robles (Stn #23231)
37. All observations by various stability classes
38. See Moffett Field
39. Also contains a contact wind rose
40. Eight directions and calm
41. Includes a percentage graph

42. 1200 LST observations only
43. Some missing data
44. Contains all weather, precipitation, and visibility $\leq$ 6 miles wind tabulations for day and night hours
45. Also called 94A
46. See Farallon Island SE
47A. 0100-0400 LST
47B. 0700-1000 LST
47C. 1300-1600 LST
47D. 1900-2200 LST
47E. 0600-2200 LST
47F. 0700 LST
47G. 1600 LST
47H. 0600-0900 LST
47I. 1600-1800 LST
47J. 0700-0900 LST
47K. 1900-0600 LST
47L. 1000-1500 LST
47M. 1200-2000 LST
47N. 0800-2100 LST
47P. 1100-1300 LST
48. Also contains bimonthly summaries
49. Located in city file
50. Three speed groups
51. June, July, August - daylight hours only
52. Special tables
53. Pre-1944 data from Bolling AAF (Stn #13710)
54. Also known as Chantilly, VA, FAA (pre-Dulles)
55. See Andrews AFB, MD
56. Data for 01/74 from Herndon Apt (Stn #12841)
57. See also Cape Kennedy AFB
58. Tower data - 8 levels (3-150 m)
59. June-August only
60. Data for 09/42-09/45 from Carlsbad AAF (Stn #23006)
61. Data after 07/53 from Key West NAS (Stn #12850)
62. Data thru 1945 from Marianna AAF (Stn #13851)
63. Contains 14 months of data from Morrison Field (Stn #12865)
64. Contains graphical wind rose
65. Tabulated by temperature and relative humidity intervals
66. Seasonal by day and night hours
67. Closed and instrument weather conditions only
68. Less 01/49
69. 24 observations daily
70. 8 observations daily
71. 1 of 3 parts
72. Tabulation by day and night hours for May 1 - September 30 and October 1 - April 30
73. Tabulated for December-March and April-November
74. Data prior to 10/42 and after 10/45 from Sioux City Apt (Stn #14943)

75. For day - clear and cloudy and night - clear and cloudy conditions
76. Also contains a ceiling-visibility tabulation
77. 0700-1900 LST only
78. All weather and 2 relative humidity classes
79. Summer season only - 1957 missing
80. May, August-November only
81. Includes separate wind rose for WSO
82. Four speed categories
83. Monthly tabulation for 0400 and 1400 LST, seasonal tabulation for all observations
84. Some data from Presque Isle AFB (Stn #14604)
85. Four observations per day
86. Semi-monthly periods
87. 1935 data from Boston WBAS (Stn #14739)
88. VFR, IFR, closed conditions
89. Pre-03/1952 data from Paso Robles (Stn #23231)
90. August 1-15 only for hours 1000 and 1400 LST
91. Partial SMOS
92. June, July only for hours 2200L - 0200L
93. April thru December only
94. Less April 1958 and 1960
95. January, April, July, and October only
96. Winter season only
97. Part "C" and "E" only
98. 36 compass points
99. Less October-December 1945 for a 2-hour period after sunrise
100. November 1951 substituted for November 1955
102. For hour groups 07-09, 10-15, 16-18, and 19-06 LST and all hours combined
103. For hours 0100, 0700, 1300, and 1900 LST (individual and all hours combined)
104. Day and night hours, clear and cloudy conditions
106. Pre-02/33 data from Albuquerque WBO (Stn #23073)
108. Precipitation wind rose tabulation
109. All observations by 6 hourly groups
110. For ceiling less than 600 feet and/or visibility less than 1-1/2 miles - also an annual hourly summary
111. Also summarized by month-hour for hours 0200 and 1400 LST
112. Summarized by days 1-15 and 16 to end of month for day and night hours
115A. 1300 LST
115B. 0400 LST
115C. 1000 LST
115D. 1600 LST
115E. 2200 LST
115F. 0700 LST
115G. 0100 LST
115H. 1900 LST
117. See Covington, Kentucky
118. Pre-04/32 data from Oklahoma City WBO (Stn #93954)
119. May to October only

120. Monthly for 1961-63, individual months 1-4/64
121. Also contains day and night summaries
124. Summary titled Scranton
125. See Wilkes-Barre
126. December-February for 0730 and 1930 LST only
128. Pre-12/44 data from Galveston AAF (Stn #12905)
129. Data for 10/62-12/63 for Greenville-Spartanburg Apt (Stn #03870)
132. February-April and June-September only
133. Pre-03/43 data from English Field (Stn #23047)
134. Post-10/66 data from Fort Wolters
135. Less 6/68
136. For hours 00-23 and 07-22 LST
140. Also contains annual ceiling/visibility tabulation
141. Less 0000 and 0300 LST
142. See Killeen
143. See Dugway PG
144. Data for 1943-49 for Wendover AFB (Stn #24111)
145. 0400-1800 LST
146. See Washington, DC - Dulles International Apt WBAS
147. See Washington, DC - National Apt WBAS
149. 0700-1200 LST
150. Tower data, year-month-level, month-level, and month-level-hour
151. Pre-11/41 data from Paine Field CAA (Stn #24222)
152. 10 observations per day - closed on weekends
153. 10 observations per day - wind speed estimated
155. By 5°F temperature intervals - with and without thunderstorms
157. One speed group - greater than 14 knots
158. Speed classes in Beaufort Force - mean speed by direction in mph
159. Hourly groups for 0600-1600 LST
160. Post-05/55 data from Forest Sherman (Stn #03855)
161. By speed classes and 5°F temperature classes
162. For all hours combined and for hours 0030 and 1230 individually

SUMMARY TYPE: STAR

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TABS/REMARKS
ANNISTON	CALHOUN CO ART CAA	AL	13871		33 35N	085 51W	0183	01 45 - 12 54	STAR	SA	T13272
BIRMINGHAM	MUNICIPAL ART WBAS	AL	13876	72228	33 34N	086 45W	0192	01 60 - 12 64	STAR	MA	T12741
BIRMINGHAM	MUNICIPAL ART WBAS	AL	13876	72228	33 34N	086 45W	0192	01 71 - 12 71	STAR	SA	T13618
BIRMINGHAM	MUNICIPAL ART WBAS	AL	13876	72228	33 34N	086 45W	0192	01 72 - 12 72	STAR	SA	T50979
FORT RUCKER	CAIRNES AAF	AL	03859		31 18N	085 43W	0091	01 65 - 12 68	STAR	SA	T12761
HUNTSVILLE	HUNTSVL-MADISON CAP WBAS	AL	03856	72323	34 42N	086 35W	0185	01 60 - 12 64	STAR	SA	T14718
HUNTSVILLE	HUNTSVL-MADISON CAP WBAS	AL	03856	72323	34 39N	086 46W	0196	01 72 - 12 72	STAR	SA	T50979
MOBILE	BATES FLD WBAS	AL	13894	72223	30 41N	088 15W	0068	01 66 - 12 70	STAR	SA	T12925
MOBILE	BATES FLD WBAS	AL	13894	72223	30 41N	088 15W	0069	01 70 - 12 74	STAR	SA	T52078
MOBILE	BATES FLD WBAS	AL	13894	72223	30 41N	088 15W	0069	01 70 - 12 70	STAR	SA	T12925
MOBILE	BATES FLD WBAS	AL	13894	72223	30 41N	088 15W	0069	01 71 - 12 71	STAR	A	T01772
MOBILE	BATES FLD WBAS	AL	13894	72223	30 41N	088 15W	0069	01 72 - 12 72	STAR	SA	T50979
MONTGOMERY	DANNELLY FLD WBAS	AL	13895	72228	32 18N	086 24W	0081	01 70 - 12 70	STAR	A	T13987
MONTGOMERY	DANNELLY FLD WBAS	AL	13895	72228	32 18N	086 24W	0081	01 72 - 12 72	STAR	SA	T50979
SELMA	CRAIG AFB	AL	12950		32 21N	086 59W	0063	01 54 - 12 58	STAR	SA	T13967
TUSCALOOSA	VAN DE GRAFF APT CAA	AL	03808		33 14N	087 37W	0097	01 48 - 12 54	STAR	A	T51682.3
ANCHORAGE	ELMENDORF AFB	AK	26401	70272	61 15N	149 48W	0094	01 51 - 12 70	STAR	MA	T15332.3
ANCHORAGE	INTERNATIONAL APT WBAS	AK	26451	70273	61 10N	150 01W	0048	01 65 - 12 88	STAR	MA	T13863
BIG DELTA	FAA	AK	26415	70267	64 00N	145 44W	0388	01 60 - 12 64	STAR	SA	T14083
BIG DELTA	FAA	AK	26415	70267	64 00N	145 44W	0388	01 67 - 12 71	STAR	SA	T14083
COBDOVA	MILE 13 APT FAA	AK	26410	70296	60 30N	145 30W	0013	01 56 - 12 82	STAR	SA	T50320
FAIRBANKS	EIELSON AFB	AK	26407	70285	64 39N	147 04W	0168	01 61 - 12 70	STAR	SA	T14703
FAIRBANKS	INTERNATIONAL APT WBAS	AK	26411	70261	64 48N	147 52W	0154	01 61 - 12 70	STAR	SA	T14703
GULKANA	INTERMEDIATE FIELD	AK	26435	70271	62 09N	145 27W	0481	01 67 - 12 71	STAR	SA	T14083
KENAI	MUNICIPAL APT CAA	AK	26523	70256	60 34N	151 15W	0037	01 48 - 12 58	STAR	MA	T15332.3
KENAI	MUNICIPAL APT FAA	AK	26523	70256	60 34N	151 15W	0032	01 68 - 12 70	STAR	SA	T13873
MIDDLETON ISL	AFS	AK	25403	70343	59 28N	146 18W	0015	01 56 - 12 82	STAR	SA	T50320
DOUGLAS	BISBEE-OGLS INL APT WBAS	AZ	03026		31 27N	109 36W	1292	01 50 - 12 54	STAR	SA	T50672.3
DOUGLAS	BISBEE-OGLS INL APT CAA	AZ	03026		31 27N	109 36W	1292	01 50 - 12 54	STAR	SA	T13389
PHOENIX	SKY HARBOR RAP WBAS	AZ	23183	72278	33 26N	112 01W	0338	01 59 - 12 64	STAR	MA	T14334
PHOENIX	SKY HARBOR RAP WBAS	AZ	23183	72278	33 26N	112 01W	0338	01 67 - 12 71	STAR	MA	T13791
PHOENIX	SKY HARBOR RAP WBAS	AZ	23183	72278	33 26N	112 01W	0338	01 68 - 12 73	STAR	SA	T50584.22
PHOENIX	SKY HARBOR RAP WBAS	AZ	23183	72278	33 26N	112 01W	0338	01 73 - 12 75	STAR	SA	T52278.3
PHOENIX	SKY HARBOR RAP WBAS	AZ	23183	72278	33 26N	112 01W	0338	01 75 - 12 75	STAR	MA	T52362.3
PHOENIX	SKY HARBOR RAP WBAS	AZ	23183	72278	33 26N	112 01W	0338	01 75 - 12 75	STAR	SA	T52278.3
PHOENIX	SKY HARBOR RAP WBAS	AZ	23183	72278	33 26N	112 01W	0338	01 75 - 12 75	STAR	MA	T52362.3
PRESCOTT	MUNICIPAL APT WBAS	AZ	23184	72372	34 38N	112 26W	1930	01 67 - 12 71	STAR	SA	T01772
TUCSON	MUNICIPAL APT WBAS	AZ	23160	72274	32 08N	110 57W	0778	01 55 - 12 64	STAR	MA	T14334
TUCSON	MUNICIPAL APT WBAS	AZ	23160	72274	32 08N	110 57W	0778	01 58 - 12 83	STAR	SA	T13111
TUCSON	INL APT WBAS	AZ	23160	72274	32 07N	110 56W	0788	01 67 - 12 71	STAR	MA	T14388
TUCSON	INL APT WBAS	AZ	23160	72274	32 07N	110 56W	0788	01 67 - 12 71	STAR	MSA	T14318
YUMA	INTERNATIONAL APT WBAS	AZ	23195	72280	32 40N	114 36W	0062	01 67 - 12 71	STAR	SA	T13385
EL DORADO	GOODWIN FIELD CAA	AR	03993		33 13N	092 49W	0082	01 50 - 12 54	STAR	SA	T50056
FORT SMITH	MUNICIPAL APT WBAS	AR	13964	72344	35 20N	094 22W	0141	01 56 - 12 74	STAR	MA	T51827.3
FORT SMITH	MUNICIPAL APT WBAS	AR	13964	72344	35 20N	094 22W	0141	01 68 - 12 72	STAR	MSA	T14655
LITTLE ROCK	ADAMS FIELD RAP WBAS	AR	13963	72340	34 44N	092 14W	0084	01 55 - 12 64	STAR	SA	T14644
LITTLE ROCK	ADAMS FIELD RAP WBAS	AR	13963	72340	34 44N	092 14W	0084	01 68 - 12 70	STAR	SA	T13028
LITTLE ROCK	ADAMS FIELD RAP WBAS	AR	13963	72340	34 44N	092 14W	0084	01 68 - 12 73	STAR	SA	T51048.3
LITTLE ROCK	ADAMS FIELD RAP WBAS	AR	13963	72340	34 44N	092 14W	0084	08 71 - 07 72	STAR	SA	T11153
LITTLE ROCK	ADAMS FIELD RAP WBAS	AR	13963	72340	34 44N	092 14W	0084	02 72 - 02 73	STAR	SA	T01772
ALAMEDA	NAS	CA	23239	74506	37 47N	122 18W	0008	01 60 - 12 64	STAR	MA	T14288
ARCATA	FAA	CA	24283		40 58N	124 06W	0086	01 68 - 12 72	STAR	MA	T14360
BAKERSFIELD	MEADOWS FIELD WBAS	CA	23155	72384	35 25N	119 03W	0151	01 60 - 12 64	STAR	A	T52295
BAKERSFIELD	MEADOWS FIELD WBAS	CA	23155	72384	35 25N	119 03W	0151	01 64 - 12 73	STAR	MA	T50715.3
BAKERSFIELD	MEADOWS FIELD WBAS	CA	23155	72384	35 25N	119 03W	0151	01 67 - 12 71	STAR	MA	T14331
BISHOP	WBAS	CA	23197	72480	37 22N	118 22W	1293	01 60 - 12 64	STAR	MA	T15356.47M
BLYTHE	RIVERSIDE COUNTY APT FAA	CA	23158		33 37N	114 43W	0120	01 48 - 12 54	STAR	SA	T14358
BLYTHE	RIVERSIDE COUNTY APT FAA	CA	23158		33 37N	114 43W	0119	08 68 - 08 74	STAR	SA	T15211
BURBANK	HOLLYWD-BURBANK APT WBAS	CA	23152	72288	34 12N	118 22W	0221	01 60 - 12 64	STAR	MA	T13297
CHINA LAKE	NAS	CA	93104		35 41N	117 41W	0680	01 54 - 12 58	STAR	ITM	T15278
CHINA LAKE	NAS	CA	93104		35 41N	117 41W	0682	01 58 - 12 63	STAR	ITM	T15278
DAGGETT	SAN BERNARDINO CAP FAA	CA	23181		34 52N	116 47W	0568	01 55 - 12 64	STAR	SA	T13284
DAGGETT	SAN BERNARDINO CAP FAA	CA	23181		34 52N	116 47W	0568	01 55 - 12 64	STAR	MA	T13284
EDWARDS	AFB RUGBC	CA	23114	72381	34 55N	117 54W	0706	01 68 - 12 70	STAR	MA	T51149
FAIRFIELD	TRAVIS AFB	CA	23202	74516	38 16N	121 56W	0018	01 60 - 12 64	STAR	MA	T14239
FRESNO	AIR TERMINAL WBAS	CA	93193	72388	36 47N	119 43W	0103	01 60 - 12 64	STAR	A	T52295
FRESNO	AIR TERMINAL WBAS	CA	93193	72388	36 47N	119 43W	0103	01 60 - 12 64	STAR	MA	T15356.3
LONG BEACH	MUNICIPAL APT WBAS	CA	23129	72297	33 48N	118 09W	0021	01 48 - 12 64	STAR	MA	T15332.3
LONG BEACH	MUNICIPAL APT WBAS	CA	23129	72297	33 48N	118 09W	0021	01 60 - 12 64	STAR	MA	T13297
LONG BEACH	MUNICIPAL APT WBAS	CA	23129	72297	33 48N	118 09W	0017	01 65 - 12 74	STAR	MA	T15332.3
LONG BEACH	MUNICIPAL APT WBAS	CA	23129	72297	33 48N	118 09W	0008	01 68 - 12 73	STAR	A	T50819.3
LOS ALAMITOS	NAS	CA	93108		33 48N	118 03W	0008	01 65 - 12 88	STAR	MA	T13297
LOS ANGELES	INTERNATIONAL APT WBAS	CA	23174	72295	33 56N	118 23W	0037	01 55 - 12 64	STAR	MA	T50348
LOS ANGELES	INTERNATIONAL APT WBAS	CA	23174	72295	33 56N	118 23W	0037	01 60 - 12 81	STAR	MA	T14088
LOS ANGELES	INTERNATIONAL APT WBAS	CA	23174	72295	33 56N	118 23W	0037	09 64 - 04 69	STAR	MA	T13297
LOS ANGELES	INTERNATIONAL APT WBAS	CA	23174	72295	33 56N	118 23W	0037	01 65 - 12 88	STAR	SA	T14088
LOS ANGELES	INTERNATIONAL APT WBAS	CA	23174	72295	33 56N	118 23W	0037	01 70 - 12 71	STAR	SA	T14088
MOFFETT FIELD	NAS SUNNYVALE	CA	23244	74508	37 25N	122 03W	0012	01 60 - 12 64	STAR	MA	T14289
NEEDLES	MUNICIPAL APT CAA	CA	23179	72380	34 46N	114 37W	0280	01 48 - 12 54	STAR	SA	T13029
NEEDLES	MUNICIPAL APT CAA	CA	23179	72380	34 46N	114 37W	0280	01 55 - 12 64	STAR	SA	T13790
NEEDLES	MUNICIPAL APT FAA	CA	23179	72380	34 46N	114 37W	0280	08 68 - 08 74	STAR	SA	T15211
OAKLAND	INTERNATIONAL APT WBAS	CA	23230	72493	37 44N	122 22W	0005	01 60 - 12 64	STAR	MA	T14289
OCEANO	AFB	CA	23136		34 13N	118 04W	0029	01 60 - 12 64	STAR	MA	T50818
POINT MUGU	NF	CA	93111	72391	34 07N	119 07W	0004	03 52 - 02 72	STAR	MA	T15332.3
POINT MUGU	NF	CA	93111	72391	34 07N	119 07W	0008	01 60 - 12 64	STAR	MA	T50818
RIVERSIDE	MARCH AFB	CA	23119	72286	33 53N	117 15W	0461	01 58 - 12 70	STAR	A	T50819.3
RIVERSIDE	MARCH AFB	CA	23119	72286	33 53N	117 15W	0461	01 66 - 12 70	STAR	MA	T14331
SACRAMENTO	MUNICIPAL APT WBAS	CA	23232	72483	38 31N	121 30W	0015	01 68 - 12 70	STAR	SA	T01772

SUMMARY TYPE: STAR

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TAPE/REMARKS
SACRAMENTO	EXECUTIVE APT WBAS	CA	23232	72483	38 31N	121 30W	0008	01 59 - 12 73	STAR	SA	T50504.47F
SACRAMENTO	EXECUTIVE APT WBAS	CA	23232	72483	38 31N	121 30W	0008	01 59 - 12 73	STAR	SA	T50504.47G
SAN DIEGO	LINDBERGH INL APT WBAS	CA	23188	72290	32 44N	117 10W	0011	01 55 - 12 64	STAR	MA	T50246
SAN DIEGO	LINDBERGH INL APT WBAS	CA	23188	72290	32 44N	117 10W	0011	01 60 - 12 64	STAR	SA	T13869
SAN DIEGO	LINDBERGH INL APT WBAS	CA	23188	72290	32 44N	117 10W	0011	01 68 - 12 72	STAR	MA	T01772
SAN DIEGO	NAS NORTH ISLAND	CA	93112		32 42N	117 12W	0019	01 67 - 12 71	STAR	MA	T76000
SAN FRANCISCO	INTERNATIONAL APT WBAS	CA	23234	72494	37 37N	122 23W	0027	01 60 - 12 64	STAR	MA	T14269
SAN FRANCISCO	INTERNATIONAL APT WBAS	CA	23234	72494	37 37N	122 23W	0002	01 58 - 12 73	STAR	SA	T50878.47G
SAN FRANCISCO	INTERNATIONAL APT WBAS	CA	23234	72494	37 37N	122 23W	0002	01 58 - 12 73	STAR	SA	T50878.47H
SAN FRANCISCO	INTERNATIONAL APT WBAS	CA	23234	72494	37 37N	122 23W	0002	01 58 - 12 73	STAR	SA	T50878.47R
SAN FRANCISCO	INTERNATIONAL APT WBAS	CA	23234	72494	37 37N	122 23W	0002	01 59 - 12 73	STAR	SA	T50878.47Q
SAN RAFAEL	HAMILTON AFB	CA	23211		38 04N	122 31W	0004	01 60 - 12 64	STAR	MA	T14269
SAN RAFAEL	HAMILTON AFB	CA	23211		38 04N	122 31W	0004	01 66 - 12 70	STAR	SA	T14156
SANTA BARBARA	MUNICIPAL APT FAA	CA	23190		34 26N	119 50W	0004	01 50 - 12 64	STAR	MA	T12329
SANTA MARIA	WBAS	CA	23238	72394	34 54N	120 25W	0071	01 49 - 12 53	STAR	MA	T50740
SANTA MARIA	WBAS	CA	23273	72394	34 54N	120 27W	0073	01 65 - 12 74	STAR	MA	T52110.3
UKIAH	MUNICIPAL APT FAA	CA	23275		39 08N	123 12W	0192	01 55 - 12 64	STAR	MA	T50175
VANDENBERG	CAMP COOKE AFB	CA	93214	72393	34 43N	120 34W	0116	01 58 - 12 72	STAR	MA	T15332.3
VANDENBERG	CAMP COOKE AFB	CA	93214	72393	34 43N	120 34W	0116	01 61 - 12 70	STAR	MA	T15029
VANDENBERG	CAMP COOKE AFB	CA	93214	72393	34 43N	120 34W	0116	01 66 - 12 70	STAR	MA	T50998.47E
VANDENBERG	CAMP COOKE AFB SUBF	CA	93214	72393	34 43N	120 34W	0116	01 70 - 12 70	STAR	SA	T01772
VICTORVILLE	GEORGE AFB	CA	23131		34 35N	117 23W	0860	01 58 - 12 67	STAR	MA	T13284
VICTORVILLE	GEORGE AFB	CA	23131		34 35N	117 23W	0860	01 58 - 12 67	STAR	SA	T13284
AKRON	WASHINGTON COUNTY APT CAA	CO	24015		40 07N	103 10W	1398	01 50 - 12 54	STAR	MA	T15038
COLORADO SPGS	PETERSON FIELD WBAS	CO	93037	72466	38 48N	104 43W	1857	01 59 - 12 73	STAR	MA	T50255
COLORADO SPGS	PETERSON FIELD WBAS	CO	93037	72466	38 48N	104 43W	1857	01 74 - 12 74	STAR	A	T51947.3
DENVER	STAPLETON INT APT WBAS	CO	23062	72469	39 46N	104 53W	1615	01 50 - 12 64	STAR	MA	T50313
DENVER	STAPLETON INT APT WBAS	CO	23062	72469	39 46N	104 53W	1615	07 58 - 02 69	STAR	A	T12211
DENVER	STAPLETON INL APT WBAS	CO	23062	72469	39 46N	104 53W	1615	01 74 - 12 74	STAR	SA	T51958.3
GRAND JUNCTION	MUNICIPAL APT WBAS	CO	23066	72476	39 07N	108 32W	1474	01 60 - 12 64	STAR	SA	T14516
PUEBLO	MEMORIAL APT WBAS	CO	93058	72464	38 17N	104 31W	1415	01 60 - 12 64	STAR	MA	T50907
PUEBLO	MEMORIAL APT WBAS	CO	93058	72464	38 17N	104 31W	1415	01 66 - 12 70	STAR	SA	T50088
PUEBLO	MEMORIAL APT WBAS	CO	93058	72464	38 17N	104 31W	1438	01 73 - 12 74	STAR	A	T15405
PUEBLO	MEMORIAL APT WBAS	CO	93058	72464	38 17N	104 31W	1438	01 74 - 12 74	STAR	A	T51947.3
BRIDGEPORT	MUNICIPAL APT WBAS	CT	94702	72504	41 10N	073 08W	0009	01 64 - 12 64	STAR	A	T12243
BRIDGEPORT	MUNICIPAL APT WBAS	CT	94702	72504	41 10N	073 08W	0009	01 65 - 12 68	STAR	SA	T14793
HARTFORD	BRAINARD FIELD WBAS	CT	14752		41 44N	072 39W	0005	01 48 - 12 52	STAR	MA	T14204
WINDSOR LOCKS	BRADLEY FIELD WBAS	CT	14740	72508	41 56N	072 41W	0061	01 68 - 12 72	STAR	SA	T14793
WINDSOR LOCKS	BRADLEY FIELD WBAS	CT	14740	72508	41 56N	072 41W	0061	05 73 - 04 74	STAR	A	T50465
WINDSOR LOCKS	BRADLEY FIELD WBAS	CT	14740	72508	41 56N	072 41W	0061	01 74 - 04 75	STAR	MA	T51792
WINDSOR LOCKS	BRADLEY FIELD WBAS	CT	14740	72508	41 56N	072 41W	0061	05 74 - 10 74	STAR	A	T52448.52
DOVER	AFB	DE	13707		39 08N	075 28W	0011	01 53 - 12 67	STAR	A	T11748
DOVER	AFB	DE	13707		39 08N	075 28W	0011	01 58 - 12 70	STAR	MA	T50485.3
DOVER	AFB	DE	13707		39 08N	075 28W	0011	07 74 - 08 75	STAR	A	T52367
WILMINGTON	GTR WIL NEW CAS APT WBAS	DE	13781		39 40N	075 36W	0028	01 60 - 12 64	STAR	MA	T13187
WILMINGTON	GTR WIL NEW CAS APT WBAS	DE	13781		39 40N	075 36W	0024	01 60 - 12 64	STAR	SA	T15634
WILMINGTON	GTR WIL NEW CAS APT WBAS	DE	13781		39 40N	075 36W	0029	01 67 - 12 67	STAR	SA	T01778
WILMINGTON	GTR WIL NEW CAS APT WBAS	DE	13781		39 40N	075 36W	0024	01 68 - 12 73	STAR	MA	T50485
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	01 60 - 12 64	STAR	A	T14151.47K
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	01 60 - 12 64	STAR	A	T14151.47I
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	01 60 - 12 64	STAR	A	T14151.47L
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	01 60 - 12 64	STAR	A	T13371
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	01 60 - 12 64	STAR	A	T14151.47J
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	01 68 - 12 72	STAR	MA	T50788.47J
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	01 68 - 12 72	STAR	MA	T14737
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	01 68 - 12 73	STAR	A	T51800.3
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	01 66 - 12 68	STAR	MSA	T13770
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	01 70 - 12 70	STAR	MSA	T13770
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	05 70 - 12 70	STAR	MA	T01772
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	01 71 - 12 71	STAR	MSA	T13770
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	01 72 - 12 72	STAR	MSA	T14175
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	11 72 - 12 72	STAR	MA	T01772
WASHINGTON	NATIONAL APT WBAS	DC	13743	72405	38 51N	077 02W	0023	01 73 - 12 73	STAR	A	T51800.3
WASHINGTON	DULLES INL APT WBAS	DC	93738	72403	38 57N	077 27W	0084	01 66 - 12 70	STAR	SA	T13303
WASHINGTON	DULLES INL APT WBAS	DC	93738	72403	38 57N	077 27W	0084	01 67 - 12 71	STAR	SA	T13672
WASHINGTON	DULLES INL APT WBAS	DC	93738	72403	38 57N	077 27W	0084	01 70 - 12 71	STAR	SA	T14686
WASHINGTON	DULLES INL APT WBAS	DC	93738	72403	38 57N	077 27W	0084	01 71 - 12 71	STAR	MSA	T14175
WASHINGTON	DULLES INL APT WBAS	DC	93738	72403	38 57N	077 27W	0084	01 72 - 12 72	STAR	MSA	T14175
DAYTONA BEACH	MUNICIPAL APT WBAS	FL	12834		29 11N	081 03W	0019	01 67 - 12 71	STAR	SA	T50033
FORT MEYERS	PAGE FIELD WBAS	FL	12835	72210	26 35N	081 52W	0004	01 58 - 12 73	STAR	A	T50872
JACKSONVILLE	IMESON APT WBAS		13889	72206	30 29N	081 39W	0012	01 66 - 12 66	STAR	SA	T12858
JACKSONVILLE	IMESON APT WBAS	FL	13889	72206	30 29N	081 39W	0012	01 70 - 12 70	STAR	SA	T12858
JACKSONVILLE	IMESON APT WBAS	FL	13889	72206	30 29N	081 39W	0012	01 72 - 12 72	STAR	SA	T01772
JACKSONVILLE	IMESON APT WBAS	FL	13889	72206	30 29N	081 39W	0012	01 73 - 12 73	STAR	SA	T50183
JACKSONVILLE	IMESON APT WBAS		13889	72206	30 29N	081 39W	0009	01 75 - 12 75	STAR	A	T52247
MIAMI	INTERNATIONAL APT WB		12839	72202	25 48N	080 16W	0004	01 67 - 12 71	STAR	MA	T13861
MIAMI	INTERNATIONAL APT		12839	72202	25 48N	080 16W	0004	01 70 - 12 74	STAR	A	T52115.3
MIAMI	INTERNATIONAL AP		12839	72202	25 48N	080 16W	0004	01 71 - 12 71	STAR	MA	T13861
MIAMI	INTERNATIONAL AP		12839	72202	25 48N	080 16W	0004	01 72 - 12 72	STAR	MA	T01772
MIAMI	INTERNATIONAL	FL	12839	72202	25 48N	080 16W	0004	01 73 - 12 73	STAR	MA	T50183
MIAMI	INTERNATIONAL	FL	12839	72202	25 48N	080 16W	0017	01 74 - 12 74	STAR	A	T52115.3
MIAMI	INTERNATIONA	FL	12839	72202	25 48N	080 16W	0017	08 74 - 08 75	STAR	MA	T51924.3
MIAMI	INTERNATIO	FL	12839	72202	25 48N	080 16W	0017	03 75 - 08 75	STAR	A	T51924.3
MILTON	WHITING F	FL	93841		30 43N	087 01W	0094	01 62 - 12 71	STAR	SA	T14457
ORLANDO	MCCOY	FL	12815		28 27N	081 18W	0032	01 66 - 12 67	STAR	SA	T01772
ORLANDO	MCCOY	FL	12815		28 27N	081 18W	0032	01 70 - 12 70	STAR	SA	T01772
ORLANDO	MCCO	FL	12815		28 27N	081 18W	0032	01 74 - 12 74	STAR	A	T51046.58

SUMMARY TYPE: STAR

CITY	NAME + TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TAPE/REMARKS
ORLANDO	MCRNOON ART WBAS	FL	12841	72205	28 33N	081 20W	0037	01 60 - 12 64	STAR	A	T11748
ORLANDO	MCRNOON ART WBAS	FL	12841	72205	28 33N	081 20W	0037	01 60 - 12 64	STAR	MM	T50590
ORLANDO	MCRNOON ART WBAS	FL	12841	72205	28 33N	081 20W	0037	01 60 - 12 64	STAR	MM	T14855
ORLANDO	MCRNOON ART WBAS	FL	12841	72205	28 33N	081 20W	0037	01 71 - 12 71	STAR	SA	T01772
ORLANDO	MCRNOON ART WBAS	FL	12841	72205	28 33N	081 20W	0037	01 73 - 12 73	STAR	MM	T50241
PANAMA CITY	TYNDALL AFB	FL	13846	74779	30 04N	085 35W	0007	01 66 - 12 70	STAR	SA	T14171
PENSACOLA	FORREST SHERMAN NAS	FL	03895	72222	30 21N	087 18W	0010	01 67 - 12 71	STAR	Y14	067
PENSACOLA	FORREST SHERMAN NAS	FL	03895	72222	30 21N	087 18W	0010	01 74 - 12 74	STAR	A	T52115.3
TALLAHASSEE	MUNICIPAL ART WBAS	FL	93805	72214	30 23N	084 22W	0021	01 60 - 12 64	STAR	MM	T50590
TALLAHASSEE	MUNICIPAL ART WBAS	FL	93805	72214	30 23N	084 22W	0021	01 68 - 12 73	STAR	SA	T50413
TALLAHASSEE	MUNICIPAL ART WBAS	FL	93805	72214	30 23N	084 22W	0021	01 72 - 12 72	STAR	MM	T50014
TALLAHASSEE	MUNICIPAL ART WBAS	FL	93805	72214	30 23N	084 22W	0021	01 72 - 12 72	STAR	MM	T50838
TAMPA	MACDILL AFB	FL	12810	74788	27 51N	082 30W	0008	01 65 - 12 68	STAR	SA	T12857
TAMPA	MACDILL AFB	FL	12810	74788	27 51N	082 30W	0008	01 70 - 12 70	STAR	SA	T12857
TAMPA	INTERNATIONAL ART WBAS	FL	12842	72211	27 58N	082 32W	0010	01 60 - 12 64	STAR	MM	T50590
TAMPA	INTERNATIONAL ART WBAS	FL	12842	72211	27 58N	082 32W	0010	01 65 - 12 68	STAR	SA	T12828
TAMPA	INTERNATIONAL ART WBAS	FL	12842	72211	27 58N	082 32W	0010	01 68 - 12 73	STAR	A	T15377
TAMPA	INTERNATIONAL ART WBAS	FL	12842	72211	27 58N	082 32W	0010	01 71 - 12 71	STAR	SA	T14113
TAMPA	INTERNATIONAL ART WBAS	FL	12842	72211	27 58N	082 32W	0010	01 72 - 12 72	STAR	SA	T14346
TAMPA	INTERNATIONAL ART WBAS	FL	12842	72211	27 58N	082 32W	0010	01 72 - 12 72	STAR	SA	T13367
TAMPA	INTERNATIONAL ART WBAS	FL	12842	72211	27 58N	082 32W	0010	01 72 - 12 72	STAR	MM	T50838
TAMPA	INTERNATIONAL ART WBAS	FL	12842	72211	27 58N	082 32W	0003	01 73 - 12 73	STAR	A	T50487.3
TAMPA	INTERNATIONAL ART WBAS	FL	12842	72211	27 58N	082 32W	0010	01 73 - 12 73	STAR	SA	T50413
TAMPA	INTERNATIONAL ART WBAS	FL	12842	72211	27 58N	082 32W	0003	01 74 - 12 74	STAR	A	T51046
TAMPA	INTERNATIONAL ART WBAS	FL	12842	72211	27 58N	082 32W	0003	01 74 - 12 74	STAR	A	T51184
WEST PALM BEACH	INTERNATIONAL ART WBAS	FL	12844	72203	26 41N	080 06W	0008	01 70 - 12 70	STAR	SA	T01772
ALBANY	TURNER AFB	GA	13815		31 38N	084 09W	0068	01 62 - 12 68	STAR	SA	T14372
ALBANY	NAS	GA	13815		31 35N	084 05W	0065	01 68 - 12 73	STAR	SA	T15175.3
ALBANY	NAS	GA	13815		31 35N	084 05W	0065	01 68 - 12 68	STAR	MM	T50690.3
ALBANY	NAS	GA	13815		31 35N	084 05W	0065	01 68 - 04 74	STAR	MM	T50690.3
ALBANY	NAS	GA	13815		31 35N	084 05W	0065	01 70 - 12 70	STAR	MM	T50690.3
ALBANY	NAS	GA	13815		31 35N	084 05W	0065	01 70 - 12 70	STAR	SA	T13252
ALBANY	NAS	GA	13815		31 35N	084 05W	0065	01 71 - 12 71	STAR	MM	T50690.3
ALBANY	NAS	GA	13815		31 35N	084 05W	0065	01 72 - 12 72	STAR	MM	T50690.3
ALBANY	NAS	GA	13815		31 35N	084 12W	0065	01 73 - 12 73	STAR	MM	T50690.3
ALBANY	NAS	GA	13815		31 35N	084 12W	0065	01 74 - 04 74	STAR	MM	T50690.3
ALMA	BACON COUNTY ART CAA	GA	13870		31 32N	082 31W	0082	01 64 - 12 68	STAR	SA	T15175.3
ATHENS	BEN EPPS FIELD WBAS	GA	13873	72311	33 57N	083 19W	0247	01 68 - 12 73	STAR	SA	T15175.3
ATHENS	BEN EPPS FIELD WBAS	GA	13873	72311	33 57N	083 19W	0246	01 70 - 12 70	STAR	SA	T13252
ATLANTA	WBAS	GA	13874	72219	33 38N	084 25W	0302	01 58 - 12 63	STAR	SA	T12698
ATLANTA	WBAS	GA	13874	72219	33 38N	084 26W	0311	01 67 - 12 71	STAR	SA	T01772
ATLANTA	WBAS	GA	13874	72219	33 38N	084 26W	0315	01 68 - 12 73	STAR	SA	T15175.3
ATLANTA	WBAS	GA	13874	72219	33 38N	084 26W	0311	01 70 - 12 70	STAR	SA	T01772
ATLANTA	WBAS	GA	13874	72219	33 38N	084 26W	0311	01 70 - 12 70	STAR	SA	T13494
ATLANTA	WBAS	GA	13874	72219	33 38N	084 26W	0311	01 72 - 12 72	STAR	MM	T14388
ATLANTA	WBAS	GA	13874	72219	33 38N	084 26W	0315	07 73 - 08 74	STAR	A	T51138
AUGUSTA	BUSH FIELD WBAS	GA	03820	72218	33 22N	081 58W	0049	01 55 - 12 59	STAR	SA	T01371
AUGUSTA	BUSH FIELD WBAS	GA	03820	72218	33 22N	081 58W	0049	01 67 - 12 71	STAR	SA	T14010
AUGUSTA	BUSH FIELD WBAS	GA	03820	72218	33 22N	081 58W	0049	01 68 - 12 73	STAR	SA	T15175.3
AUGUSTA	BUSH FIELD WBAS	GA	03820	72218	33 22N	081 58W	0049	01 70 - 12 70	STAR	SA	T13252
AUGUSTA	BUSH FIELD WBAS	GA	03820	72218	33 22N	081 58W	0049	01 72 - 12 72	STAR	MM	T14388
AUGUSTA	BUSH FIELD WBAS	GA	03820	72218	33 22N	081 58W	0049	01 73 - 12 73	STAR	MM	T15802
AUGUSTA	BUSH FIELD WBAS	GA	03820	72218	33 22N	081 58W	0049	01 74 - 03 74	STAR	MM	T15873.52
BRUNSWICK	GLYNCO NAS	GA	93838		31 19N	081 28W	0010	01 67 - 12 71	STAR	SA	T14372
BRUNSWICK	GLYNCO NAS	GA	93838		31 19N	081 28W	0010	01 68 - 12 73	STAR	SA	T15175.3
BRUNSWICK	GLYNCO NAS	GA	93838		31 19N	081 28W	0010	01 70 - 12 70	STAR	SA	T13252
COLUMBUS	METROPOLITAN ART WBAS	GA	93842		32 31N	084 56W	0123	01 67 - 12 71	STAR	SA	T14089
COLUMBUS	METROPOLITAN ART WBAS	GA	93842		32 31N	084 56W	0118	01 68 - 12 73	STAR	SA	T15175.3
COLUMBUS	METROPOLITAN ART WBAS	GA	93842		32 31N	084 56W	0123	01 70 - 12 70	STAR	A	T14041
MACON	LEWIS B WILSON ART WBAS	GA	03813	72217	32 42N	083 39W	0110	01 67 - 12 71	STAR	SA	T14372
MACON	LEWIS B WILSON ART WBAS	GA	03813	72217	32 42N	083 39W	0110	01 68 - 12 73	STAR	SA	T15175.3
MACON	LEWIS B WILSON ART WBAS	GA	03813	72217	32 42N	083 39W	0110	01 70 - 12 70	STAR	SA	T13252
SAVANNAH	TRAVIS FLD MAP WBAS	GA	03822	72207	32 08N	081 12W	0016	01 68 - 12 70	STAR	SA	T13050
SAVANNAH	TRAVIS FLD MAP WBAS	GA	03822	72207	32 08N	081 12W	0016	01 67 - 12 71	STAR	SA	T14085
SAVANNAH	TRAVIS FLD MAP WBAS	GA	03822	72207	32 08N	081 12W	0016	01 68 - 12 73	STAR	SA	T15175.3
SAVANNAH	TRAVIS FLD MAP WBAS	GA	03822	72207	32 08N	081 12W	0016	01 70 - 12 70	STAR	SA	T01772
SAVANNAH	TRAVIS FLD MAP WBAS	GA	03822	72207	32 08N	081 12W	0016	01 70 - 12 70	STAR	SA	T01772
SAVANNAH	TRAVIS FLD MAP WBAS	GA	03822	72207	32 08N	081 12W	0016	01 72 - 12 72	STAR	MM	T14388
SAVANNAH	TRAVIS FLD MAP WBAS	GA	03822	72207	32 08N	081 12W	0016	07 73 - 08 74	STAR	SA	T50849
SAVANNAH	TRAVIS FLD MAP WBAS	GA	03822	72207	32 08N	081 12W	0016	01 75 - 12 75	STAR	A	T52184
SAVANNAH	HUNTER AFB	GA	13824		32 01N	081 08W	0016	01 68 - 12 70	STAR	SA	T15175.3
BARBERS POINT	NAS	HI	22514	91170	21 18N	158 04W	0015	01 62 - 12 72	STAR	MM	T50709
BARBERS POINT	NAS	HI	22514	91170	21 18N	158 04W	0015	01 67 - 12 71	STAR	MM	T50121
HILO	LYMAN FIELD WBAS	HI	21504	91205	19 43N	155 04W	0010	08 62 - 07 67	STAR	MM	T13223
HONOLULU	JOHN ROGERS INL ART WBAS	HI	22521	91182	21 21N	157 56W	0012	01 60 - 12 64	STAR	MM	T50121
KAHULUI	NAS	HI	22519	91190	20 54N	156 26W	0015	01 66 - 12 70	STAR	SA	T13335
PUUNENE	CAA	HI	22529		20 50N	156 28W	0040	01 53 - 12 57	STAR	SA	T13204
BOISE	MUNICIPAL ART WBAS	ID	24131	72681	43 34N	116 13W	0870	01 60 - 12 64	STAR	MM	T50544
IDAHO FALLS	FANNING FIELD FAA	ID	24145		43 31N	112 04W	1448	01 55 - 12 64	STAR	MM	T51224.3
MALAD CITY	CAA	ID	24151		42 10N	112 19W	1366	01 48 - 12 54	STAR	MM	T51224.3
MOUNTAIN HOME	AFB	ID	24108		43 03N	115 52W	0912	01 65 - 12 68	STAR	MM	T50544
POCATELLO	MUNICIPAL ART WBAS	ID	24156	72578	42 55N	112 36W	1358	01 55 - 12 64	STAR	MM	T51224.3.68
POCATELLO	MUNICIPAL ART WBAS	ID	24156	72578	42 55N	112 36W	1356	01 58 - 12 62	STAR	SA	T13870
POCATELLO	MUNICIPAL ART WBAS	ID	24156	72578	42 56N	112 36W	1369	01 65 - 12 74	STAR	MM	T51224.3.70
BELLEVILLE	SCOTT AFB	IL	13802		38 33N	089 51W	0135	01 61 - 12 70	STAR	SA	T51003.3
CHICAGO	MIDWAY ART WBAS	IL	14819	72534	41 47N	087 45W	0187	01 64 - 12 73	STAR	SA	T50468
CHICAGO	MIDWAY ART WBAS	IL	14819	72534	41 47N	087 45W	0187	01 54 - 12 73	STAR	SA	T50404
CHICAGO	MIDWAY ART WBAS	IL	14819	72534	41 47N	087 45W	0187	01 67 - 12 67	STAR	SA	T11930

SUPPORT TYPE: STAR

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUPPORT TYPE	SUPP FREQ	TAPE/REMARKS
CHICAGO	MIDWAY APT WBAS	IL	14819	72534	41 47N	087 45W	0187	01 50 - 12 68	STAR	A	T14843
CHICAGO	MIDWAY APT WBAS	IL	14819	72534	41 47N	087 45W	0187	01 70 - 12 70	STAR	SA	T01772
CHICAGO	MIDWAY APT WBAS	IL	14819	72534	41 47N	087 45W	0190	01 71 - 12 73	STAR	A	T51304
CHICAGO	MIDWAY APT WBAS	IL	14819	72534	41 47N	087 45W	0187	01 71 - 12 71	STAR	SA	T01772
CHICAGO	MIDWAY APT WBAS	IL	14819	72534	41 47N	087 45W	0187	01 72 - 12 72	STAR	A	T14843
CHICAGO	MIDWAY APT WBAS	IL	14819	72534	41 47N	087 45W	0187	12 72 - 11 73	STAR	SA	T50404
CHICAGO	MIDWAY APT WBAS	IL	14819	72534	41 47N	087 45W	0187	12 72 - 11 73	STAR	SA	T50468
CHICAGO	MIDWAY APT WBAS	IL	14819	72534	41 47N	087 45W	0190	01 73 - 12 73	STAR	A	T50549.3
CHICAGO	MIDWAY APT WBAS	IL	14819	72534	41 47N	087 45W	0190	01 74 - 12 74	STAR	SA	T51207.3
CHICAGO	MIDWAY APT WBAS	IL	14819	72534	41 47N	087 45W	0190	01 75 - 12 75	STAR	A	T52401.3
CHICAGO	MIDWAY APT WBAS	IL	14819	72534	41 47N	087 45W	0190	01 75 - 12 75	STAR	A	T52344.3
CHICAGO	O'HARE INL APT WBAS	IL	94846	72530	41 58N	087 54W	0211	01 83 - 12 85	STAR	A	T11860
CHICAGO	O'HARE INL APT WBAS	IL	94846	72530	41 58N	087 54W	0211	01 83 - 12 83	STAR	A	T11860
CHICAGO	O'HARE INL APT WBAS	IL	94846	72530	41 58N	087 54W	0211	01 85 - 12 88	STAR	SA	T12761
CHICAGO	O'HARE INL APT WBAS	IL	94846	72530	41 58N	087 54W	0211	01 86 - 12 86	STAR	A	T11860
CHICAGO	O'HARE INL APT WBAS	IL	94846	72530	41 58N	087 54W	0211	01 87 - 12 87	STAR	A	T11860
CHICAGO	O'HARE INL APT WBAS	IL	94846	72530	41 58N	087 54W	0211	01 88 - 12 94	STAR	SA	T51956.3
CHICAGO	O'HARE INL APT WBAS	IL	94846	72530	41 58N	087 54W	0211	01 88 - 12 88	STAR	A	T11860
CHICAGO	O'HARE INL APT WBAS	IL	94846	72530	41 58N	087 54W	0211	08 71 - 11 71	STAR	MA	T13303
CHICAGO	MEIGS FIELD LAWR	IL	94868		41 52N	087 37W	0179	01 68 - 08 70	STAR	MA	T14401
GLENVIEW	NAS	IL	14899		42 05N	087 50W	0198	01 80 - 12 84	STAR	MA	T50259
GLENVIEW	NAS	IL	14899		42 05N	087 50W	0198	01 74 - 12 74	STAR	A	T51888.3
MOLINE	QUAD-CITY APT WBAS	IL	14923	72544	41 27N	090 31W	0184	01 87 - 12 71	STAR	SA	T13593
MOLINE	QUAD-CITY APT WBAS	IL	14923	72544	41 27N	090 31W	0181	01 70 - 12 74	STAR	SA	T51193.3
PEORIA	GREATER PEORIA APT WBAS	IL	14842	72532	40 40N	089 41W	0202	01 84 - 12 73	STAR	SA	T14842
PEORIA	GREATER PEORIA APT WBAS	IL	14842	72532	40 40N	089 41W	0202	01 85 - 12 85	STAR	SA	T12089
PEORIA	GREATER PEORIA APT WBAS	IL	14842	72532	40 40N	089 41W	0202	01 85 - 12 89	STAR	SA	T50860.3
PEORIA	GREATER PEORIA APT WBAS	IL	14842	72532	40 40N	089 41W	0202	01 85 - 12 89	STAR	SA	T51209.3
PEORIA	GREATER PEORIA APT WBAS	IL	14842	72532	40 40N	089 41W	0202	01 70 - 12 70	STAR	SA	T12787
PEORIA	GREATER PEORIA APT WBAS	IL	14842	72532	40 40N	089 41W	0202	01 72 - 12 72	STAR	MA	T50443
PEORIA	GREATER PEORIA APT WBAS	IL	14842	72532	40 40N	089 41W	0202	01 73 - 12 73	STAR	SA	T14842
PEORIA	GREATER PEORIA APT WBAS	IL	14842	72532	40 40N	089 41W	0202	01 73 - 12 73	STAR	MA	T50443
QUINCY	BALDWIN FIELD CAA	IL	93988		39 56N	091 12W	0255	01 50 - 12 54	STAR	A	T13708
RANTOUL	CHANUTE AFB	IL	14808	72551	40 18N	088 09W	0230	01 58 - 12 62	STAR	MA	T14484
RANTOUL	CHANUTE AFB	IL	14808	72551	40 18N	088 09W	0230	01 83 - 12 87	STAR	SA	T01772
ROCKFORD	GREATER ROCKFORD APT WBAS	IL	94822	72543	42 12N	089 06W	0223	01 68 - 12 70	STAR	MA	T13597
ROCKFORD	GREATER ROCKFORD APT WBAS	IL	94822	72543	42 12N	089 06W	0223	01 70 - 12 70	STAR	MA	T14823
ROCKFORD	GREATER ROCKFORD APT WBAS	IL	94822	72543	42 12N	089 06W	0226	01 70 - 12 74	STAR	SA	T51193.3
SPRINGFIELD	CAPITAL APT WBAS	IL	93822	72438	39 50N	089 40W	0183	01 67 - 12 71	STAR	SA	T13244
SPRINGFIELD	CAPITAL APT WBAS	IL	93822	72438	39 50N	089 40W	0183	01 87 - 12 71	STAR	MA	T13583
SPRINGFIELD	CAPITAL APT WBAS	IL	93822	72438	39 50N	089 40W	0187	01 70 - 12 74	STAR	SA	T51193.3
EVANSVILLE	DRESS MEMORIAL APT WBAS	IN	93817	72432	38 03N	087 32W	0123	01 80 - 12 84	STAR	SA	T11898
EVANSVILLE	DRESS MEMORIAL APT WBAS	IN	93817	72432	38 03N	087 32W	0123	01 84 - 12 84	STAR	A	T50423
EVANSVILLE	DRESS MEMORIAL APT WBAS	IN	93817	72432	38 03N	087 32W	0123	01 86 - 12 70	STAR	SA	T12881
EVANSVILLE	DRESS MEMORIAL APT WBAS	IN	93817	72432	38 03N	087 32W	0123	01 86 - 12 70	STAR	SA	T50020
EVANSVILLE	DRESS MEMORIAL APT WBAS	IN	93817	72432	38 03N	087 32W	0123	01 72 - 12 72	STAR	SA	T15207
FORT WAYNE	BAER FIELD	IN	14827	72533	41 00N	085 12W	0252	01 80 - 12 84	STAR	SA	T52126.3
FORT WAYNE	BAER FIELD	IN	14827	72533	41 00N	085 12W	0252	01 70 - 12 74	STAR	SA	T15675.3
FORT WAYNE	BAER FIELD	IN	14827	72533	41 00N	085 12W	0252	01 70 - 12 74	STAR	SA	T15675.3
FORT WAYNE	BAER FIELD	IN	14827	72533	41 00N	085 12W	0252	01 75 - 12 75	STAR	SA	T52409.3
INDIANAPOLIS	WEIR COOK MAP WBAS	IN	93819	72438	39 44N	086 16W	0246	01 59 - 12 74	STAR	MA	T51827
INDIANAPOLIS	WEIR COOK MAP WBAS	IN	93819	72438	39 44N	086 16W	0247	01 88 - 12 71	STAR	SA	T50282
SOUTH BEND	ST JOSEPH COUNTY APT WBAS	IN	14848	72535	41 42N	086 19W	0238	01 87 - 12 71	STAR	A	T13709
SOUTH BEND	ST JOSEPH COUNTY APT WBAS	IN	14848	72535	41 42N	086 19W	0238	01 70 - 12 70	STAR	A	T13534
SOUTH BEND	ST JOSEPH COUNTY APT WBAS	IN	14848	72535	41 42N	086 19W	0238	01 71 - 12 71	STAR	A	T13534
TERRE HAUTE	HULMAN FIELD CAA	IN	93823	72437	39 27N	087 18W	0181	01 90 - 12 94	STAR	A	T13709
BURLINGTON	MUNICIPAL APT WBAS	IA	14831		40 47N	091 07W	0212	01 87 - 12 71	STAR	A	T13709
DES MOINES	MUNICIPAL APT WBAS	IA	14933	72546	41 32N	093 39W	0290	01 72 - 12 72	STAR	A	T15198
MASON CITY	MUNICIPAL APT FAA	IA	14940		43 10N	093 20W	0373	01 70 - 12 74	STAR	A	T51798
SIOUX CITY	MUNICIPAL APT WBAS	IA	14943	72557	42 24N	096 23W	0338	01 70 - 12 74	STAR	A	T51798
WATERLOO	MUNICIPAL APT SAWR	IA	94910	72548	42 33N	092 24W	0270	01 80 - 12 84	STAR	SA	T50708.3
FT LEAVENWORTH	SHERMAN FIELD AAF	KS	13821		39 22N	094 55W	0239	01 82 - 12 70	STAR	MA	T50127
GARDEN CITY	MUNICIPAL APT CAA	KS	93084		37 56N	100 43W	0878	01 50 - 12 94	STAR	MA	T50874.3
GOODLAND	RENNER FIELD WBAS	KS	23065	72465	39 22N	101 42W	1112	01 54 - 12 58	STAR	MA	T15038
GOODLAND	RENNER FIELD WBAS	KS	23065	72465	39 22N	101 42W	1112	01 68 - 12 73	STAR	SA	T15168
TOPEKA	BILLARD MAP WBAS	KS	13996	72456	39 04N	095 38W	0268	01 83 - 12 72	STAR	MA	T14659
TOPEKA	BILLARD MAP WBAS	KS	13996	72456	39 04N	095 38W	0266	01 72 - 12 72	STAR	MA	T01772
WICHITA	MUNICIPAL APT WBAS	KS	03928	72450	37 39N	097 39W	0403	01 83 - 12 72	STAR	MA	T50300
WICHITA	MUNICIPAL APT WBAS	KS	03928	72450	37 39N	097 39W	0408	01 70 - 12 74	STAR	MA	T51200.3
WICHITA	MUNICIPAL APT WBAS	KS	03928	72450	37 39N	097 39W	0409	01 73 - 12 73	STAR	MA	T50300
BOWLING GREEN	CITY-COUNTY APT CAA	KY	93808		36 58N	086 26W	0184	01 90 - 12 94	STAR	SA	T11898
CORBIN	CAA	KY	03814		36 58N	084 08W	0358	10 48 - 08 54	STAR	SA	T11898
COVINGTON	GTR CINCINNATI APT WBAS	KY	93814	72421	39 04N	084 40W	0270	01 58 - 12 62	STAR	SA	T11898
COVINGTON	GTR CINCINNATI APT WBAS	KY	93814	72421	39 04N	084 40W	0270	01 84 - 12 84	STAR	A	T50084
COVINGTON	GTR CINCINNATI APT WBAS	KY	93814	72421	39 03N	084 40W	0265	01 68 - 12 73	STAR	SA	T15172
COVINGTON	GTR CINCINNATI APT WBAS	KY	93814	72421	39 03N	084 40W	0265	01 70 - 12 74	STAR	SA	T15675.3
COVINGTON	GTR CINCINNATI APT WBAS	KY	93814	72421	39 04N	084 40W	0265	01 70 - 12 74	STAR	SA	T15675.3
COVINGTON	GTR CINCINNATI APT WBAS	KY	93814	72421	39 03N	084 40W	0265	01 72 - 12 72	STAR	SA	T15207
COVINGTON	GTR CINCINNATI APT WBAS	KY	93814	72421	39 03N	084 40W	0265	01 73 - 12 73	STAR	SA	T51144.3
COVINGTON	GTR CINCINNATI APT WBAS	KY	93814	72421	39 03N	084 40W	0265	04 74 - 07 74	STAR	A	T50329
COVINGTON	GTR CINCINNATI APT WBAS	KY	93814	72421	39 04N	084 40W	0271	01 79 - 12 79	STAR	SA	T52409.3
FORT CAMPBELL	CAMPBELL AFB	KY	13808	74871	36 40N	087 30W	0172	01 58 - 12 62	STAR	SA	T11898
FORT KNOX	GODMAN AAF	KY	13807	72423	37 54N	085 58W	0238	01 84 - 12 88	STAR	SA	T11898
LEXINGTON	BLUE GRASS FIELD WBAS	KY	93820	72422	38 02N	084 36W	0298	01 80 - 12 84	STAR	SA	T11898
LOUISVILLE	STANDIFORD FIELD WBAS	KY	93821	72423	38 11N	085 44W	0149	01 80 - 12 84	STAR	SA	T11898
LOUISVILLE	STANDIFORD FIELD WBAS	KY	93821	72423	38 11N	085 44W	0149	01 84 - 12 84	STAR	A	T52098
LOUISVILLE	STANDIFORD FIELD WBAS	KY	93821	72423	38 11N	085 44W	0149	01 68 - 12 70	STAR	SA	T12881
LOUISVILLE	STANDIFORD FIELD WBAS	KY	93821	72423	38 11N	085 44W	0149	01 87 - 12 71	STAR	MSA	T14318

SUMMARY TYPE: STAR

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TAPE/REMARKS
LOUISVILLE	STANDIFORD FIELD WBAS	KY	93821	72423	38 11N	085 44W	0149	01 70 - 12 70	STAR	SA	T12274
LOUISVILLE	STANDIFORD FIELD WBAS	KY	93821	72423	38 11N	085 44W	0149	01 72 - 12 72	STAR	A	T15172
LOUISVILLE	STANDIFORD FIELD WBAS	KY	93821	72423	38 11N	085 44W	0149	01 73 - 12 73	STAR	SA	T50328
PADUCAH	BARKLEY APT CAA	KY	03818		37 04N	088 46W	0121	01 50 - 12 54	STAR	SA	T11698
PADUCAH	BARKLEY APT FSS	KY	03818		37 04N	088 46W	0121	01 55 - 12 84	STAR	ITT	T13084
PADUCAH	BARKLEY APT FSS	KY	03818		37 04N	088 46W	0121	01 60 - 12 84	STAR	MA	T14528
ALEXANDRIA	ESLER FIELD	LA	13935		31 23N	092 18W	0038	01 70 - 12 73	STAR	SA	T50568
ALEXANDRIA	ESLER FIELD	LA	13935		31 23N	092 18W	0038	01 70 - 12 74	STAR	SA	T51266.3
BATON ROUGE	RYAN FIELD MAP WBAS	LA	13970		30 32N	091 09W	0024	01 55 - 12 84	STAR	MA	T14291
BATON ROUGE	RYAN FIELD MAP WBAS	LA	13970		30 32N	091 09W	0024	01 66 - 12 70	STAR	A	T13080
BATON ROUGE	RYAN FIELD MAP WBAS	LA	13970		30 32N	091 09W	0023	01 70 - 12 74	STAR	SA	T51266.3
BATON ROUGE	RYAN FIELD MAP WBAS	LA	13970		30 32N	091 09W	0024	01 70 - 12 70	STAR	A	T13080
BATON ROUGE	RYAN FIELD MAP WBAS	LA	13970		30 32N	091 09W	0024	01 72 - 12 72	STAR	MA	T14338
BATON ROUGE	RYAN FIELD MAP WBAS	LA	13970		30 32N	091 09W	0023	01 72 - 12 72	STAR	A	T51056.3
LAFAYETTE	MUNICIPAL APT CAA	LA	13978		30 12N	091 59W	0013	01 54 - 12 56	STAR	SA	T50793
LAKE CHARLES	MUNICIPAL APT WBAS	LA	03937	72240	30 07N	093 13W	0005	01 66 - 12 70	STAR	A	T50866
LAKE CHARLES	MUNICIPAL APT WBAS	LA	03937	72240	30 07N	093 13W	0005	01 66 - 12 70	STAR	A	T13060
LAKE CHARLES	MUNICIPAL APT WBAS	LA	03937	72240	30 07N	093 13W	0005	01 70 - 12 70	STAR	A	T13060
LAKE CHARLES	MUNICIPAL APT WBAS	LA	03937	72240	30 07N	093 13W	0005	01 70 - 12 74	STAR	SA	T51268.3
LAKE CHARLES	WBAS	LA	13841	72240	30 12N	093 09W	0005	01 58 - 12 82	STAR	MA	T50748
LAKE CHARLES	CHENNAULT AFB	LA	13841	72240	30 12N	093 09W	0005	01 58 - 12 82	STAR	SA	T51082.3
MONROE	SELMAN FIELD CAA	LA	13942		32 31N	092 03W	0028	01 54 - 12 58	STAR	SA	T51265.3
MONROE	SELMAN FIELD CAA	LA	13942		32 31N	092 03W	0028	01 54 - 12 58	STAR	SA	T50595
NEW ORLEANS	MOISANT INL APT WBAS	LA	A2916	72231	29 58N	090 15W	0006	01 60 - 12 84	STAR	MA	T13287
NEW ORLEANS	MOISANT INL APT WBAS	LA	12916	72231	29 58N	090 15W	0006	01 66 - 12 70	STAR	A	T13060
NEW ORLEANS	MOISANT INL APT WBAS	LA	12916	72231	29 58N	090 15W	0006	01 67 - 12 71	STAR	MA	T13574
NEW ORLEANS	MOISANT INL APT WBAS	LA	12916	72231	29 58N	090 15W	0001	01 68 - 12 73	STAR	SA	T50827
NEW ORLEANS	MOISANT INL APT WBAS	LA	12916	72231	29 58N	090 15W	0006	01 69 - 12 73	STAR	MA	T50308
NEW ORLEANS	MOISANT INL APT WBAS	LA	12916	72231	29 58N	090 15W	0006	01 70 - 12 70	STAR	A	T13080
NEW ORLEANS	MOISANT INL APT WBAS	LA	12916	72231	29 58N	090 15W	0006	01 74 - 12 74	STAR	MA	T52214.3
NEW ORLEANS	MOISANT INL APT WBAS	LA	12916	72231	29 58N	090 15W	0006	01 75 - 12 75	STAR	MA	T52214.3
NEW ORLEANS	MOISANT INL APT WBAS	LA	12916	72231	29 58N	090 15W	0006	10 75 - 12 75	STAR	MA	T52221
NEW ORLEANS	MOISANT INL APT WBAS	LA	12916	72231	29 58N	090 15W	0006	01 76 - 09 76	STAR	MA	T52221
NEW ORLEANS	CALLENDER NAS	LA	12956		29 50N	090 01W	0001	01 67 - 12 71	STAR	SA	T51018
NEW ORLEANS	CALLENDER NAS	LA	12956		29 50N	090 01W	0001	01 70 - 12 74	STAR	SA	T51904.3
SHREVEPORT	MUNICIPAL APT WBAS	LA	13957	72248	32 28N	093 49W	0081	01 60 - 12 84	STAR	A	T13131
SHREVEPORT	MUNICIPAL APT WBAS	LA	13957	72248	32 28N	093 49W	0081	01 67 - 12 71	STAR	SA	T14024
SHREVEPORT	MUNICIPAL APT WBAS	LA	13957	72248	32 28N	093 49W	0081	01 70 - 12 74	STAR	SA	T51268.3
SHREVEPORT	MUNICIPAL APT WBAS	LA	13957	72248	32 28N	093 49W	0081	01 71 - 12 75	STAR	SA	T52296.47M
SHREVEPORT	MUNICIPAL APT WBAS	LA	13957	72248	32 28N	093 49W	0081	01 71 - 12 75	STAR	SA	T52296.47M
SHREVEPORT	MUNICIPAL APT WBAS	LA	13957	72248	32 28N	093 49W	0081	01 73 - 12 73	STAR	SA	T14339
SHREVEPORT	MUNICIPAL APT WBAS	LA	13957	72248	32 28N	093 49W	0081	01 75 - 12 75	STAR	MA	T52446
AUGUSTA	STATE APT CAA	ME	14605		44 19N	069 48W	0108	01 50 - 12 54	STAR	SA	T50831.70
AUGUSTA	STATE APT CAA	ME	14605		44 19N	069 48W	0108	01 50 - 12 54	STAR	MSA	T50394
AUGUSTA	STATE APT CAA	ME	14605		44 19N	069 48W	0108	01 50 - 12 54	STAR	SA	T50462
AUGUSTA	STATE APT CAA	ME	14605		44 19N	069 48W	0108	01 50 - 12 54	STAR	SA	T50831.68
BRUNSWICK	NAS	ME	14611	74082	43 53N	069 56W	0024	01 60 - 12 68	STAR	SA	T13786
CARIBOU	MUNICIPAL APT WBAS	ME	14607	72712	46 52N	068 01W	0181	01 53 - 12 62	STAR	SA	T13786
OLD TOWN	FAM	ME	14622		44 57N	068 40W	0041	01 60 - 12 84	STAR	MA	T50949
PORTLAND	INTERNATIONAL APT WBAS	ME	14764	72606	43 39N	070 19W	0024	01 55 - 12 84	STAR	SA	T13786
PORTLAND	INTERNATIONAL APT WBAS	ME	14764	72606	43 39N	070 19W	0024	01 60 - 12 84	STAR	SA	T13841
PORTLAND	INTERNATIONAL APT WBAS	ME	14764	72606	43 39N	070 18W	0024	10 73 - 08 74	STAR	MA	T51268.3
ABERDEEN	PHILLIPS FIELD AAF	MD	13701		39 28N	076 10W	0018	01 59 - 12 67	STAR	MA	T13818
ANDREWS AFB	WASHINGTON DC	MD	13705	72403	38 48N	076 52W	0086	01 66 - 12 70	STAR	MA	T50028
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0060	01 60 - 12 84	STAR	SA	T14478.47J
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0060	01 60 - 12 84	STAR	A	T14635.47M
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0060	01 60 - 12 84	STAR	SA	T14478.47I
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0060	01 60 - 12 84	STAR	SA	T14478.47L
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0060	01 60 - 12 84	STAR	SA	T14478.47K
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0060	01 64 - 12 84	STAR	SA	T11878
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0060	01 68 - 12 68	STAR	SA	T11878
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0060	01 68 - 12 73	STAR	MA	T50851
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0060	01 68 - 12 88	STAR	MSA	T13770
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0060	01 70 - 12 70	STAR	MSA	T13770
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0060	01 71 - 12 71	STAR	MSA	T13770
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0060	01 72 - 12 72	STAR	MSA	T14175
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0060	01 73 - 12 73	STAR	SA	T50262
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0047	01 74 - 12 74	STAR	MSA	T15290
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0047	01 74 - 12 74	STAR	MA	T51156
BALTIMORE	FRIENDSHIP INL APT WBAS	MD	93721	72406	39 11N	076 40W	0047	01 75 - 12 75	STAR	A	T52258.3
CAMP DETRICK	AF	MD	13748		39 26N	077 27W	0101	01 48 - 12 52	STAR	SA	T50787.3
FORT MEADE	TIPTON AAF	MD	93733		39 09N	076 46W	0043	01 60 - 12 64	STAR	SA	T14478.47I
FORT MEADE	TIPTON AAF	MD	93733		39 09N	076 46W	0043	01 60 - 12 64	STAR	SA	T52371
FORT MEADE	TIPTON AAF	MD	93733		39 09N	076 46W	0043	01 60 - 12 64	STAR	SA	T14478.47L
FORT MEADE	TIPTON AAF	MD	93733		39 09N	076 46W	0043	01 60 - 12 64	STAR	SA	T14478.47K
FORT MEADE	TIPTON AAF	MD	93733		39 09N	076 46W	0043	01 60 - 12 64	STAR	SA	T14478.47J
HAGERSTOWN	MUNICIPAL APT SAWS	MD	93706		39 42N	077 45W	0215	01 74 - 12 74	STAR	MSA	T15290.28
PATUXENT RIVER	NAS	MD	13721	72404	38 18N	076 25W	0014	01 53 - 12 72	STAR	MA	T14030
PATUXENT RIVER	NAS	MD	13721	72404	38 18N	076 25W	0014	01 67 - 12 71	STAR	MA	T50230
PATUXENT RIVER	NAS	MD	13721	72404	38 18N	076 25W	0014	01 68 - 12 88	STAR	MSA	T13770
PATUXENT RIVER	NAS	MD	13721	72404	38 18N	076 25W	0014	01 70 - 12 70	STAR	MA	T13466
PATUXENT RIVER	NAS	MD	13721	72404	38 18N	076 25W	0014	01 71 - 12 71	STAR	MSA	T13770
PATUXENT RIVER	NAS	MD	13721	72404	38 18N	076 25W	0014	01 72 - 12 72	STAR	MSA	T14175
SALISBURY	WICOMICO COUNTY APT CAA	MD	93730		38 20N	075 30W	0021	01 48 - 12 58	STAR	MA	T14030
SALISBURY	WICOMICO COUNTY APT CAA	MD	93730		38 20N	075 30W	0018	01 74 - 12 74	STAR	MSA	T15290
BEDFORD	L G HANSCOM FIELD AFB	MA	14702	74480	42 46N	071 17W	0049	01 83 - 12 87	STAR	SA	T01772
BOSTON	LOGAN INL APT WBAS	MA	14739	72509	42 22N	071 02W	0009	01 66 - 12 70	STAR	SA	T13333
BOSTON	LOGAN INL APT WBAS	MA	14739	72509	42 22N	071 02W	0009	01 87 - 12 71	STAR	SA	T01772

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TAPE/REMARKS
BOSTON	LOGAN INL APT WBAS	MA	14739	72509	42 22N	071 02W	0009	01 72 - 12 72	STAR	SA	T50855
CHICOPEE FALLS	WESTOVER AFB	MA	14703	74491	42 12N	072 32W	0079	01 60 - 12 64	STAR	SA	T13772
CHICOPEE FALLS	WESTOVER AFB	MA	14703	74491	42 12N	072 32W	0079	01 60 - 12 68	STAR	SA	T50972
FALMOUTH	OTIS AFB	MA	14704		41 38N	070 31W	0043	01 60 - 12 64	STAR	SA	T50421
PITTSFIELD	MUNICIPAL APT CAA	MA	14763		42 28N	073 18W	0358	01 48 - 12 68	STAR	SA	T14019
SOUTH WEYMOUTH	NAS	MA	14790		42 08N	070 56W	0051	01 70 - 12 74	STAR	SA	T52094.3
WORCESTER	MUNICIPAL APT WBAS	MA	94746		42 16N	071 52W	0305	01 65 - 12 68	STAR	S	T11827
WORCESTER	MUNICIPAL APT WBAS	MA	94746		42 16N	071 52W	0310	01 72 - 12 72	STAR	SA	T50859
WORCESTER	MUNICIPAL APT WBAS	MA	94746		42 16N	071 52W	0310	05 74 - 04 75	STAR	SA	T51792
BENTON HARBOR	ROSS FIELD	MI	94871		42 08N	086 26W	0191	01 74 - 12 74	STAR	SA	T51045.47N
DETROIT	CITY APT WBAS	MI	14822		42 25N	083 01W	0191	01 68 - 12 73	STAR	A	T15016
DETROIT	CITY APT WBAS	MI	14822		42 25N	083 01W	0191	01 72 - 12 72	STAR	SA	T50049
DETROIT	CITY APT WBAS	MI	14822		42 25N	083 01W	0191	01 73 - 12 73	STAR	SA	T50206
DETROIT	CITY APT WBAS	MI	14822		42 25N	083 01W	0191	01 74 - 12 74	STAR	SA	T51021
DETROIT	CITY APT WBAS	MI	14822		42 25N	083 01W	0191	01 75 - 12 75	STAR	SA	T52135
DETROIT	METRO-WAYNE CAP WBAS	MI	94847	72537	42 14N	083 20W	0197	01 71 - 12 71	STAR	SA	T01772
DETROIT	METRO-WAYNE CAP WBAS	MI	94847	72537	42 14N	083 20W	0197	01 72 - 12 72	STAR	SA	T50049
DETROIT	METRO-WAYNE CAP WBAS	MI	94847	72537	42 14N	083 20W	0197	01 73 - 12 73	STAR	SA	T50206
DETROIT	METRO-WAYNE CAP WBAS	MI	94847	72537	42 14N	083 20W	0202	01 74 - 12 74	STAR	MA	T52442
DETROIT	METRO-WAYNE CAP WBAS	MI	94847	72537	42 14N	083 20W	0202	01 74 - 12 74	STAR	SA	T51021
DETROIT	METRO-WAYNE CAP WBAS	MI	94847	72537	42 14N	083 20W	0202	01 75 - 12 75	STAR	SA	T52135
FLINT	BISHOP APT WBAS	MI	14828	72637	42 58N	083 44W	0235	01 80 - 12 84	STAR	MA	T50440
FLINT	BISHOP APT WBAS	MI	14828	72637	42 58N	083 44W	0235	01 65 - 12 68	STAR	SA	T11872
FLINT	BISHOP APT WBAS	MI	14828	72637	42 58N	083 44W	0235	01 86 - 12 75	STAR	MA	T52408
FLINT	BISHOP APT WBAS	MI	14828	72637	42 58N	083 44W	0235	01 72 - 12 72	STAR	SA	T01772
FLINT	BISHOP APT WBAS	MI	14828	72637	42 58N	083 44W	0235	01 73 - 12 73	STAR	SA	T50512
FLINT	BISHOP APT WBAS	MI	14828	72637	42 58N	083 44W	0235	01 74 - 12 74	STAR	SA	T51021
FLINT	BISHOP APT WBAS	MI	14828	72637	42 58N	083 44W	0235	01 75 - 12 75	STAR	SA	T52135
FLINT	BISHOP APT WBAS	MI	14828	72637	42 58N	083 44W	0235	05 75 - 02 76	STAR	MA	T52408
GWINN	KI SAWYER AFB	MI	94836		46 21N	087 24W	0377	01 63 - 12 67	STAR	SA	T50828.3
GWINN	KI SAWYER AFB	MI	94836		46 21N	087 24W	0377	01 65 - 12 70	STAR	MA	T50922
LANSING	CAPITAL CITY APT WBAS	MI	14836	72536	42 47N	084 35W	0266	01 68 - 12 73	STAR	A	T15016
MUSKEGON	MUSKEGON COUNTY APT WBAS	MI	14840	72638	43 10N	086 14W	0192	01 87 - 12 71	STAR	SA	T13800
SAGINAW	TRI-CITY APT CAA	MI	14845		43 32N	084 05W	0185	01 40 - 12 54	STAR	SA	T12890
SAGINAW	TRI-CITY APT CAA	MI	14845		43 32N	084 05W	0203	01 46 - 12 54	STAR	MA	T52383.3
SAGINAW	TRI-CITY APT CAA	MI	14845		43 32N	084 05W	0204	01 50 - 12 54	STAR	SA	T14338
SAGINAW	TRI-CITY APT CAA	MI	14845		43 32N	084 05W	0204	01 50 - 12 54	STAR	MA	T13859
TRAVERSE CITY	CHERRY CAP CAA	MI	14850		44 44N	085 35W	0192	01 74 - 12 74	STAR	MSA	T19290
YPSILANTI	WILLOW RUN APT WBAS	MI	14853		42 14N	083 32W	0237	10 83 - 09 88	STAR	A	T15016
YPSILANTI	WILLOW RUN APT WBAS	MI	14853		42 14N	083 32W	0237	10 83 - 09 88	STAR	SA	T52139.3
ALEXANDRIA	MUNICIPAL APT CAA	MN	14810		45 52N	095 23W	0439	01 52 - 12 54	STAR	SA	T13083
DULUTH	INTERNATIONAL APT WBAS	MN	14913	72745	46 50N	092 11W	0434	01 87 - 12 71	STAR	SA	T14008
DULUTH	INTERNATIONAL APT WBAS	MN	14913	72745	46 50N	092 11W	0434	01 70 - 12 74	STAR	SA	T15660.3
DULUTH	INTERNATIONAL APT WBAS	MN	14913	72745	46 50N	092 11W	0434	01 70 - 12 70	STAR	SA	T12791
MINNEAPOLIS	INTERNATIONAL APT WBAS	MN	14922	72658	44 53N	093 13W	0262	01 58 - 12 72	STAR	MSA	T50087
MINNEAPOLIS	INTERNATIONAL APT WBAS	MN	14922	72658	44 53N	093 13W	0262	01 60 - 12 64	STAR	MA	T50219
MINNEAPOLIS	INTERNATIONAL APT WBAS	MN	14922	72658	44 53N	093 13W	0262	01 65 - 12 74	STAR	MA	T52351.3
MINNEAPOLIS	INTERNATIONAL APT WBAS	MN	14922	72658	44 53N	093 13W	0262	01 87 - 12 71	STAR	SA	T14008
MINNEAPOLIS	INTERNATIONAL APT WBAS	MN	14922	72658	44 53N	093 13W	0262	01 70 - 12 70	STAR	SA	T12751
ROCHESTER	MUNICIPAL APT WBAS	MN	14925	72644	43 54N	092 30W	0402	01 88 - 12 73	STAR	MA	T51089
BILOXI	KEESLER AFB	MS	13820		30 24N	088 55W	0008	01 80 - 12 84	STAR	MA	T50779
BILOXI	KEESLER AFB	MS	13820		30 24N	088 55W	0008	01 80 - 12 84	STAR	A	T50010
COLUMBUS	AFB	MS	13825		33 38N	088 27W	0085	01 68 - 12 74	STAR	SA	T50475
COLUMBUS	AFB	MS	13825		33 38N	088 27W	0088	01 66 - 12 70	STAR	SA	T50838
GREENVILLE	AFB	MS	13838	72338	33 31N	091 00W	0042	11 59 - 10 60	STAR	SA	T14394
JACKSON	THOMPSON FAP WBAS	MS	03940	72235	32 18N	090 05W	0110	01 55 - 12 84	STAR	A	T52191
JACKSON	THOMPSON FAP WBAS	MS	03940	72235	32 18N	090 05W	0110	01 85 - 12 68	STAR	MSA	T14408
JACKSON	THOMPSON FAP WBAS	MS	03940	72235	32 18N	090 05W	0110	01 85 - 12 68	STAR	SA	T11875
JACKSON	THOMPSON FAP WBAS	MS	03940	72235	32 18N	090 05W	0110	01 68 - 12 70	STAR	SA	T12835
JACKSON	THOMPSON FAP WBAS	MS	03940	72235	32 18N	090 05W	0110	01 70 - 12 70	STAR	SA	T12925
JACKSON	HAWKINS FIELD WBAS	MS	13856	72235	32 20N	090 13W	0088	01 80 - 12 84	STAR	MSA	T14408
JACKSON	HAWKINS FIELD WBAS	MS	13856	72235	32 20N	090 13W	0086	01 80 - 12 84	STAR	MA	T13267
JACKSON	HAWKINS FIELD WBAS	MS	13856	72235	32 20N	090 13W	0086	01 80 - 12 84	STAR	MA	T13930
MCCOMB	PIKE COUNTY CAA	MS	83918		31 15N	090 28W	0141	01 48 - 12 48	STAR	SA	T51038
MERIDIAN	KEY FIELD WBAS	MS	13865	72234	32 20N	088 45W	0090	01 88 - 12 70	STAR	SA	T12835
MERIDIAN	KEY FIELD WBAS	MS	13865	72234	32 20N	088 45W	0090	01 70 - 12 70	STAR	SA	T12925
COLUMBIA	REGIONAL APT WBAS	MO	03945	72445	38 49N	092 13W	0272	01 73 - 12 73	STAR	MA	T50300
COLUMBIA	MUNICIPAL APT WBAS	MO	13993	72445	38 58N	092 22W	0238	01 84 - 12 66	STAR	A	T13746
KANSAS CITY	MUNICIPAL APT WBAS	MO	03947	72446	39 18N	094 33W	0315	01 88 - 12 74	STAR	MA	T52333
KANSAS CITY	MUNICIPAL APT WBAS	MO	13988	72446	39 07N	094 36W	0241	01 84 - 12 84	STAR	A	T50692.3
KANSAS CITY	MUNICIPAL APT WBAS	MO	13988	72446	39 07N	094 36W	0238	01 87 - 12 71	STAR	A	T13765
KANSAS CITY	MUNICIPAL APT WBAS	MO	13988	72446	39 07N	094 36W	0238	01 68 - 08 72	STAR	SA	T50635
KANSAS CITY	MUNICIPAL APT WBAS	MO	13988	72446	39 07N	094 36W	0238	01 69 - 12 69	STAR	SA	T12881
KIRKSVILLE	CARMOR MEMORIAL APT	MO	14938		40 06N	092 33W	0284	01 50 - 12 54	STAR	A	T51867
SAINT LOUIS	LAMBERT FIELD WBAS	MO	13994	72434	38 45N	090 22W	0172	01 80 - 12 84	STAR	MA	T50284
SAINT LOUIS	LAMBERT FIELD WBAS	MO	13994	72434	38 45N	090 22W	0172	01 84 - 12 68	STAR	SA	T11930.86
SAINT LOUIS	LAMBERT FIELD WBAS	MO	13994	72434	38 45N	090 22W	0172	01 85 - 12 88	STAR	SA	T12038.2
SAINT LOUIS	LAMBERT FIELD WBAS	MO	13994	72434	38 45N	090 22W	0172	01 68 - 12 72	STAR	SA	T50123
SAINT LOUIS	LAMBERT FIELD WBAS	MO	13994	72434	38 45N	090 22W	0172	01 69 - 12 69	STAR	A	T12084
SAINT LOUIS	LAMBERT FIELD WBAS	MO	13994	72434	38 45N	090 22W	0172	01 70 - 12 74	STAR	SA	T51153.3
SAINT LOUIS	LAMBERT FIELD WBAS	MO	13994	72434	38 45N	090 22W	0172	10 70 - 09 71	STAR	A	T13157
SAINT LOUIS	LAMBERT FIELD WBAS	MO	13994	72434	38 45N	090 22W	0172	12 70 - 02 71	STAR	S	T11930
SPRINGFIELD	MUNICIPAL APT WBAS	MO	13995	72440	37 14N	093 23W	0388	01 88 - 12 70	STAR	SA	T13183
BILLINGS	LOGAN FIELD WBAS	MT	24033	72677	45 48N	108 32W	1082	01 87 - 12 71	STAR	SA	T14135
BUTTE	SILVER BOW COUNTY APT CAA	MT	24135	72678	45 57N	112 30W	1690	01 58 - 12 60	STAR	SA	T13385
CUSTER	CAA	MT	24040		46 07N	107 31W	0878	01 48 - 05 50	STAR	MA	T14627
CUT BANK	MUNICIPAL APT CAA	MT	24137		48 38N	112 22W	1174	01 48 - 12 58	STAR	MA	T50288

SUMMARY TYPE: STAR

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TAPE/REMARKS
GLASGOW	INTERNATIONAL ART WBAS	MT	94008	72768	48 13N	106 37W	0696	01 65 - 12 69	STAR	SA	T51080.43
GLASGOW	INTERNATIONAL ART WBAS	MT	94008	72768	48 13N	106 37W	0696	01 67 - 12 71	STAR	T14	827
HAVRE	CITY-COUNTY ART WBAS	MT	94012	72770	48 33N	109 46W	0788	01 67 - 12 71	STAR	MA	T14627
HELENA	WBAS	MT	24144	72772	46 36N	112 00W	1188	01 58 - 12 62	STAR	SA	T13835
HELENA	WBAS	MT	24144	72772	46 36N	112 00W	1188	01 65 - 10 74	STAR	MA	T15236
KALISPELL	GLACIER PARK INL ART WBAS	MT	24146	72779	48 18N	114 16W	0906	01 50 - 12 52	STAR	SA	T15081
KALISPELL	GLACIER PARK INL ART WBAS	MT	24146	72779	48 18N	114 16W	0906	01 63 - 12 72	STAR	SA	T14723
LEWISTOWN	MUNICIPAL ART FAA	MT	24038		47 03N	109 27W	1263	01 67 - 12 71	STAR	MA	T14627
MILES CITY	MUNICIPAL ART FAA	MT	24037		46 25N	105 52W	0802	01 67 - 12 71	STAR	MA	T14135
MISSOULA	JOHNSON-BELL FIELD WBAS	MT	24153	72773	46 55N	114 05W	0960	01 67 - 12 71	STAR	MA	T14627
LINCOLN	AFB	NE	14904	72561	40 51N	096 45W	0359	01 58 - 12 63	STAR	A	T52091
NORTH PLATTE	LEE BIRD FIELD WBAS	NE	24023	72562	41 08N	100 41W	0848	01 60 - 12 64	STAR	MA	T14312
NORTH PLATTE	LEE BIRD FIELD WBAS	NE	24023	72562	41 08N	100 41W	0848	01 68 - 12 73	STAR	SA	T15169
NORTH PLATTE.	LEE BIRD FIELD WBAS	NE	24023	72562	41 08N	100 41W	0848	05 73 - 04 75	STAR	MA	T52015.3
OMAHA	EPPLEY FIELD WBAS	NE	14942	72553	41 18N	095 54W	0303	01 64 - 12 64	STAR	A	T51932
OMAHA	EPPLEY FIELD WBAS	NE	14942	72553	41 18N	095 54W	0304	01 64 - 12 73	STAR	A	T51298
OMAHA	EPPLEY FIELD WBAS	NE	14942	72553	41 18N	095 54W	0303	08 67 - 12 73	STAR	MA	T52008
OMAHA	EPPLEY FIELD WBAS	NE	14942	72553	41 18N	095 54W	0299	01 69 - 12 73	STAR	A	T01776
OMAHA	EPPLEY FIELD WBAS	NE	14942	72553	41 18N	095 54W	0299	01 73 - 12 73	STAR	A	T51020
OMAHA	OFFUTT AFB	NE	14949	72554	41 07N	095 55W	0314	01 60 - 12 64	STAR	MA	T14312
SCOTTSBLUFF	MUNICIPAL ART WBAS	NE	24028	72566	41 52N	103 36W	1204	01 67 - 12 71	STAR	MA	T50883.3
SCOTTSBLUFF	MUNICIPAL ART WBAS	NE	24028	72566	41 52N	103 36W	1204	01 67 - 12 71	STAR	MA	T14642
SCOTTSBLUFF	MUNICIPAL ART WBAS	NE	24028	72566	41 52N	103 36W	1204	01 68 - 12 72	STAR	SA	T50296
ELKO	MUNICIPAL ART FAA	NV	24121	72582	40 50N	115 47W	1947	01 69 - 12 73	STAR	SA	T51029
ELY	YELLAND FIELD WBAS	NV	23154	72486	39 17N	114 51W	1907	01 67 - 12 71	STAR	SA	T13385
LAS VEGAS	NELLIS AFB	NV	23112		36 15N	115 02W	0573	01 58 - 12 67	STAR	MA	T15029
LAS VEGAS	MCCARRAN INL ART WBAS	NV	23188	72386	36 05N	115 10W	0664	01 69 - 12 73	STAR	SA	T50529.47D
LAS VEGAS	MCCARRAN INL ART WBAS	NV	23188	72386	36 05N	115 10W	0664	01 69 - 12 73	STAR	SA	T50529.47F
LOVELOCK	DERBY ART FAA	NV	24172		40 04N	118 33W	1190	01 69 - 12 73	STAR	SA	T51029
RENO	STEAD AFB	NV	23118	72488	39 40N	119 52W	1531	01 58 - 12 65	STAR	MA	T15029
RENO	INTERNATIONAL ART WBAS	NV	23185	72488	39 30N	119 47W	1343	01 60 - 12 64	STAR	A	T52240
RENO	INTERNATIONAL ART WBAS	NV	23185	72488	39 30N	119 47W	1345	01 60 - 12 60	STAR	MA	T50678
WINNEMUCCA	MUNICIPAL ART WBAS	NV	24128	72583	40 54N	117 48W	1322	01 69 - 12 73	STAR	SA	T51029
CONCORD	MUNICIPAL ART WBAS	NH	14745	72605	43 12N	071 30W	0104	01 60 - 12 64	STAR	A	T15140.102
CONCORD	MUNICIPAL ART WBAS	NH	14745	72605	43 12N	071 30W	0104	01 60 - 12 64	STAR	MA	T50303
CONCORD	MUNICIPAL ART WBAS	NH	14745	72605	43 12N	071 30W	0105	01 70 - 12 70	STAR	SA	T12928
PORTSMOUTH	PEASE AFB	NH	04743		43 05N	070 48W	0039	01 68 - 12 69	STAR	SA	T12928
ATLANTIC CITY	WBAS	NJ	93730	72407	39 27N	074 35W	0020	01 64 - 12 64	STAR	A	T52113
ATLANTIC CITY	WBAS	NJ	93730	72407	39 27N	074 35W	0020	01 64 - 12 64	STAR	MA	T13831
ATLANTIC CITY	WBAS	NJ	93730	72407	39 27N	074 35W	0020	01 68 - 12 72	STAR	MA	T14622
ATLANTIC CITY	WBAS	NJ	93730	72407	39 27N	074 35W	0020	01 70 - 12 74	STAR	A	T52039
BELMAR	ASC	NJ	04738		40 11N	074 04W	0026	01 55 - 12 58	STAR	MA	T13381
LAKEHURST	NAS	NJ	14780	72408	40 02N	074 19W	0036	01 58 - 12 72	STAR	SA	T14630
NEWARK	WBAS	NJ	14734	72502	40 42N	074 10W	0008	01 56 - 12 64	STAR	SA	T128'2
NEWARK	WBAS	NJ	14734	72502	40 42N	074 10W	0008	01 60 - 12 64	STAR	SA	T14547.47L
NEWARK	WBAS	NJ	14734	72502	40 42N	074 10W	0009	01 60 - 12 64	STAR	SA	T14547.47I
NEWARK	WBAS	NJ	14734	72502	40 42N	074 10W	0009	01 60 - 12 64	STAR	SA	T14547.47K
NEWARK	WBAS	NJ	14734	72502	40 42N	074 10W	0009	01 60 - 12 64	STAR	SA	T14547.47J
NEWARK	WBAS	NJ	14734	72502	40 42N	074 10W	0009	01 66 - 12 .0	STAR	MA	T12910
NEWARK	WBAS	NJ	14734	72502	40 42N	074 10W	0009	01 70 - 12 70	STAR	SA	T12892
NEWARK	WBAS	NJ	14734	72502	40 42N	074 10W	0009	01 71 - 12 71	STAR	SA	T50200
TETERBORO	SAWR	NJ	04741		40 51N	074 03W	0002	01 52 - 12 56	STAR	MA	T12910
WRIGHTSTOWN	MCGUIRE AFB	NJ	14708		40 00N	074 36W	0049	01 68 - 12 70	STAR	SA	T15100
ALBUQUERQUE	SUN-AIRLAND INL ART WBAS	NM	23050	72385	35 03N	106 37W	1618	01 60 - 12 64	STAR	MA	T14164
ALBUQUERQUE	SUN-AIRLAND INL ART WBAS	NM	23050	72385	35 03N	106 37W	1619	01 75 - 12 75	STAR	MA	T52113
FARMINGTON	MUNICIPAL ART CAA	NM	23090		36 45N	108 14W	1677	01 54 - 12 56	STAR	SA	T13028
FARMINGTON	MUNICIPAL ART FAA	NM	23090		36 45N	108 14W	1677	05 63 - 04 68	STAR	MA	T13160
GALLUP	SENATOR CLARKE FIELD SAWR	NM	23081		35 31N	108 47W	1870	01 73 - 12 75	STAR	SA	T52178
HOBBS	LEA COUNTY ART CAA	NM	93034		32 41N	103 12W	1117	01 48 - 12 48	STAR	SA	T52038
HOBBS	LEA COUNTY ART CAA	NM	93034		32 41N	103 12W	1117	01 48 - 12 54	STAR	MA	T14040
HOBBS	LEA COUNTY ART CAA	NM	93034		32 41N	103 12W	1117	01 53 - 12 54	STAR	SA	T52038
LAS CRUCES	WHITE SANDS AF	NM	23038	72389	32 22N	106 29W	1281	01 51 - 12 55	STAR	MA	T52246
SANTA FE	CAA	NM	23048		35 37N	106 05W	1929	01 50 - 12 54	STAR	MA	T52246
ZUNI	INTERMEDIATE FIELD FSS	NM	93044		35 05N	108 48W	1965	01 67 - 12 71	STAR	SA	T14358
ALBANY	MUNICIPAL ART WBAS	NY	14735	72518	42 45N	073 48W	0088	01 60 - 12 64	STAR	SA	T14613
ALBANY	MUNICIPAL ART WBAS	NY	14735	72518	42 45N	073 48W	0090	01 68 - 12 70	STAR	MA	T12910
ALBANY	MUNICIPAL ART WBAS	NY	14735	72518	42 45N	073 48W	0090	01 67 - 12 71	STAR	SA	T14384.115G
ALBANY	MUNICIPAL ART WBAS	NY	14735	72518	42 45N	073 48W	0090	01 67 - 12 71	STAR	SA	T14384.47G
ALBANY	MUNICIPAL ART WBAS	NY	14735	72518	42 45N	073 48W	0090	01 67 - 12 71	STAR	SA	T14384.115A
ALBANY	MUNICIPAL ART WBAS	NY	14735	72518	42 45N	073 48W	0090	01 67 - 12 71	STAR	SA	T14384.115C
ALBANY	MUNICIPAL ART WBAS	NY	14735	72518	42 45N	073 48W	0090	01 67 - 12 71	STAR	SA	T14384.115N
ALBANY	MUNICIPAL ART WBAS	NY	14735	72518	42 45N	073 48W	0090	01 67 - 12 71	STAR	SA	T14384.47F
ALBANY	MUNICIPAL ART WBAS	NY	14735	72518	42 45N	073 48W	0090	01 67 - 12 71	STAR	SA	T14384.115B
ALBANY	MUNICIPAL ART WBAS	NY	14735	72518	42 45N	073 48W	0090	01 67 - 12 71	STAR	SA	T14384.115E
ALBANY	MUNICIPAL ART WBAS	NY	14735	72518	42 45N	073 48W	0090	01 72 - 12 72	STAR	SA	T50855
BINGHAMTON	BROOME COUNTY ART WBAS	NY	04725	72515	42 13N	075 58W	0483	01 60 - 12 64	STAR	SA	T14640
BINGHAMTON	BROOME COUNTY ART WBAS	NY	04725	72515	42 13N	075 58W	0483	01 64 - 12 64	STAR	SA	T01772
BINGHAMTON	BROOME COUNTY ART WBAS	NY	04725	72515	42 13N	075 58W	0483	01 64 - 12 64	STAR	SA	T50408
BINGHAMTON	TRI-CITIES ART WBAS	NY	14738		42 05N	076 06W	0294	01 50 - 12 50	STAR	SA	T50408
BUFFALO	GTR BUFFALO INL ART WBAS	NY	14733	72528	42 56N	078 44W	0218	01 64 - 12 73	STAR	MA	T50388
BUFFALO	GTR BUFFALO INL ART WBAS	NY	14733	72528	42 56N	078 44W	0218	01 67 - 12 71	STAR	SA	T01772
BUFFALO	GTR BUFFALO INL ART WBAS	NY	14733	72528	42 56N	078 44W	0218	01 67 - 12 71	STAR	MA	T14462
BUFFALO	GTR BUFFALO INL ART WBAS	NY	14733	72528	42 56N	078 44W	0218	01 73 - 12 73	STAR	MA	T50847.3
ELMIRA	CHEMUNG COUNTY ART CAA	NY	14748	72516	42 10N	076 54W	0268	01 50 - 12 54	STAR	MA	T51195.3
GLENS FALLS	WARREN COUNTY ART CAA	NY	14750		43 21N	077 37W	0104	01 50 - 12 54	STAR	MA	T51185.3
NEW YORK	LA GUARDIA ART WBAS	NY	14732	72503	40 46N	073 52W	0015	01 51 - 12 60	STAR	A	T14022

SUMMARY TYPE: STAR

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TABLE/REMARKS
NEW YORK	LA GUARDIA ART WBAS	NY	14732	72503	40 46N	073 54W	0012	01 60 - 12 61	STAR	SA	T14089
NEW YORK	LA GUARDIA ART WBAS	NY	14732	72503	40 46N	073 54W	0012	01 65 - 12 70	STAR	A	T12795
NEW YORK	LA GUARDIA ART WBAS	NY	14732	72503	40 46N	073 54W	0012	01 65 - 12 66	STAR	SA	T14089
NEW YORK	LA GUARDIA ART WBAS	NY	14732	72503	40 46N	073 54W	0012	01 66 - 12 70	STAR	MA	T12910
NEW YORK	LA GUARDIA ART WBAS	NY	14732	72503	40 46N	073 54W	0012	01 70 - 12 70	STAR	A	T13880
NEW YORK	LA GUARDIA ART WBAS	NY	14732	72503	40 46N	073 54W	0012	01 70 - 12 71	STAR	SA	T14089
NEW YORK	LA GUARDIA ART WBAS	NY	14732	72503	40 46N	073 54W	0012	01 71 - 12 71	STAR	A	T13880
NEW YORK	LA GUARDIA ART WBAS	NY	14732	72503	40 46N	073 54W	0012	12 71 - 11 72	STAR	SA	T14745
NEW YORK	LA GUARDIA ART WBAS	NY	14732	72503	40 46N	073 54W	0012	01 72 - 12 72	STAR	SA	T90003
NEW YORK	LA GUARDIA ART WBAS	NY	14732	72503	40 46N	073 54W	0012	01 74 - 12 74	STAR	SA	T31951.3
NEW YORK	CENTRAL PARK WSO	NY	94728		40 47N	073 58W	0040	01 66 - 12 70	STAR	MSA	T12840.40
NEW YORK	J F KENNEDY INL ART WBAS	NY	94789	74486	40 39N	073 47W	0010	01 60 - 12 61	STAR	SA	T14088
NEW YORK	J F KENNEDY INL ART WBAS	NY	94789	74486	40 39N	073 47W	0010	01 65 - 12 69	STAR	SA	T12781
NEW YORK	J F KENNEDY INL ART WBAS	NY	94789	74486	40 39N	073 47W	0010	01 65 - 12 66	STAR	SA	T14088
NEW YORK	J F KENNEDY INL ART WBAS	NY	94789	74486	40 39N	073 47W	0010	01 66 - 12 70	STAR	MA	T12910
NEW YORK	J F KENNEDY INL ART WBAS	NY	94789	74486	40 39N	073 47W	0010	01 70 - 12 71	STAR	SA	T14089
NEW YORK	J F KENNEDY INL ART WBAS	NY	94789	74486	40 39N	073 47W	0010	01 74 - 12 74	STAR	SA	T31951.3
NEWBURGH	STEWART AFB	NY	14714	74482	41 30N	074 06W	0177	01 65 - 12 69	STAR	SA	T50251.115C
NEWBURGH	STEWART AFB	NY	14714	74482	41 30N	074 06W	0177	01 65 - 12 69	STAR	SA	T50251.115W
NEWBURGH	STEWART AFB	NY	14714	74482	41 30N	074 06W	0177	01 65 - 12 69	STAR	SA	T50251.115E
NEWBURGH	STEWART AFB	NY	14714	74482	41 30N	074 06W	0177	01 65 - 12 69	STAR	SA	T50251.115A
NEWBURGH	STEWART AFB	NY	14714	74482	41 30N	074 06W	0177	01 65 - 12 69	STAR	SA	T50251.115B
NEWBURGH	STEWART AFB	NY	14714	74482	41 30N	074 06W	0177	01 66 - 12 68	STAR	MA	T12910
NEWBURGH	STEWART AFB	NY	14714	74482	41 30N	074 06W	0177	01 66 - 12 69	STAR	SA	T50251.47F
NEWBURGH	STEWART AFB	NY	14714	74482	41 30N	074 06W	0177	01 66 - 12 69	STAR	SA	T50251.115D
NEWBURGH	STEWART AFB	NY	14714	74482	41 30N	074 06W	0177	01 69 - 12 69	STAR	SA	T50251.47D
NIAGARA FALLS	MISSILE SITE AF	NY	04724		43 08N	078 57W	0181	01 55 - 12 59	STAR	MA	T31195.3
ONEONTA	MUNICIPAL ART	NY	94731	74484	42 27N	075 00W	0384	01 67 - 12 67	STAR	A	T50428
POUGHKEEPSIE	DUTCHESS COUNTY ART CAA	NY	14757		41 38N	073 53W	0048	01 50 - 12 54	STAR	MA	T12910
ROCHESTER	MONROE COUNTY ART WBAS	NY	14768	72529	43 07N	077 40W	0168	01 55 - 12 64	STAR	MSA	T50221
ROCHESTER	MONROE COUNTY ART WBAS	NY	14768	72529	43 07N	077 40W	0167	01 60 - 12 64	STAR	SA	T14460
ROCHESTER	MONROE COUNTY ART WBAS	NY	14768	72529	43 07N	077 40W	0167	01 67 - 12 71	STAR	SA	T14237.115C
ROCHESTER	MONROE COUNTY ART WBAS	NY	14768	72529	43 07N	077 40W	0167	01 67 - 12 71	STAR	SA	T14237.115B
ROCHESTER	MONROE COUNTY ART WBAS	NY	14768	72529	43 07N	077 40W	0167	01 67 - 12 71	STAR	SA	T14237.115E
ROCHESTER	MONROE COUNTY ART WBAS	NY	14768	72529	43 07N	077 40W	0167	01 67 - 12 71	STAR	SA	T14237.47F
ROCHESTER	MONROE COUNTY ART WBAS	NY	14768	72529	43 07N	077 40W	0167	01 67 - 12 71	STAR	SA	T14237.115D
ROCHESTER	MONROE COUNTY ART WBAS	NY	14768	72529	43 07N	077 40W	0167	01 67 - 12 71	STAR	SA	T14237.115A
ROCHESTER	MONROE COUNTY ART WBAS	NY	14768	72529	43 07N	077 40W	0167	01 67 - 12 71	STAR	SA	T14237.47D
ROCHESTER	MONROE COUNTY ART WBAS	NY	14768	72529	43 07N	077 40W	0167	01 67 - 12 71	STAR	SA	T14237.115M
ROCHESTER	MONROE COUNTY ART WBAS	NY	14768	72529	43 07N	077 40W	0167	01 72 - 12 72	STAR	SA	T50224
ROME	GRIFFISS AFB	NY	14717	72518	43 14N	075 25W	0149	01 68 - 12 70	STAR	SA	T50784
SYRACUSE	C E HANCOCK ART WBAS	NY	14771	72518	43 07N	076 07W	0128	01 55 - 12 64	STAR	MA	T31175.3
SYRACUSE	C E HANCOCK ART WBAS	NY	14771	72518	43 07N	076 07W	0128	01 55 - 12 84	STAR	MA	T31175
SYRACUSE	C E HANCOCK ART WBAS	NY	14771	72518	43 07N	076 07W	0128	01 67 - 12 67	STAR	SA	T12322
SYRACUSE	C E HANCOCK ART WBAS	NY	14771	72518	43 07N	076 07W	0124	01 68 - 12 73	STAR	MA	T50884
WATERTOWN	MUNICIPAL ART FSS	NY	94790		44 00N	076 01W	0301	01 60 - 12 64	STAR	SA	T50784
WHITE PLAINS	WESTCHESTER CAP SALM	NY	94745		41 04N	073 43W	0122	01 49 - 12 53	STAR	MA	T12810
WHITE PLAINS	WESTCHESTER CAP SALM	NY	94745		41 04N	073 43W	0135	01 72 - 12 72	STAR	A	T50956
ASHEVILLE	MUNICIPAL ART WBAS	NC	03812	72315	35 26N	082 32W	0658	01 66 - 12 70	STAR	SA	T12781
ASHEVILLE	MUNICIPAL ART WBAS	NC	03812	72315	35 26N	082 32W	0658	01 71 - 12 71	STAR	MA	T13877
CAPE HATTERAS	WSO	NC	93728	72304	35 16N	075 33W	0008	01 68 - 12 70	STAR	SA	T12781
CHARLOTTE	DOUGLAS MAP WBAS	NC	13881	72314	35 13N	080 56W	0228	01 60 - 12 64	STAR	SA	T51881
CHARLOTTE	DOUGLAS MAP WBAS	NC	13881	72314	35 13N	080 56W	0228	01 66 - 12 70	STAR	SA	T12781
CHARLOTTE	DOUGLAS MAP WBAS	NC	13881	72314	35 13N	080 56W	0228	01 68 - 12 73	STAR	SA	T50544
CHARLOTTE	DOUGLAS MAP WBAS	NC	13881	72314	35 13N	080 56W	0228	01 70 - 12 70	STAR	SA	T12781
CHARLOTTE	DOUGLAS MAP WBAS	NC	13881	72314	35 13N	080 56W	0228	10 70 - 10 71	STAR	A	T50464
CHARLOTTE	DOUGLAS MAP WBAS	NC	13881	72314	35 13N	080 56W	0224	01 72 - 12 73	STAR	SA	T50897
CHERRY POINT	MCAS	NC	13794	72308	34 54N	076 53W	0010	01 67 - 12 71	STAR	MA	T14256
FORT BRAGG	POPE AFB	NC	13714	72302	35 11N	079 01W	0061	01 68 - 12 70	STAR	SA	T14256
GOLDSBORO	SEYMOUR JOHNSON AFB	NC	13713		35 20N	077 58W	0027	01 68 - 12 70	STAR	MA	T14256
GREENSBORO	GREENSBORO HI PT ART WBAS	NC	13723	72317	36 05N	079 57W	0275	01 68 - 12 70	STAR	SA	T12781
GREENSBORO	GREENSBORO HI PT ART WBAS	NC	13723	72317	36 05N	079 57W	0275	01 68 - 12 72	STAR	SA	T14487
GREENSBORO	GREENSBORO HI PT ART WBAS	NC	13723	72317	36 05N	079 57W	0275	01 73 - 12 73	STAR	SA	T50897
GREENSBORO	GREENSBORO HI PT ART WBAS	NC	13723	72317	36 05N	079 57W	0275	10 73 - 08 74	STAR	SA	T50796
RALEIGH	RALEIGH DURHAM ART WBAS	NC	13722	72306	35 52N	078 47W	0132	01 55 - 12 64	STAR	SA	T12310.108
RALEIGH	RALEIGH DURHAM ART WBAS	NC	13722	72306	35 52N	078 47W	0132	01 55 - 12 64	STAR	SA	T12310
RALEIGH	RALEIGH DURHAM ART WBAS	NC	13722	72306	35 52N	078 47W	0132	01 55 - 12 64	STAR	SA	T12310.108
RALEIGH	RALEIGH DURHAM ART WBAS	NC	13722	72306	35 52N	078 47W	0132	01 66 - 12 70	STAR	SA	T12781
WILMINGTON	NEW HANOVER ART WBAS	NC	13748	72501	34 16N	077 55W	0014	01 66 - 12 70	STAR	SA	T12781
WILMINGTON	NEW HANOVER ART WBAS	NC	13748	72501	34 16N	077 55W	0014	01 67 - 12 67	STAR	SA	T51279.6
WINSTON SALEM	SMITH REYNOLDS ART WBAS	NC	93407	72318	36 08N	080 14W	0305	01 60 - 12 64	STAR	SA	T14487
BISMARCK	MUNICIPAL ART WBAS	ND	24011	72764	46 46N	100 45W	0507	01 67 - 12 71	STAR	SA	T13823
DICKINSON	MUNICIPAL ART FAA	ND	24013		46 47N	102 48W	0792	01 60 - 12 64	STAR	MA	T14827
MINOT	INTERNATIONAL ART FAA	ND	24013		48 16N	101 17W	0526	01 67 - 12 71	STAR	MA	T14827
WILLISTON	SLOULIN FLD INL ART WBAS	ND	94014	72767	48 11N	103 38W	0581	01 67 - 12 71	STAR	MA	T14827
AKRON	AKRON-CANTON ART WBAS	OH	14895	72521	40 55N	081 26W	0378	01 60 - 12 64	STAR	SA	T50148
AKRON	AKRON-CANTON ART WBAS	OH	14895	72521	40 55N	081 26W	0378	01 64 - 12 73	STAR	SA	T50805.3
AKRON	AKRON-CANTON ART WBAS	OH	14895	72521	40 55N	081 26W	0378	01 70 - 12 74	STAR	SA	T15675.3
AKRON	AKRON-CANTON ART WBAS	OH	14895	72521	40 55N	081 26W	0378	01 70 - 12 74	STAR	MA	T51253.3
AKRON	AKRON-CANTON ART WBAS	OH	14895	72521	40 55N	081 26W	0378	01 73 - 12 73	STAR	SA	T51144.3
AKRON	AKRON-CANTON ART WBAS	OH	14895	72521	40 55N	081 26W	0378	01 73 - 12 73	STAR	A	T14800
AKRON	AKRON-CANTON ART WBAS	OH	14895	72521	40 55N	081 26W	0378	01 74 - 12 74	STAR	SA	T15675.3
AKRON	AKRON-CANTON ART WBAS	OH	14895	72521	40 55N	081 26W	0378	01 75 - 12 75	STAR	SA	T52409.3
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0247	01 64 - 12 64	STAR	A	T50084
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0247	01 65 - 12 67	STAR	A	T11938
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0247	01 65 - 12 67	STAR	SA	T11983
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0247	01 67 - 12 71	STAR	SA	T01772
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0247	01 68 - 12 73	STAR	A	T50959.3
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0247	01 68 - 12 68	STAR	SA	T11983

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	*REMARKS
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0247	01 70 - 12 74	STAR	SA	T52044
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0247	01 70 - 12 74	STAR	SA	T15675.3
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0247	01 70 - 12 70	STAR	A	T01772
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0247	01 70 - 12 70	STAR	A	T14828
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0247	01 72 - 12 72	STAR	A	T14997
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0245	01 73 - 12 73	STAR	A	T50705.3
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0245	01 74 - 12 74	STAR	SA	T15351.3
CLEVELAND	HOPKINS INL ART WBAS	OH	14820	72524	41 24N	081 51W	0245	01 75 - 12 75	STAR	SA	T52408.3
COLUMBUS	PORT COLUMBUS ART WBAS	OH	14821	72426	40 00N	082 53W	0253	01 50 - 12 64	STAR	SA	T51850
COLUMBUS	PORT COLUMBUS ART WBAS	OH	14821	72426	40 00N	082 53W	0253	01 60 - 12 64	STAR	SA	T14132
COLUMBUS	PORT COLUMBUS ART WBAS	OH	14821	72426	40 00N	082 53W	0253	01 70 - 12 74	STAR	SA	T15675.3
COLUMBUS	PORT COLUMBUS ART WBAS	OH	14821	72426	40 00N	082 53W	0253	01 74 - 12 74	STAR	SA	T15675.3
COLUMBUS	PORT COLUMBUS ART WBAS	OH	14821	72426	40 00N	082 53W	0253	01 75 - 12 75	STAR	SA	T52408.3
DAYTON	J M COX-DAYTON MAP WBAS	OH	93815	72429	39 54N	084 13W	0313	01 65 - 12 69	STAR	SA	T11983
DAYTON	J M COX-DAYTON MAP WBAS	OH	93815	72429	39 54N	084 13W	0313	01 69 - 12 69	STAR	SA	T11983
DAYTON	J M COX-DAYTON MAP WBAS	OH	93815	72429	39 54N	084 13W	0306	01 69 - 12 73	STAR	A	T50959.3
DAYTON	J M COX-DAYTON MAP WBAS	OH	93815	72429	39 54N	084 13W	0306	01 70 - 12 74	STAR	SA	T15675.3
DAYTON	J M COX-DAYTON MAP WBAS	OH	93815	72429	39 54N	084 13W	0306	01 73 - 12 73	STAR	A	T15022
DAYTON	J M COX-DAYTON MAP WBAS	OH	93815	72429	39 54N	084 13W	0306	01 73 - 12 73	STAR	A	T50959.3
DAYTON	J M COX-DAYTON MAP WBAS	OH	93815	72429	39 54N	084 13W	0306	01 74 - 12 74	STAR	A	T51287
DAYTON	J M COX-DAYTON MAP WBAS	OH	93815	72429	39 54N	084 13W	0306	01 74 - 12 74	STAR	SA	T15675.3
DAYTON	J M COX-DAYTON MAP WBAS	OH	93815	72429	39 54N	084 13W	0306	01 75 - 12 75	STAR	SA	T52408.3
FINDLAY	CAA	OH	14829		41 01N	083 40W	0244	01 50 - 12 54	STAR	A	T13708
FINDLAY	CAA	OH	14829		41 01N	083 40W	0244	01 50 - 12 54	STAR	A	T50708.3
FINDLAY	CAA	OH	14829		41 01N	083 40W	0244	01 50 - 12 54	STAR	SA	T52126.3
MANSFIELD	LAHM MUNICIPAL ART FAA	OH	14891		40 49N	082 31W	0397	01 70 - 12 74	STAR	SA	T15675.3
MANSFIELD	LAHM MUNICIPAL ART FAA	OH	14891		40 49N	082 31W	0397	01 74 - 12 74	STAR	SA	T15675.3
MANSFIELD	LAHM MUNICIPAL ART FAA	OH	14891		40 49N	082 31W	0397	01 75 - 12 75	STAR	SA	T52408.3
PERRY	CAA	OH	14843		41 47N	081 08W	0211	01 48 - 12 48	STAR	A	T50875.3
TOLEDO	EXPRESS ART WBAS	OH	94830	72536	41 36N	083 48W	0211	01 60 - 12 64	STAR	SA	T52126.3
TOLEDO	EXPRESS ART WBAS	OH	94830	72536	41 36N	083 48W	0211	01 64 - 12 68	STAR	SA	T12221
TOLEDO	EXPRESS ART WBAS	OH	94830	72536	41 36N	083 48W	0211	08 68 - 09 70	STAR	SA	T12221
TOLEDO	EXPRESS ART WBAS	OH	94830	72536	41 36N	083 48W	0211	01 70 - 12 74	STAR	SA	T15675.3
TOLEDO	EXPRESS ART WBAS	OH	94830	72536	41 36N	083 48W	0211	01 73 - 12 73	STAR	SA	T51144.3
TOLEDO	EXPRESS ART WBAS	OH	94830	72536	41 36N	083 48W	0211	01 74 - 12 74	STAR	SA	T15675.3
TOLEDO	EXPRESS ART WBAS	OH	94830	72536	41 36N	083 48W	0211	01 75 - 12 75	STAR	SA	T52409.3
YOUNGSTOWN	MUNICIPAL ART WBAS	OH	14852	72535	41 16N	080 40W	0365	01 67 - 12 71	STAR	SA	T01772
YOUNGSTOWN	MUNICIPAL ART WBAS	OH	14852	72535	41 16N	080 40W	0365	01 70 - 12 74	STAR	SA	T15675.3
YOUNGSTOWN	MUNICIPAL ART WBAS	OH	14852	72535	41 16N	080 40W	0365	01 73 - 12 73	STAR	A	T14800
YOUNGSTOWN	MUNICIPAL ART WBAS	OH	14852	72535	41 16N	080 40W	0365	01 74 - 12 74	STAR	SA	T15675.3
YOUNGSTOWN	MUNICIPAL ART WBAS	OH	14852	72535	41 16N	080 40W	0365	01 75 - 12 75	STAR	SA	T52409.3
ENID	VANCE AFB	OK	13908		36 20N	097 54W	0382	01 65 - 12 69	STAR	SA	T12781
MCALESTER		OK	93950		34 53N	095 47W	0227	01 54 - 12 54	STAR	MA	T51827.3
OKLAHOMA CITY	TINKER AFB	OK	13919	72354	35 25N	097 23W	0384	07 65 - 06 70	STAR	SA	T12897
OKLAHOMA CITY	WILL ROGERS ART WBAS	OK	13967	72353	35 24N	097 36W	0395	01 70 - 12 74	STAR	MA	T51200.3
PONCA CITY	MUNICIPAL ART CAA	OK	13968		36 44N	097 08W	0304	01 48 - 12 54	STAR	MA	T51200.3
TULSA	INTERNATIONAL ART WBAS	OK	13968	72356	36 12N	095 54W	0207	01 54 - 12 74	STAR	MA	T51827.3
TULSA	INTERNATIONAL ART WBAS	OK	13968	72356	36 12N	095 54W	0207	01 63 - 12 71	STAR	MA	T01772
TULSA	INTERNATIONAL ART WBAS	OK	13968	72356	36 12N	095 54W	0208	01 70 - 12 70	STAR	MA	T51200.3
TULSA	INTERNATIONAL ART WBAS	OK	13968	72356	36 12N	095 54W	0208	12 73 - 09 74	STAR	MA	T50430.3
TULSA	INTERNATIONAL ART WBAS	OK	13968	72356	36 12N	095 54W	0208	12 73 - 11 74	STAR	MSA	T50987
ASTORIA	CLATSOP COUNTY ART WBAS	OR	94224	72781	46 10N	123 52W	0003	01 60 - 12 64	STAR	MA	T12845
EUGENE	MAHLON-SWEET FIELD WBAS	OR	24221	72683	44 07N	123 13W	0111	01 67 - 12 71	STAR	SA	T14488
KLAMATH FALLS	KINGSLEY FIELD AF	OR	94236		42 09N	121 44W	1246	01 61 - 12 65	STAR	MSA	T12273
KLAMATH FALLS	KINGSLEY FIELD AF	OR	94236		42 09N	121 44W	1246	07 68 - 08 70	STAR	MSA	T12273
MEDFORD	JACKSON COUNTY ART WBAS	OR	24229	72587	42 22N	122 52W	0400	01 70 - 12 74	STAR	A	T52143.3
MEDFORD	JACKSON COUNTY ART WBAS	OR	24229	72587	42 22N	122 52W	0400	01 73 - 12 73	STAR	SA	T52143.3
MEDFORD	JACKSON COUNTY ART WBAS	OR	24229	72587	42 22N	122 52W	0400	01 73 - 12 74	STAR	A	T52143.3
PENDLETON	PENDLETON FIELD WBAS	OR	24156	72688	45 41N	118 51W	0498	01 55 - 12 64	STAR	MA	T14834
PORTLAND	INTERNATIONAL ART WBAS	OR	24229	72698	45 36N	122 36W	0008	01 67 - 12 71	STAR	SA	T13530
PORTLAND	INTERNATIONAL ART WBAS	OR	24229	72698	45 36N	122 36W	0008	01 68 - 12 73	STAR	A	T50372
REDMOND	ROBERTS FIELD CAA	OR	24230		44 15N	121 09W	0834	01 55 - 12 64	STAR	MA	T14834
SALEM	MCNARY FIELD WBAS	OR	24232	72694	44 55N	123 01W	0081	01 67 - 12 71	STAR	SA	T14488
ALLENTOWN	BETHLEHEM EST ART WBAS	PA	14737	72517	40 38N	075 28W	0117	01 60 - 12 64	STAR	SA	T12845
ALLENTOWN	BETHLEHEM EST ART WBAS	PA	14737	72517	40 38N	075 28W	0117	01 64 - 12 73	STAR	SA	T15347.3
ALLENTOWN	BETHLEHEM EST ART WBAS	PA	14737	72517	40 38N	075 28W	0117	01 65 - 12 69	STAR	SA	T13540
ALLENTOWN	BETHLEHEM EST ART WBAS	PA	14737	72517	40 38N	075 28W	0117	01 69 - 12 73	STAR	SA	T15347.3
ALLENTOWN	BETHLEHEM EST ART WBAS	PA	14737	72517	40 38N	075 28W	0117	01 73 - 12 73	STAR	SA	T15347.3
ALLENTOWN	BETHLEHEM EST ART WBAS	PA	14737	72517	40 38N	075 28W	0116	01 74 - 12 74	STAR	SA	T51938.3
ALTOONA	BLAIR CAR PET MEM FLD CAA	PA	14738		40 18N	078 19W	0447	10 48 - 09 54	STAR	SA	T14015
BEAVER FALLS	REGIONAL ART FSS	PA	04751		41 48N	078 38W	0847	01 60 - 12 64	STAR	MA	T13909
BEAVER FALLS	REGIONAL ART FSS	PA	04751		41 48N	078 38W	0847	01 60 - 12 64	STAR	SA	T13909
ERIE	INTERNATIONAL ART WBAS	PA	14860	72528	42 05N	080 11W	0225	01 64 - 12 73	STAR	MA	T50388
ERIE	INTERNATIONAL ART WBAS	PA	14860	72528	42 05N	080 11W	0225	01 64 - 12 73	STAR	SA	T15347.3
ERIE	INTERNATIONAL ART WBAS	PA	14860	72528	42 05N	080 11W	0225	01 68 - 12 73	STAR	SA	T15347.3
ERIE	INTERNATIONAL ART WBAS	PA	14860	72528	42 05N	080 11W	0225	01 70 - 12 74	STAR	SA	T15675.3
ERIE	INTERNATIONAL ART WBAS	PA	14860	72528	42 05N	080 11W	0225	01 73 - 12 73	STAR	SA	T15347.3
ERIE	INTERNATIONAL ART WBAS	PA	14860	72528	42 05N	080 11W	0225	01 74 - 12 74	STAR	SA	T15675.3
ERIE	INTERNATIONAL ART WBAS	PA	14860	72528	42 05N	080 11W	0225	01 74 - 12 74	STAR	SA	T51938.3
ERIE	INTERNATIONAL ART WBAS	PA	14860	72528	42 05N	080 11W	0225	01 75 - 12 75	STAR	SA	T52408.3
HARRISBURG	STATE ART WBAS	PA	14751	72511	40 13N	076 51W	0107	01 64 - 12 64	STAR	A	T50451
HARRISBURG	STATE ART WBAS	PA	14751	72511	40 13N	076 51W	0107	01 64 - 12 73	STAR	SA	T15347.3
HARRISBURG	STATE ART WBAS	PA	14751	72511	40 13N	076 51W	0107	01 65 - 12 69	STAR	SA	T13432
HARRISBURG	STATE ART WBAS	PA	14751	72511	40 13N	076 51W	0107	01 69 - 12 74	STAR	A	T50819.3
HARRISBURG	STATE ART WBAS	PA	14751	72511	40 13N	076 51W	0107	11 70 - 10 71	STAR	SA	T01772
HARRISBURG	STATE ART WBAS	PA	14751	72511	40 13N	076 51W	0107	01 73 - 12 73	STAR	SA	T15347.3
HARRISBURG	STATE ART WBAS	PA	14751	72511	40 13N	076 51W	0107	01 74 - 12 74	STAR	SA	T51938.3
MARTINS CREEK		PA	94768		40 48N	075 07W	0108	01 38 - 03 38	STAR	MA	T12746.52
MARTINS CREEK		PA	94768		40 48N	075 07W	0108	01 38 - 03 38	STAR	SA	T12746.52

SUMMARY TYPE: STAR

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TAPE/REMARKS
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 60 - 12 64	STAR	SA	T14623.47J
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 60 - 12 64	STAR	SA	T14623.47J
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 60 - 12 64	STAR	SA	T14623.47P
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 60 - 12 64	STAR	MA	T13167
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 60 - 12 64	STAR	A	T14635.47M
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 68 - 12 73	STAR	MA	T50412
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 70 - 12 70	STAR	A	T14252
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 71 - 12 71	STAR	A	T14252
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 71 - 12 71	STAR	SA	T01772
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 72 - 12 72	STAR	A	T50884
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 72 - 12 72	STAR	A	T01772
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 73 - 12 73	STAR	SA	T50963
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 74 - 12 74	STAR	A	T52217
PHILADELPHIA	INTERNATIONAL ART WBAS	PA	13739	72408	39 53N	075 15W	0009	01 74 - 12 74	STAR	SA	T51936.3
PHILIPSBURG	MID STATE ART CAA	PA	14781	72512	40 53N	078 05W	0586	01 50 - 12 54	STAR	SA	T14019
PITTSBURGH	ALLEGHENY COUNTY ART	PA	14762		40 21N	079 56W	0166	01 74 - 12 75	STAR	SA	T52345.3
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 63 - 12 65	STAR	A	T14407
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 64 - 12 73	STAR	SA	T15347.3
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 65 - 12 68	STAR	SA	T12069
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 66 - 12 66	STAR	A	T14407
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 67 - 12 67	STAR	A	T14407
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 68 - 12 68	STAR	A	T14407
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 68 - 12 68	STAR	MA	T11802
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 68 - 12 73	STAR	SA	T15347.3
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 68 - 12 73	STAR	A	T50958
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 70 - 12 70	STAR	MA	T13680
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 70 - 12 74	STAR	SA	T15679.3
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 71 - 12 71	STAR	MA	T13680
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 72 - 12 72	STAR	A	T01772
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 72 - 12 72	STAR	A	T01772
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 72 - 08 72	STAR	MA	T01772
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 73 - 12 73	STAR	A	T50959
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 73 - 12 73	STAR	SA	T19347.3
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 74 - 12 74	STAR	SA	T15679.3
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 74 - 12 74	STAR	SA	T51838.3
PITTSBURGH	GTR PITTSBURGH ART WBAS	PA	94823	72520	40 30N	080 13W	0373	01 75 - 12 75	STAR	SA	T52408.3
READING	GEN SPRATZ FLD MAP AAF	PA	14712	72510	40 23N	075 58W	0096	01 48 - 12 48	STAR	SA	T13389
READING	GEN SPRATZ FLD MAP AAF	PA	14712	72510	40 23N	075 58W	0096	01 48 - 12 48	STAR	SA	T13921
WILKES-BARRE	WBAS SCRANTON	PA	14777	72513	41 20N	075 44W	0282	01 60 - 12 64	STAR	SA	T14643
WILKES-BARRE	WBAS SCRANTON	PA	14777	72513	41 20N	075 44W	0282	01 64 - 12 73	STAR	SA	T15347.3
WILKES-BARRE	WBAS SCRANTON	PA	14777	72513	41 20N	075 44W	0282	01 68 - 12 73	STAR	SA	T15347.3
WILKES-BARRE	WBAS SCRANTON	PA	14777	72513	41 20N	075 44W	0282	01 71 - 12 75	STAR	MA	T51840
WILKES-BARRE	WBAS SCRANTON	PA	14777	72513	41 20N	075 44W	0282	01 73 - 12 73	STAR	SA	T15347.3
WILKES-BARRE	WBAS SCRANTON	PA	14777	72513	41 20N	075 44W	0282	01 74 - 12 74	STAR	SA	T51838.3
WILLIAMSPORT	LYCOMING COUNTY ART WBAS	PA	14778	72514	41 15N	076 55W	0160	01 64 - 12 73	STAR	SA	T15347.3
WILLIAMSPORT	LYCOMING COUNTY ART WBAS	PA	14778	72514	41 15N	076 55W	0160	01 68 - 12 73	STAR	SA	T15347.3
WILLIAMSPORT	LYCOMING COUNTY ART WBAS	PA	14778	72514	41 15N	076 55W	0160	01 73 - 12 73	STAR	SA	T15347.3
WILLOW GROVE	NAS	PA	14793		40 12N	075 09W	0102	01 70 - 12 70	STAR	A	T14252
WILLOW GROVE	NAS	PA	14793		40 12N	075 09W	0102	01 71 - 12 71	STAR	A	T14252
WILLOW GROVE	NAS	PA	14793		40 12N	075 09W	0102	01 74 - 12 74	STAR	SA	T51838.3
PROVIDENCE	T F GREEN ART WBAS	RI	14765	72507	41 44N	071 26W	0018	01 60 - 12 64	STAR	SA	T14116
PROVIDENCE	T F GREEN ART WBAS	RI	14765	72507	41 44N	071 26W	0018	01 64 - 12 73	STAR	MA	T50378
PROVIDENCE	T F GREEN ART WBAS	RI	14765	72507	41 44N	071 26W	0018	01 68 - 12 73	STAR	SA	T14783
PROVIDENCE	T F GREEN ART WBAS	RI	14765	72507	41 44N	071 26W	0018	01 73 - 12 73	STAR	SA	T50899
PROVIDENCE	T F GREEN ART WBAS	RI	14765	72507	41 44N	071 26W	0018	01 73 - 12 73	STAR	MA	T13902
PROVIDENCE	T F GREEN ART WBAS	RI	14765	72507	41 44N	071 26W	0018	08 73 - 08 73	STAR	MA	T50728
PROVIDENCE	T F GREEN ART WBAS	RI	14765	72507	41 44N	071 26W	0018	01 74 - 12 74	STAR	A	T52448
PROVIDENCE	T F GREEN ART WBAS	RI	14765	72507	41 44N	071 26W	0018	01 74 - 12 74	STAR	SA	T51176.3
PROVIDENCE	T F GREEN ART WBAS	RI	14765	72507	41 44N	071 26W	0018	05 74 - 10 74	STAR	A	T52448.52
ANDERSON	ANDERSON COUNTY ART CAA	SC	93646		34 30N	082 43W	0253	01 54 - 12 56	STAR	SA	T13686
CHARLESTON	MUNICIPAL ART WBAS	SC	13880	72208	32 54N	080 02W	0018	01 60 - 12 64	STAR	SA	T12818
CHARLESTON	MUNICIPAL ART WBAS	SC	13880	72208	32 54N	080 02W	0018	01 68 - 12 72	STAR	MA	T14415
CHARLESTON	MUNICIPAL ART WBAS	SC	13880	72208	32 54N	080 02W	0018	01 70 - 12 70	STAR	SA	T12818
CHARLESTON	MUNICIPAL ART WBAS	SC	13880	72208	32 54N	080 02W	0018	01 72 - 12 72	STAR	MA	T14415
COLUMBIA	METROPOLITAN ART WBAS	SC	13883	72310	33 57N	081 07W	0079	01 67 - 12 68	STAR	SA	T14140
COLUMBIA	METROPOLITAN ART WBAS	SC	13883	72310	33 57N	081 07W	0079	01 67 - 12 71	STAR	SA	T14140
COLUMBIA	METROPOLITAN ART WBAS	SC	13883	72310	33 57N	081 07W	0079	01 68 - 12 71	STAR	SA	T14140
COLUMBIA	METROPOLITAN ART WBAS	SC	13883	72310	33 57N	081 07W	0086	01 70 - 12 74	STAR	SA	T51979
COLUMBIA	METROPOLITAN ART WBAS	SC	13883	72310	33 57N	081 07W	0086	08 72 - 07 73	STAR	SA	T19164
FLORENCE	GILBERT FIELD MAP WBAS	SC	13744		34 11N	079 43W	0046	01 60 - 12 64	STAR	SA	T50268
GREENVILLE	GREEN-SPART ART WBAS	SC	03870	72312	34 54N	082 13W	0290	01 63 - 12 67	STAR	SA	T12818
GREENVILLE	GREEN-SPART ART WBAS	SC	03870	72312	34 54N	082 13W	0290	01 68 - 12 72	STAR	SA	T14587
GREENVILLE	GREEN-SPART ART WBAS	SC	03870	72312	34 54N	082 13W	0290	01 68 - 12 72	STAR	A	T14542
GREENVILLE	GREEN-SPART ART WBAS	SC	03870	72312	34 54N	082 13W	0290	01 68 - 12 72	STAR	MA	T14413
GREENVILLE	GREEN-SPART ART WBAS	SC	03870	72312	34 54N	082 13W	0290	01 70 - 12 70	STAR	SA	T12818
GREENVILLE	GREEN-SPART ART WBAS	SC	03870	72312	34 54N	082 13W	0290	01 72 - 12 72	STAR	MA	T14413
SPARTANBURG	MEMORIAL ART WBAS	SC	93804	72312	34 55N	081 57W	0246	01 57 - 12 61	STAR	SA	T14587
PIERRE	MUNICIPAL ART FSS	SD	24025		44 23N	100 17W	0528	01 67 - 12 71	STAR	MA	T14316
RAPID CITY	MUNICIPAL ART WBAS	SD	24090	72662	44 03N	103 04W	0966	01 67 - 12 71	STAR	MA	T14122
SIOUX FALLS	FOSS FIELD WBAS	SD	14944	72651	43 34N	096 44W	0435	01 58 - 12 72	STAR	MA	T14678
SIOUX FALLS	FOSS FIELD WBAS	SD	14944	72651	43 34N	096 44W	0435	01 74 - 12 74	STAR	A	T52157.3
BRISTOL	TRI-CITY ART WBAS	TN	13877	72318	36 29N	082 24W	0475	01 60 - 12 64	STAR	SA	T51965.3
BRISTOL	TRI-CITY ART WBAS	TN	13877	72318	36 29N	082 24W	0475	01 66 - 12 70	STAR	SA	T13054
BRISTOL	TRI-CITY ART WBAS	TN	13877	72318	36 29N	082 24W	0475	01 74 - 12 74	STAR	A	T51543
CHATTANOOGA	LOVELL FIELD WBAS	TN	13882	72334	35 02N	085 12W	0210	01 60 - 12 64	STAR	SA	T50242.47N
CHATTANOOGA	LOVELL FIELD WBAS	TN	13882	72334	35 02N	085 12W	0210	01 60 - 12 64	STAR	SA	T51955.3
CHATTANOOGA	LOVELL FIELD WBAS	TN	13882	72334	35 02N	085 12W	0210	01 67 - 12 71	STAR	SA	T14372
CHATTANOOGA	LOVELL FIELD WBAS	TN	13882	72334	35 02N	085 12W	0210	01 68 - 12 73	STAR	SA	T50821

SUMMARY TYPE: STAR

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUMM FREQ	TAPE/REMARKS
CHATTANOOGA	LOVELL FIELD WBAS	TN	13882	72324	35 02N	085 12W	0210	01 70 - 12 70	STAR	SA	T13252
JACKSON	MCKELLER	TN	03811		35 36N	088 55W	0129	01 48 - 12 54	STAR	MA	T52436
KNOXVILLE	MCGHEE TYSON ART WBAS	TN	13891	72326	35 49N	083 59W	0297	01 58 - 12 70	STAR	SA	T13054
KNOXVILLE	MCGHEE TYSON ART WBAS	TN	13891	72326	35 49N	083 59W	0299	01 58 - 12 73	STAR	SA	T50621
MEMPHIS	INTERNATIONAL ART WBAS	TN	13893	72334	35 03N	089 59W	0066	01 57 - 12 71	STAR	SA	T13479
NASHVILLE	BERRY FIELD MAP WBAS	TN	13897	72327	36 07N	086 41W	0177	01 50 - 12 64	STAR	A	T14424,47M
NASHVILLE	BERRY FIELD MAP WBAS	TN	13897	72327	36 07N	086 41W	0183	01 58 - 12 70	STAR	SA	T12881
NASHVILLE	BERRY FIELD MAP WBAS	TN	13897	72327	36 07N	086 41W	0183	01 70 - 12 70	STAR	A	T12781
NASHVILLE	BERRY FIELD MAP WBAS	TN	13897	72327	36 07N	086 41W	0184	01 71 - 12 75	STAR	MA	T52420,3
NASHVILLE	BERRY FIELD MAP WBAS	TN	13897	72327	36 07N	086 41W	0184	01 73 - 12 73	STAR	SA	T50926
ABILENE	MUNICIPAL ART WBAS	TX	13962	72286	32 26N	099 41W	0937	01 57 - 12 71	STAR	SA	T01772
ABILENE	MUNICIPAL ART WBAS	TX	13962	72286	32 26N	099 41W	0937	10 72 - 10 73	STAR	MSA	T50309
AMARILLO	ENGLISH FLD MAP WBAS	TX	23047	72363	35 14N	101 42W	1098	01 55 - 12 64	STAR	SA	T50360
AUSTIN	MUELLER MAP WBAS	TX	13958	72254	30 18N	097 42W	0189	01 57 - 12 71	STAR	MA	T14784
AUSTIN	MUELLER MAP WBAS	TX	13958	72254	30 18N	097 42W	0189	01 58 - 12 73	STAR	MA	T51101
BEEVILLE	CHASE FIELD NAAS	TX	12925		28 22N	097 40W	0060	01 65 - 12 68	STAR	SA	T50893
BEEVILLE	CHASE FIELD NAAS	TX	12925		28 22N	097 40W	0060	01 68 - 12 70	STAR	A	T13121
CORPUS CHRISTI	NAS	TX	12926		27 41N	097 17W	0006	01 65 - 12 68	STAR	SA	T12781
COTULLA	MUNICIPAL ART CAA	TX	12947		28 26N	099 15W	0141	01 50 - 12 54	STAR	SA	T50893
DALLAS	LOVE FIELD WBAS	TX	13960	72258	32 51N	096 51W	0159	01 60 - 12 64	STAR	SA	T13080
DALLAS	LOVE FIELD WBAS	TX	13960	72258	32 51N	096 51W	0158	01 67 - 12 71	STAR	MA	T14181
DALLAS	LOVE FIELD WBAS	TX	13960	72258	32 51N	096 51W	0158	05 72 - 04 73	STAR	A	T14468
DALLAS	LOVE FIELD WBAS	TX	13960	72258	32 51N	096 51W	0158	05 72 - 12 72	STAR	A	T01772
DEL RIO	LAUGHLIN AFB	TX	22001	72261	29 22N	100 47W	0327	01 65 - 12 68	STAR	SA	T12781
EL PASO	INTERNATIONAL ART WBAS	TX	23044	72270	31 48N	106 24W	1200	01 60 - 12 64	STAR	SA	T14482
EL PASO	INTERNATIONAL ART WBAS	TX	23044	72270	31 48N	106 24W	1198	01 72 - 12 72	STAR	SA	T01772
FORT WORTH	GREATER SW INL ART WBAS	TX	03927	72259	32 50N	097 03W	0175	01 57 - 12 71	STAR	MA	T52415
FORT WORTH	GREATER SW INL ART WBAS	TX	03927	72259	32 50N	097 03W	0175	01 67 - 12 71	STAR	SA	T14024
FORT WORTH	GREATER SW INL ART WBAS	TX	03927	72259	32 50N	097 03W	0175	09 72 - 04 74	STAR	MA	T52415
FORT WORTH	MEACHAM FLD WBAS	TX	13961		32 46N	097 21W	0219	01 48 - 12 52	STAR	SA	T52393,3
GALVESTON	SCHOLES FIELD WBAS	TX	12833	72242	29 18N	094 51W	0008	01 58 - 12 60	STAR	SA	T14432
GALVESTON	SCHOLES FIELD WBAS	TX	12833	72242	29 16N	094 51W	0008	01 58 - 12 62	STAR	A	T14356
HOUSTON	ELLINGTON AFB	TX	12906		29 37N	095 10W	0012	01 68 - 12 70	STAR	MA	T50955,3
HOUSTON	ELLINGTON AFB	TX	12906		29 37N	095 10W	0012	01 68 - 12 69	STAR	SA	T12243
HOUSTON	HOBBY INL ART WBAS	TX	12918	72243	29 38N	095 17W	0016	01 64 - 12 68	STAR	SA	T13874
HOUSTON	HOBBY INL ART WBAS	TX	12918	72243	29 38N	095 17W	0016	01 68 - 12 67	STAR	SA	T13429
HOUSTON	INTERCONTINENTAL ART WBAS	TX	12960	72243	29 58N	095 22W	0033	08 68 - 12 71	STAR	MA	T14181
HOUSTON	INTERCONTINENTAL ART WBAS	TX	12960	72243	29 58N	095 22W	0033	08 68 - 07 72	STAR	A	T14568
HOUSTON	INTERCONTINENTAL ART WBAS	TX	12960	72243	29 58N	095 22W	0033	08 68 - 12 71	STAR	SA	T13813
HOUSTON	INTERCONTINENTAL ART WBAS	TX	12960	72243	29 58N	095 22W	0033	09 71 - 12 73	STAR	TYP	T50174
HOUSTON	INTERCONTINENTAL ART WBAS	TX	12960	72243	29 58N	095 22W	0033	08 72 - 12 73	STAR	A	T01772
HOUSTON	INTERCONTINENTAL ART WBAS	TX	12960	72243	29 58N	095 22W	0033	08 72 - 07 73	STAR	A	T14568
LAREDO	AFB	TX	12907	72253	27 32N	099 28W	0154	04 65 - 05 70	STAR	SA	T12781
LUFKIN	ANGELINA COUNTY ART FIS	TX	03987		31 14N	094 45W	0089	01 67 - 12 71	STAR	MA	T14443
MIDLAND	MID-ODESSA RGL ATL WBAS	TX	23023	72265	31 56N	102 12W	0875	01 60 - 12 64	STAR	SA	T13931
MIDLAND	MID-ODESSA RGL ATL WBAS	TX	23023	72265	31 56N	102 12W	0874	01 71 - 12 71	STAR	MA	T01772
PORT ARTHUR	JEFFERSON COUNTY ART WBAS	TX	12917	72241	29 57N	094 01W	0008	01 67 - 12 71	STAR	SA	T01772,141
SAN ANGELO	MATHIS FIELD WBAS	TX	23034	72263	31 22N	100 30W	0569	01 60 - 12 64	STAR	SA	T13931
SAN ANTONIO	INTERNATIONAL ART WBAS	TX	12921	72253	29 32N	098 28W	0243	01 60 - 12 64	STAR	SA	T13931
TYLER	POUNDS FIELD CAA	TX	13972		32 22N	095 24W	0173	01 50 - 12 54	STAR	SA	T51272
VICTORIA	FOSTER AFB	TX	12912	72255	28 51N	096 55W	0031	01 65 - 12 74	STAR	SA	T52254
WACO	MUNICIPAL ART WBAS	TX	13960	72256	31 37N	097 13W	0159	01 68 - 12 73	STAR	MA	T51101
BRYCE CANYON	CAA	UT	23198		37 42N	112 09W	2317	01 48 - 12 54	STAR	SA	T13028
DELTA	MUNICIPAL ART CAA	UT	23163	72479	39 23N	112 31W	1452	01 50 - 12 54	STAR	SA	T12781
HANKSVILLE	CAA	UT	23170	72473	38 25N	110 42W	1380	01 48 - 12 54	STAR	SA	T13028
MILFORD	MUNICIPAL ART CAA	UT	23176	72475	38 25N	113 01W	1934	07 47 - 12 51	STAR	MA	T51121
OGDEN	HILL AFB	UT	24101	72575	41 07N	111 58W	1459	01 65 - 12 68	STAR	SA	T12908
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1296	01 48 - 12 48	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1296	01 48 - 12 48	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1296	01 50 - 12 50	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1296	01 51 - 12 51	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1296	01 52 - 12 52	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1296	01 53 - 12 53	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1287	01 54 - 12 54	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1287	01 55 - 12 55	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1287	01 56 - 12 56	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1287	01 57 - 12 57	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1287	01 58 - 12 58	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1287	01 59 - 12 59	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1287	01 60 - 12 60	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1287	01 61 - 12 61	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1287	01 62 - 12 62	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1287	01 63 - 12 63	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1287	01 64 - 12 64	STAR	A	T13658
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1287	01 68 - 12 70	STAR	SA	T12745
SALT LAKE CITY	INTERNATIONAL ART WBAS	UT	24127	72572	40 46N	111 58W	1287	01 70 - 12 72	STAR	SA	T01772
BURLINGTON	INTERNATIONAL ART WBAS	VT	14742	72617	44 28N	073 09W	0108	01 65 - 12 68	STAR	MA	T12178
BURLINGTON	INTERNATIONAL ART WBAS	VT	14742	72617	44 28N	073 09W	0104	01 70 - 12 74	STAR	SA	T52031,3
BURLINGTON	INTERNATIONAL ART WBAS	VT	14742	72617	44 28N	073 09W	0104	01 70 - 12 74	STAR	SA	T15370
DANVILLE	MUNICIPAL ART CAA	VA	13728		36 34N	079 20W	0180	01 50 - 12 54	STAR	MA	T50870
DANVILLE	CAA	VA	13733		36 04N	079 09W	0135	01 58 - 12 60	STAR	MA	T50870
LYNCHBURG	MUNICIPAL ART WBAS	VA	13733	72410	37 20N	079 12W	0298	01 58 - 12 73	STAR	SA	T50447
NORFOLK	REGIONAL ART WBAS	VA	13737	72308	36 54N	076 12W	0013	01 55 - 12 64	STAR	SA	T14008
NORFOLK	REGIONAL ART WBAS	VA	13737	72308	36 54N	076 12W	0013	01 73 - 12 73	STAR	SA	T11703
NORFOLK	NAS	VA	13790		36 57N	076 17W	001C	12 68 - 12 71	STAR	SA	T13589
PULASKI	NEW RIVER ART CAA	VA	13868		37 05N	080 47W	0688	01 50 - 12 54	STAR	SA	T51095
QUANTICO	MCAS	VA	13773		38 30N	077 18W	0004	01 65 - 12 68	STAR	MSA	T14427
QUANTICO	MCAS	VA	13773		38 30N	077 18W	0004	09 72 - 05 73	STAR	MA	T13590

SUMMARY TYPE: STAR

CITY	NAME - TYPE	ST	WBAN #	WMO #	LAT	LONG	ELEV	PERIOD OF RECORD	SUMMARY TYPE	SUM FREQ	TAPE/PC-PAKS
RICHMOND	BYRD FIELD WBAS	VA	13740	72401	37 30N	077 20W	0054	01 64 - 12 73	STAR	SA	T50833
RICHMOND	BYRD FIELD WBAS	VA	13740	72401	37 30N	077 20W	0055	01 71 - 12 71	STAR	MM	T01772
RICHMOND	BYRD FIELD WBAS	VA	13740	72401	37 30N	077 20W	0055	01 72 - 12 72	STAR	MM	T14228
RICHMOND	BYRD FIELD WBAS	VA	13740	72401	37 30N	077 20W	0054	01 74 - 12 74	STAR	A	T52083.3
ROANOKE	WOODRUM FIELD TRB WBAS	VA	13741	72411	37 19N	079 58W	0364	01 68 - 12 72	STAR	MM	T14656
WALLOPS ISLAND	WBO	VA	93739	72402	37 51N	075 29W	0004	01 67 - 12 72	STAR	MM	T14630
WALLOPS ISLAND	WBO	VA	93739	72402	37 51N	075 29W	0004	01 68 - 12 73	STAR	MM	T50495.3
BELLINGHAM	MUNICIPAL ART CAA	WA	24217		48 48N	122 32W	0047	01 48 - 12 58	STAR	MM	T50891
BELLINGHAM	MUNICIPAL ART CAA	WA	24217		48 48N	122 32W	0048	01 58 - 12 58	STAR	MM	T14112
OMLLESPORT		WA	24218		46 37N	121 09W	0073	01 64 - 12 64	STAR	SA	T52308
ELLENSBURG	CAA	WA	24220		47 02N	120 31W	0527	01 50 - 12 54	STAR	A	T14478
EDMONDS	MUNICIPAL ART CAA	WA	24141		47 18N	119 32W	0387	01 50 - 12 54	STAR	A	T14478
EVERETT	PAINE FIELD AFB	WA	24203		47 54N	122 17W	0182	01 83 - 12 87	STAR	A	T14478
MOSQUIAM	BOWERMAN ART CAA	WA	94225		46 58N	123 56W	0008	01 54 - 12 58	STAR	A	T14478
MOSES LAKE	LARSON AFB	WA	24110		47 11N	119 20W	0361	01 81 - 12 89	STAR	A	T14478
OLYMPIA	WBAS	WA	24227	72793	46 58N	122 54W	0066	01 60 - 12 64	STAR	A	T14478
PORT ANGELES	WBAS	WA	24228	74301	48 08N	123 24W	0005	01 48 - 12 53	STAR	MM	T14411
SEATTLE	SEA-TAC INL ART WBAS	WA	24233	72793	47 27N	122 18W	0137	01 48 - 12 53	STAR	SA	T14411
SEATTLE	SEA-TAC INL ART WBAS	WA	24233	72793	47 27N	122 18W	0137	01 67 - 12 71	STAR	MM	T11170
SEATTLE	BOEING FIELD TRB WBAS	WA	24234		47 32N	122 18W	0010	01 60 - 12 64	STAR	A	T14478
SPOKANE	GEIGER FIELD INL ART WBAS	WA	24157	72785	47 38N	117 32W	0721	01 67 - 12 71	STAR	SA	T10365
TACOMA	MCCHORD AFB	WA	24267	74205	47 09N	122 28W	0088	01 68 - 12 70	STAR	MM	T14411
TOLEDO	WINLOCK ART CAA	WA	24241		46 26N	122 48W	0108	01 50 - 12 54	STAR	A	T14478
WALLA WALLA	CITY-COUNTY ART CAA	WA	24160		46 06N	118 17W	0383	01 50 - 12 54	STAR	A	T14478
WHIDBEY ISLAND	NAS	WA	24238		48 21N	122 40W	0010	01 67 - 12 71	STAR	MM	T14411
YAKIMA	MUNICIPAL ART WBAS	WA	24243	72781	46 34N	120 32W	0324	01 60 - 12 64	STAR	A	T14478
CHARLESTON	KANAWHA ART WBAS	WV	13866	72414	38 22N	081 36W	0301	01 58 - 12 73	STAR	MM	T50556.3
HUNTINGTON	TRI-STATE ART WBAS	WV	03860	72425	38 22N	082 33W	0258	01 67 - 12 71	STAR	SA	T13828
HUNTINGTON	TRI-STATE ART WBAS	WV	03860	72425	38 22N	082 33W	0258	01 70 - 12 74	STAR	SA	T15879.3
HUNTINGTON	TRI-STATE ART WBAS	WV	03860	72425	38 22N	082 33W	0258	01 74 - 12 74	STAR	SA	T19879.3
HUNTINGTON	TRI-STATE ART WBAS	WV	03860	72425	38 22N	082 33W	0258	01 75 - 12 75	STAR	SA	T52408.3
HUNTINGTON	CHESAPEAKE ART CAA	WV	03818	72435	38 25N	082 30W	0173	01 50 - 12 54	STAR	SA	T11898
MARTINSBURG	MUNICIPAL ART CAA	WV	13734		39 24N	077 58W	0186	01 60 - 12 64	STAR	MM	T50833
MORGANTOWN	MUNICIPAL ART CAA	WV	13736		39 38N	079 55W	0380	01 50 - 12 54	STAR	A	T50886
PARKERSBURG	WBO	WV	13867		39 16N	081 34W	0209	01 50 - 12 54	STAR	SA	T13824
EAU CLAIRE	MUNICIPAL ART FSS	WI	14991		44 52N	091 29W	0273	01 68 - 12 73	STAR	SA	T50648
GREEN BAY	AUSTIN STRAUBEL ART WBAS	WI	14898	72645	44 29N	088 08W	0212	01 64 - 12 73	STAR	SA	T15137
GREEN BAY	AUSTIN STRAUBEL ART WBAS	WI	14898	72645	44 29N	088 08W	0212	01 67 - 12 71	STAR	SA	T14008
GREEN BAY	AUSTIN STRAUBEL ART WBAS	WI	14898	72645	44 29N	088 08W	0212	01 68 - 12 73	STAR	SA	T50648
GREEN BAY	AUSTIN STRAUBEL ART WBAS	WI	14898	72645	44 29N	088 08W	0212	01 73 - 12 73	STAR	SA	T15137
LA CROSSE	MUNICIPAL ART WBAS	WI	14920	72645	43 52N	091 15W	0201	01 48 - 12 53	STAR	SA	T01772
LA CROSSE	MUNICIPAL ART WBAS	WI	14920	72645	43 52N	091 15W	0201	01 67 - 12 71	STAR	SA	T14008
MADISON	TRUAX FIELD WBAS	WI	14837	72641	43 08N	089 20W	0269	01 64 - 12 73	STAR	SA	T15137
MADISON	TRUAX FIELD WBAS	WI	14837	72641	43 08N	089 20W	0269	01 67 - 12 71	STAR	SA	T13396
MADISON	TRUAX FIELD WBAS	WI	14837	72641	43 08N	089 20W	0269	01 71 - 12 71	STAR	SA	T01772
MADISON	TRUAX FIELD WBAS	WI	14837	72641	43 08N	089 20W	0263	01 73 - 12 73	STAR	SA	T15137
MILWAUKEE	MITCHELL FIELD WBAS	WI	14839	72640	42 57N	087 54W	0219	01 60 - 12 64	STAR	MM	T50259
MILWAUKEE	MITCHELL FIELD WBAS	WI	14839	72640	42 57N	087 54W	0215	01 60 - 12 64	STAR	SA	T50885
MILWAUKEE	MITCHELL FIELD WBAS	WI	14839	72640	42 57N	087 54W	0215	01 64 - 12 73	STAR	SA	T15137
MILWAUKEE	MITCHELL FIELD WBAS	WI	14839	72640	42 57N	087 54W	0215	01 68 - 12 70	STAR	SA	T13174
MILWAUKEE	MITCHELL FIELD WBAS	WI	14839	72640	42 57N	087 54W	0211	01 67 - 12 71	STAR	SA	T14008
MILWAUKEE	MITCHELL FIELD WBAS	WI	14839	72640	42 57N	087 54W	0211	01 68 - 12 72	STAR	MM	T14482
MILWAUKEE	MITCHELL FIELD WBAS	WI	14839	72640	42 57N	087 54W	0211	01 70 - 07 70	STAR	A	T11873
MILWAUKEE	MITCHELL FIELD WBAS	WI	14839	72640	42 57N	087 54W	0209	01 73 - 12 73	STAR	SA	T15137
MILWAUKEE	MITCHELL FIELD WBAS	WI	14839	72640	42 57N	087 54W	0209	07 73 - 08 74	STAR	SA	T50875
MILWAUKEE	MITCHELL FIELD WBAS	WI	14839	72640	42 57N	087 54W	0209	01 74 - 12 74	STAR	A	T52042
MILWAUKEE	L J TIMMERMAN ART FAA	WI	94868		43 07N	088 02W	0227	01 68 - 12 72	STAR	MM	T14837
CASPER	AIR TERMINAL WBAS	WY	24089	72568	42 55N	106 28W	1422	01 68 - 12 75	STAR	SA	T52227.3
CASPER	AIR TERMINAL WBAS	WY	24089	72568	42 55N	106 28W	1422	01 67 - 12 71	STAR	MM	T14229
CASPER	AIR TERMINAL WBAS	WY	24089	72568	42 55N	106 28W	1422	01 67 - 12 71	STAR	MM	T50863.3
CHEYENNE	MUNICIPAL ART WBAS	WY	24018	72564	41 09N	104 48W	1871	01 60 - 12 64	STAR	MM	T50313
CHEYENNE	MUNICIPAL ART WBAS	WY	24018	72564	41 09N	104 48W	1871	01 67 - 12 71	STAR	MM	T50863.3
CHEYENNE	MUNICIPAL ART WBAS	WY	24018	72564	41 09N	104 48W	1871	01 67 - 12 71	STAR	MSA	T14318
CHEYENNE	MUNICIPAL ART WBAS	WY	24018	72564	41 09N	104 48W	1871	01 74 - 12 74	STAR	A	T51847.3
LANDER	HUNT ART WBAS	WY	24021	72578	42 49N	108 44W	1868	01 70 - 12 74	STAR	A	T51819.3
MOORCROFT		WY	24089	72563	44 16N	104 57W	1305	01 50 - 07 52	STAR	MM	T14335
ROCK SPRINGS	MUNICIPAL ART WBAS	WY	24027	72574	41 35N	109 04W	2056	01 60 - 12 64	STAR	SA	T14283
ROCK SPRINGS	MUNICIPAL ART WBAS	WY	24027	72574	41 35N	109 04W	2056	01 67 - 12 71	STAR	SA	T01772
ROCK SPRINGS	MUNICIPAL ART WBAS	WY	24027	72574	41 35N	109 04W	2057	01 71 - 12 75	STAR	SA	T52211.3
SHERIDAN	SHERIDAN CAA WBAS	WY	24028	72686	44 46N	106 58W	1202	01 48 - 12 53	STAR	SA	T14135

APPENDIX D

CHEMICAL PROFILES

Acetaldehyde 121
Acrolein 133
Acrylonitrile 144
Allyl chloride 157
Arsenic 161
Asbestos 168
Benzene 180
Benzyl chloride 189
Beryllium 195
Cadmium 208
Carbon tetrachloride 217
Chlorobenzene 225
Chloroform 235
Chloroprene 245
Chromium 249
Dioxin 255
Epichlorohydrin 262
Methyl chloroform 270
Nickel 274
Nitrobenzene 280
Nitrosomorpholine 285
Polychlorinated biphenyls 288
Toluene 295
Trichloroethylene 306
Vinyl chloride 316
Vinylidene chloride 323

Chemical Name

Acetaldehyde

CAS Number

75-07-0

Chemical Classification

Aldehyde

Synonyms

Acetic aldehyde, aldehyde, ethanol, ethyl aldehyde

Physical/Chemical Properties

Description:
1. Colorless liquid or gas with irritant, fruity taste
2. Exceedingly volatile (flashes back)
3. Readily oxidized in air, forming explosive peroxides

Boiling point:
20.2° C

Melting point:
-123.5° C

Molecular weight:
44.05

Chemical formula:
C_2H_4O

Vapor pressure:
740.0 mm Hg (20° C)

Refractive index:
$n_D^{20} = 1.33113$

Log partition coefficient (Octanol/H_2O):
0.43

Solubility:
Infinitely soluble in hot H_2O; freely soluble in water, alcohol, ether, benzene, gasoline, solvent naphtha, toluene, xylene, turpentine, oil and acetone

Photochemical reactivity:
Effective ambient air decay rate: 7.3×10^{-5} s^{-1} (daytime)
No reaction toward O_3

Atmospheric reactivity:
Transformation products: peroxyacetyl nitrate; formaldehyde

Reactivity toward OH: 4x butane

Reactivity toward photolysis: 0.5x formaldehyde

Major atmospheric precursors: hydrocarbons (C_3+)

Formation reactivity: equilibrium concentration 5% NMHC

Density:
0.7834 at 18° C/4° C

Chemical reactivity:
Highly reactive; exhibits general reactions of aldehydes

Sources of Emissions

Production/processing:
1. Oxidation of ethylene
2. Vapor phase oxidation and dehydration of ethanol or of propane and butane
3. Direct conversion of ethylene

Uses:
1. Chemical intermediate, especially for manufacture of acetic acid and peracetic acid
2. Used in manufacture of synthetic resins, pesticides, and pharmaceuticals
3. Used to make rubber processing chemicals
4. Used in coating operations in manufacturing of mirrors
5. Hardening agent in photography
6. Used in manufacturing of gelatin, glues, casein products
7. Used as preservative in food products and leather

Tables D-1 through D-6 and Figure D-1 graphically present acetaldehyde production, consumption, and emission data

TABLE D-1. ACETALDEHYDE PRODUCERS

Company	Location	1978 Capacity (10^6 lb/yr)	1978 Production (10^6 lb/yr)	Geographical Location Latitude/Longitude
Celanese	Bay City, TX	300	204	28 51 45/96 01 00
	Clear Lake, TX	600	408	29 37 17/95 03 51
Texas Eastman	Longview, TX	500	340	32 25 55/94 41 06
Publicker Industries	Philadelphia, PA	65	44	39 53 30/75 12 18
Shell Chemical	Norco, LA	5	4	30 00 11/90 23 42
Total		1470	1000	

Total production distributed over individual sites based on site capacity compared to total industry capacity.

Source: Systems Applications, Inc. 1980

TABLE D-2. 1978 ACETALDEHYDE END-USE DISTRIBUTION

End Use	Usage (%)	Acetaldehyde Use (million lb/yr)
Acetic acid	69	690
Peracetic acid	10	100
Pentaerythritol	8	80
Pyridenes	4	40
Glyoxal	4	40
1,3-Butylene glycol	2	20
Miscellaneous	3	30
Total	100	1000

Source: Systems Applications, Inc. 1980

TABLE D-3. ACETALDEHYDE EMISSIONS FROM PRODUCTION SITES

Company	Location	Emissions (lb/yr)			Total Emissions[a]	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)[b]
Celanese	Bay City, TX	46,510	5,915	2,650	55,080	0.79
	Clear Lake, TX	93,025	11,830	5,305	110,160	1.59
Tennessee Eastman	Longview, TX	77,520	9,860	4,420	91,800	1.32
Publicker Industries	Philadelphia, PA	10,030	1,275	570	11,880	0.17
Shell Chemical	Norco, LA	910	115	50	1,080	0.02
Total		228,000	29,000	13,000	270,000	

[a]Based on the following emission factors (lb acetaldehyde emitted per lb produced).

Process	0.000228	B - (derived from state air emission files)
Storage	0.000029	B - (derived from state air emission files)
Fugitive	0.000013	B - (derived from state air emission files)
Total	0.000270	

[b]Based on 8760 hr/yr operation.

Source: Systems Applications, Inc. 1980

TABLE D-4. 1978 ACETALDEHYDE NATIONWIDE EMISSIONS

Source	Nationwide Emissions (lb/yr)
Production	270,000
Acetic acid	2,801,550
Peracetic acid	450,000
Pentaerythritol	688,000
Pyridenes	300,000
Glyoxal	180,000
1,3-Butylene glycol	27,000
Miscellaneous*	137,400
Total	4,853,950

*Based on a weighted average of emission factors for other user categories. Factor: 0.00458 lb lost/lb used.

Source: Systems Applications, Inc. 1980

TABLE D-5. ACETALDEHYDE EMISSIONS FROM END-USERS

Company	Location	End-Use	Emissions (lb/yr)			Total Emissions	
			Process	Storage	Fugitive	(lb/yr)	(g/sec)
Celanese	Bay City, TX	Acetic acid	180,880	22,440	10,200	213,520	3.07
	Clear Lake, TX	Acetic acid	992,180	123,090	55,950	1,171,220	16.86
Eastman	Kingsport, TN	Acetic acid	1,197,690	151,890	67,230	1,416,810	20.40
FMC	Buffalo, NY	Peracetic acid	135,000	7,330	7,670	150,000	2.16
High Point	High Point, NC	Peracetic acid	135,000	7,330	7,670	150,000	2.16
Union Carbide	Taft, LA	Peracetic acid	135,000	7,330	7,670	150,000	2.16
Celanese	Bishop, TX	Pentaerythritol	241,230	29,040	13,530	283,800	4.09
Hercules	Louisiana, MO	Pentaerythritol	151,510	18,480	8,610	180,600	2.60
IMC	Seiple, PA	Pentaerythritol	80,410	9,680	4,510	94,600	1.36
Perstorp	Toledo, OH	Pentaerythritol	109,650	13,200	6,150	129,000	1.86
Hepara	Harriman, NY	Pyridenes	108,460	10,880	8,160	127,500	1.84
Reilly	Indianapolis, IN	Pyridenes	146,740	14,720	11,040	172,500	2.48
American Cyanamide	Charlotte, NC	Glyoxal	81,000	4,400	4,600	90,000	1.30
Union Carbide	Taft, LA	Glyoxal	81,000	4,400	4,600	90,000	1.30
Celanese	Bishop, TX	1,3-Butylene glycol	8,135	0	865	9,000	0.13
Eastman	Rochester, NY	1,3-Butylene glycol	8,135	0	865	9,000	0.13
Hallinckrodt	Lodi, NJ	1,3-Butylene glycol	8,135	0	865	9,000	0.13
Total			3,802,155	424,210	220,185	4,446,550	

Source: Systems Applications, Inc. 1980

TABLE D-6. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF ACETALDEHYDE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	CELANESE	BAY CITY, TX	28 51 45	96 01 00	12923	1	1	.669744	.083176	.038160
							2	2.604672	.323136	.146880
2	CELANESE	CLEAR LAKE, TX	29 37 17	95 03 51	12906	1	1	1.339560	.170352	.076992
							2	14.207892	1.772496	.805680
3	EASTMAN KODAK	LONGVIEW, TX	32 25 53	94 41 06	13972	2	1	1.116300	.141984	.063640
4	PUBLICKER	PHILADELPHIA, PA	39 53 30	75 12 10	13739	2	1	.144432	.018360	.000200
5	SHELL	NORCO,LA	30 00 11	90 23 42	12958	2	1	.013104	.001656	.000720
6	EASTMAN KODAK	KINGSPORT, TN	36 31 41	82 12 22	13877	3	2	17.246736	2.107216	.960112
7	FMC	BUFFALO, NY	42 59 10	78 50 30	14747	4	3	1.944000	.105552	.110448
8	HIGHPOINT	HIGH POINT, NC	35 59 10	80 00 37	93007	4	3	1.944000	.105552	.110448
9	UNION CARBIDE	TAFT, LA	27 58 00	97 27 00	13970	5	3	1.944000	.105552	.110448
							6	1.166400	.063360	.066240
10	CELANESE	BISHOP, TX	27 34 06	97 49 27	12925	6	4	3.473712	.418176	.194032
							7	.117144	0.	.012456
11	HERCULES	LOUISIANA, MO	39 26 24	91 03 37	93909	7	4	2.210544	.266112	.123984
12	INC	SEIPLE, PA	40 30 21	75 31 30	14737	7	4	1.157904	.139392	.064944
13	PENSTORP	TOLEDO, OH	41 43 10	83 31 20	94830	7	4	1.578960	.190080	.088560
14	REPAPA	HARRIMAN, NY	41 16 40	74 08 24	14757	8	5	1.561824	.155520	.117504
15	REILLY TAR	INDIANAPOLIS, IN	39 42 00	86 14 00	93819	8	5	2.113056	.211968	.158976
16	AMER CYANAMID	CHARLOTTE,NC	33 12 16	80 50 32	13881	9	6	1.166400	.063360	.066240
17	EASTMAN KODAK	ROCHESTER, NY	43 12 01	77 37 56	14717	10	7	.117144	0.	.012456
18	MALLINCKRODT	LODI, NJ	40 52 56	74 05 46	94741	10	7	.117144	0.	.012456

Source: Systems Applications, Inc. 1980

KEY TO TABLE D-6

* Plant Types:	† Source Types:
Type 1: Plant produces acetaldehyde and acetic acid	Type 1: Acetaldehyde production
Type 2: Plant produces acetaldehyde	Type 2: Acetic acid production
Type 3: Plant produces acetic acid	Type 3: Peracetic acid production
Type 4: Plant produces peracetic acid	Type 4: Pentaerythritol production
Type 5: Plant produces peracetic acid and glyoxal	Type 5: Pyridenes production
Type 6: Plant produces pentaerythritol and 1,3-butylene glycol	Type 6: Glyoxal production
Type 7: Plant produces pentaerythritol	Type 7: 1,3-bytylene glycol
Type 8: Plant produces pyridenes	
Type 9: Plant produces glyoxal	
Type 10: Plant produces 1,3-butylene glycol	

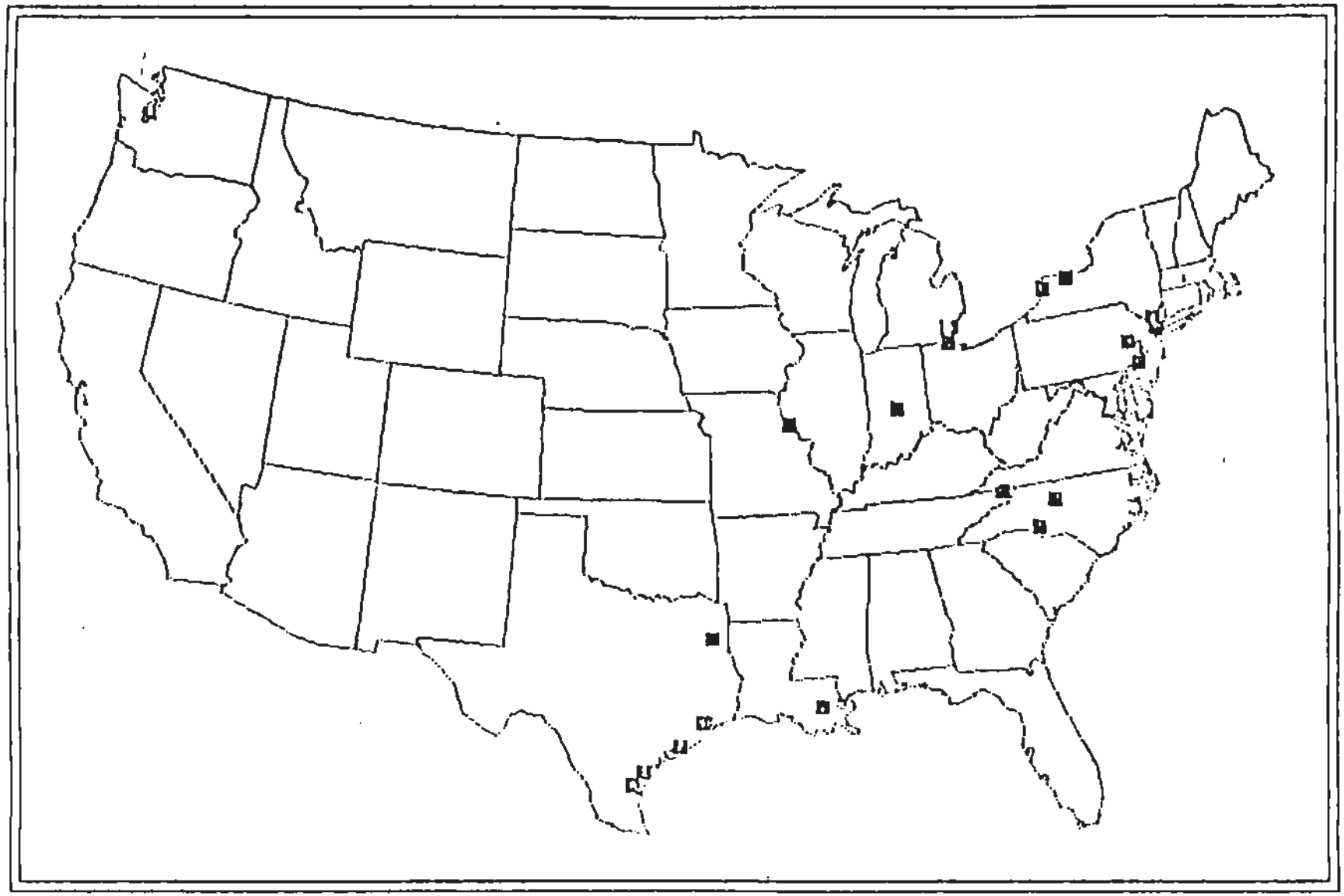

Figure D-1. Specific point sources of acetaldehyde emissions.

Source: Systems Applications, Inc. 1980

Storage:

Bulk storage outside in detached tanks provided with refrigeration and inert gas blanket
Small container storage in detached noncombustible building
Inside storage in standard flammable liquids storage room or cabinet

Transportation:

Shipped in 1-quart glass pressure bottles, 5- to 55-gallon metal drums, insulated tank cars and trucks, tank barges

Disposition:

Liquid acetaldehyde may be disposed of by atomizing it in a suitable combustion chamber

Materials damage:

Liquid acetaldehyde will attack some forms of plastics, rubbers, and coatings

Sampling and Analytical Methods

(Compound very unstable. Requires immediate analysis or derivation.)

1. NIOSH Method S345
   a. Bubbler collection
   b. Derivative from Girard T. reagent
   c. HPLC

   Detection limit:
   170-670 mg/m^3 at STP with 60 l sample

   Possible interferences:
   Other volatile aldehydes

2. Tentative method of analysis for low molecular weight aliphatic aldehydes in the atmosphere (Method K, Appendix A)
   a. Collect in 1% $NaHSO_3$ solution in midget impingers
   b. C_2-C_5 aldehydes measured by gas chromatographic/flame ionization procedures

   Detection limits:
   0.02 ppm at sampling rates of 2 l/min over a 1-hr period

3. Method J from Appendix A

a. Collection in dinitrophenyl hydrazine (DNPH)
b. Solvent extraction
c. Reversed phase HPLC analysis

Detection limits:
1-5 ppb for a 40 l sample

Possible interferences:
Reagents must be carefully prepared to avoid significant contamination

Material Damage

Liquid acetaldehyde will attack some forms of plastics, rubbers, and coatings

Permissible Exposure Limits

	OSHA	ACGIH
TWA	200 ppm (360 mg/m^3)	100 ppm (180 mg/m^3)
Ceiling		150 ppm (270 mg/m^3)
TLV (odor)		2.3 ppm

Human Toxicity

Acute toxicity:
TC_{LO} by inhalation is 134 ppm; produces narcosis in humans

Chronic toxicity

Mutagenicity--Mutagenesis/genetic toxicity testing ongoing in FY83 (U.S. DHHS 1983)

Other chronic toxicity:
Biochemical/cellular/tissue effects, pharmacokinetics/ metabolism effects, and systemic/organ toxicity testing ongoing in FY83 (U.S. DHHS 1983)

Acetaldehyde is an eye, nose, and throat irritant and can cause skin burns and dermatitis

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Chemical Name

Acrolein

CAS Number

107-02-8

Chemical Classification

Aldehyde (unsaturated)

Synonyms

Acraldehyde, acrylic aldehyde, allyl aldehyde, 2-propenal, ethylene aldehyde, acrylaldehyde

Physical/Chemical Properties

Description:
Colorless to yellowish, watery, volatile liquid; powerful lacrimator

Boiling point:
52.5° C

Melting point:
-86.95° C

Molecular weight:
56.06

Chemical formula:
C_3H_4O

Vapor pressure:
288.2 mm Hg at 25° C
215 mm Hg 20° C

Refractive index:
$n_D^{20} = 1.4013$

Solubility:
Very soluble in water (200 g/l at 20° C) and many organic liquids

Photochemical reactivity:
Effective ambient air decay rate: 1.6×10^{-4} s^{-1} (daytime)
5.0×10^{-6} s^{-1} (nighttime)

Reactivity toward: OH is 0.5x butane
O_3 is 0.5x propylene
photolysis is 5x formaldehyde

Vapor density:
1.94 (air = 1)

Density:
0.84 g/cm^3 at 20° C/4° C

Chemical reactivity:
Extremely reactive with oxidizing materials; can be stored only in the presence of stabilizers (0.1% hydroquinone); atmospheric oxygen, alkalies, mineral acids and peroxides can trigger violent polymerization reactions

Environmental Fate

Total release rate of acrolein to the environment is not known. Fugitive acrolein emissions come from industrial processes, and acrolein is formed in the environment by burning tobacco, forest fires, and by heating fats or glycerine

Sources of Emissions

Production:
1. Pre-1959: vapor phase concentration of acetaldehyde and formaldehyde
2. Post-1959: direct catalytic vapor phase oxidation of propylene (or allyl alcohol)
3. Heat glycerol with magnesium sulfate
4. Synthesized from propylene with bismuth-phosphorous-molybdenum catalyst

Uses:
1. Unisolated acrolein is an intermediate in the production of acrylic acid and its derivatives
2. Refined, or isolated acrolein end-uses:
   a. Production of synthetic glycerin
   b. Methionine and methionine hydroxy manufacture (poultry feed supplements)

c. Used as fungicide to prevent slime (especially in paper industry)
d. Denaturant in alcohol
e. Tissue fixative
f. Used in leather tanning
g. Aquatic herbicide and to control growth of microbes in feed lines of wastewater treatment and in liquid fuels
h. Used to make tear gas

3. Present in:
a. Smog
b. Fuel combustion products
c. Woodfire smoke
d. Cigarette smoke

Tables D-7 through D-11 and Figure D-2 graphically present acrolein production, consumption, and emission data

Storage:

Uninhibited acrolein is not to be stored under any circumstances. Outside or detached storage preferable. Inside storage in a standard flammable liquids storage room or cabinet. No alkaline or oxidizing materials are to be stored with acrolein

Disposition:

Acrolein wastes occur in both manufacturing and processing plants

Nonreusable acrolein is contained in waste gases and process water from synthesis plants or occurs in the form of defective batches and superposed reserves

Aqueous wastes with low concentrations of acrolein are usually neutralized with sodium hydroxide and fed to a sewage treatment plant for biological secondary treatment

Concentrated wastes are reprocessed whenever possible or burned in special waste incinerators

Sampling and Analytical Methods

1. NIOSH Method P&CAM 118, "Acrolein in Air"
a. Collection in midget impingers containing the absorbing solution or reagent

TABLE D-7. PRODUCTION OF ALLYL CHLORIDE, EPICHLOROHYDRIN, AND ACROLEIN

Source	Location	1978 Estimated Production (M lb)			1978 Estimated Capacity (M lb)		
		Allyl Chloride	Epichlorohydrin	Acrolein	Allyl Chloride	Epichlorohydrin	Acrolein
Dow Chemical Co.	Freeport, TX	176	166		265	250	
Shell Chemical Co.	Deer Park, TX	77	73		117	110	
Shell Chemical Co.	Norco, LA	77	73	24	117	110	55
Union Carbide Corp.	Taft, La			22			40
Celanese Corp.	Clear Lake, TX			89			147
Rohm and Haas Co.	Deer Park, TX			146			273
Union Carbide Corp.	Taft, LA			73			137
Total		330	312	354	499	470	692

Source: Systems Applications, Inc. 1980

TABLE D-8. 1978 ACROLEIN PRODUCTION EMISSIONS

Company	Location	Process Emissions (lb/yr)	Storage Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions (lb/yr)	Total Emissions (g/sec)[a]
Shell	Norco, LA	26,400	0	2,640	29,040[b]	0.416
Union Carbide	Taft, LA	24,200	0	2,420	26,620[b]	0.383
Celanese	Clear Lake, TX	5,530	0	445	5,965[c]	0.086
Rohm and Haas	Deer Park, TX	9,050	0	730	9,780[c]	0.141
Union Carbide	Taft, LA	4,530	0	365	4,895[c]	0.071
Total		69,700	0	6,600	76,300	

[a]Based on 8760 hr/yr operation.

[b]Isolated acrolein emission factor (lb lost per lb produced).

Process	0.00110	A - Derived from site visit data
Storage	0	A - Derived from site visit data
Fugitive	0.00011	A - Derived from site visit data
Total	0.00121	

[c]Unisolated acrolein emission factor (lb lost per lb acrolein produced).

Process	0.000062	A - Derived from site visit data
Storage	0	A - Derived from site visit data
Fugitive	0.000005	A - Derived from site visit data
Total	0.000067	

Source: Systems Applications, Inc. 1980

TABLE D-9. 1978 ESTIMATED ACROLEIN NATIONWIDE EMISSION LOSSES

Source	Estimated National Emissions (lb/yr)
Production	
Acrylic acid intermediate	20,640
Refined acrolein and glycerin	55,660
Chemical intermediate*	
Methionine	24,200
Miscellaneous	2,420
Total	102,920

*Based on emission factor of 0.00121 determined for isolated acrolein production.

Source: Systems Applications, Inc. 1980

TABLE D-10. 1978 ACROLEIN CONSUMPTION BY END-USE

End-Use	Usage (%)	End-Use Consumption (M lb)
Acrylic acid and esters	87	308
Glycerin	7	24
Methionine and methionine hydroxy analogue	6	20
Miscellaneous	>1	2
Total	100	354

Source: Systems Applications, Inc. 1980

TABLE D-11. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF ACROLEIN

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	SHELL	NORCO, LA	30 00 11	090 23 42	12930	1	1	.300160	0.	.030016
2	UNION CARBIDE	TAFT, LA	29 58 00	090 27 00	13970	2	1	.340400	0.	.034040
							2	.065232	0.	.006523
3	CELANESE	CLEAR LAKE, TX	29 37 17	095 03 51	12906	3	2	.079400	0.	.006460
4	ROHMAND HAAS	DEER PARK, TX	29 43 38	095 06 30	12906	3	2	.130320	0.	.010512
5	DEGUSSA	THEODOR, AL	30 33 06	088 10 35	03033	4	3	.079200	0.	.007920
6	NAPP	LODI, NT	40 52 30	074 06 14	94741	4	3	.050400	0.	.007920
7	DUPONT	BEAUMONT, TX	30 00 51	094 01 40	12917	4	3	.079200	0.	.007920
8	MONSANTO	NITRO, WV	38 24 26	081 51 26	13866	4	3	.079200	0.	.007920

* Plant Types:

Type 1: Plant produces refined acrolein

Type 2: Plant produces refined acrolein and acrylic acid

Type 3: Plant produces acrylic acid and acrolein is the intermediate

Type 4: Plant produces methionine

† Source Types:

Type 1: Refined acrolein production

Type 2: Acrylic acid production

Type 3: Methionine production

Source: Systems Applications, Inc. 1980

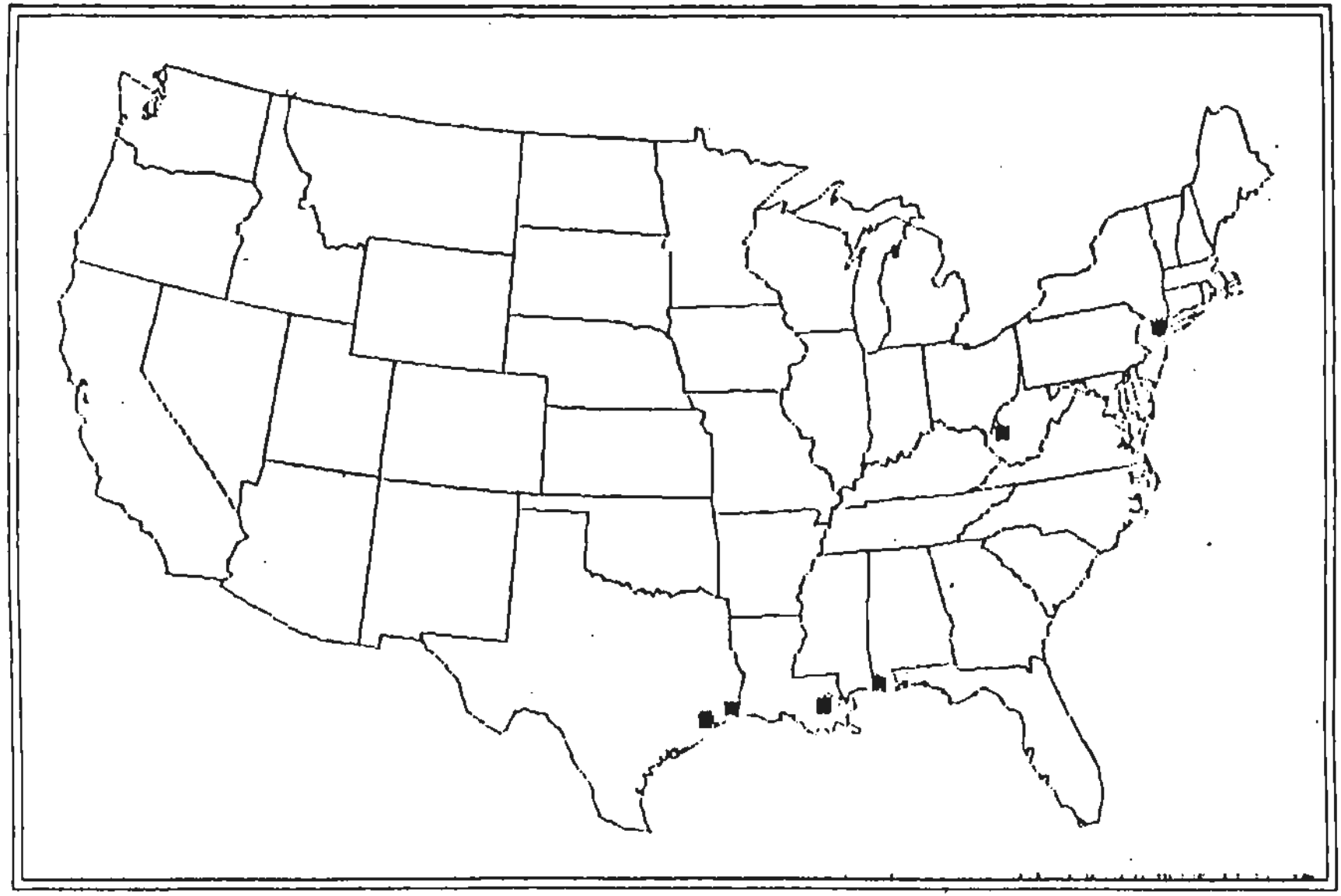

Figure D-2. Specific point sources of acrolein emissions.

Source: Systems Applications, Inc. 1980

b. Complexation in presence of mercuric chloride
c. Colorimetric analyses
    Detection limits:
        1-30 µg/10 ml
    Possible interferences:
        Slight interference from dienes
        Samples must be analyzed soon after collection due to 2-hour limit on color development

2. NIOSH Method P&CAM 211, "Acrolein in Air."

a. Collection in midget impingers with 1% aqueous $NaHSO_3$
b. Reaction with 4-hexylresorcinol
c. Colorimetric analyses
    Detection limits:
        0.01 ppm/50 l air sample
        1-30 µg/10 ml sample
    Possible interferences:
        Slight interferences from dienes.
        Samples should be analyzed soon after collection, unless refrigerated (for up to 48 hours)

3. Method J from Appendix A

a. Collection in dinitrophenylhydrazine (DNPH)
b. Solvent extraction of DNPH derivatives
c. Reverse phase HPLC analysis

    Detection limits:
        1-5 ppb (40 l sample)

    Possible interferences:
        Blank levels of aldehydes (usually formaldehydes) will usually determine the detection limits

        Reagents must be carefully prepared to avoid significant contamination

        Analysis within 24 hours is recommended

Materials Damage

Contact of acrolein with oxidizing agents, acids, alkalies, and ammonia may cause fires and explosions

Permissible Exposure Limits

	OSHA	ACGIH
TWA	0.1 ppm (0.25 mg/m^3)	0.1 ppm (0.25 mg/m^3)
Ceiling		0.3 ppm (0.8 mg/m^3)
Odor Threshold		0.2 to 15 ppm reported

Human Toxicity

Acute toxicity:

The LC_{LO} for inhalation (humans) is 153 ppm/10 minutes. Acrolein is a severe pulmonary irritant and lacrimating agent. As a liquid, acrolein causes severe corrosive burns on the skin and mucous membranes

Chronic toxicity:

Carcinogenesis--Carcinogenesis testing to be completed by FY83 (U.S. DHHS 1983)

Other chronic toxicity:

Acrolein is on test in FY83 for biochemical, cellular, and tissue effects, and for pulmonary toxicity (U.S. DHHS 1983)

Acrolein causes lacrymation and respiratory tract irritation and can cause CNS damage

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Chemical Name

Acrylonitrile

CAS Number

107-13-1

Chemical Classification

Substituted allyl; nitrile

Synonyms and Trade Names

ACN, acrylon, acrylonitrile (DOT), acrylonitrile (8CI), acrylonitrile monomer, AN, carbacryl, cyanoethylene, ENT 54, Fumi-grain, Millers Fumigrain, propenenitrile, 2-propenenitrile, TL 314, VCN, Ventox, vinyl cyanide

Physical/Chemical Properties

Description:
Volatile, colorless liquid; explosive, flammable; characteristic odor resembling peach seeds

Boiling point:
77.5° C

Melting point:
-83.5° C

Molecular weight:
53.06

Chemical formula:
C_3H_3N

Vapor pressure:
113.8 mm Hg at 25° C; 83 mm Hg at 20° C

Vapor density:
1.83 (air = 1.0)

Density:
0.8060 at 20° C/4° C

Refractive index:

$n_D^{25} = 1.3888$

Solubility:

Acrylonitrile is moderately soluble in water (50 g/l at 20° C); it is soluble in acetone and benzene, and is miscible with ethanol and ether

Octanol/water partition coefficient:

-0.92

Photochemical reactivity:

Olefins generally, as a class, enhance atmospheric oxidation reactions. Acrylonitrile has been found to be reactive, with an atmospheric half-life of 9-10 hours

Density:

806 g/l at 20° C

Chemical reactivity:

Reacts with oxidizing materials. Cannot be stored without the addition of polymerization inhibitors

Environmental Fate

The atmospheric half-life of acrylonitrile is sufficiently long to allow for its atmospheric transport, especially when coupled with its high volatility and its low solubility in water

Sources of Emissions

Production:

1. SOHIO process: oxidation of propylene in the presence of ammonia (ammoxidation of propylene) using either a bismuth phosphomolybdate or uranium-base catalyst (the only process used commercially in the United States)
2. Addition of hydrogen cyanide to acetylene using cuprous chloride catalyst
3. Catalytic reaction of propylene with nitrous oxide

4. Reaction of ethylene oxide with hydrogen cyanide followed by catalytic dehydrogenation of ethylene cyanohydrin

5. Ammoxidation of propane

Uses:

1. Acrylic and Modacrylic Fibers
   More than 60% of these fibers are used in apparel. Carpeting is the second largest use. Home furnishing uses include blankets, draperies, and upholstery. Industrial uses include sandbags, filter cloths, tents, and tarpaulins. The fibers are also used in synthetic hair wigs

2. ABS Resin
   Major markets are pipes and pipe fittings, and automotive components. Other important markets are large appliances, housing for business machines and telephones, recreational vehicle components, toys, sporting goods, sheeting material for luggage, and food containers

3. SAN Resin
   Primary uses are for drinking tumblers and other houseware items, for automobile instrument panels, instrument lenses, and food containers

4. Nitrile Elastomers
   Major uses are in rubber hose, seals, gaskets, latex, adhesives, polyvinyl chloride blending, paper coatings, and pigment binders

5. Adiponitrile
   It is hydrogenated to hexamethylenediamine, which is used to produce nylon

6. Acrylamide
   The largest use is in the production of polyacrylomides for waste and water treatment flocculants. Other acrylamide products are used to aid sewage dewatering, and for papermaking strengtheners and retention aids

7. Nitrile Barrier Resins
   They are used in the manufacture of non-beverage containers for glue, nail polish, correction fluid, air freshener, contact lenses, tooth brushes, and combs

The major sources of acrylonitrile emissions in the United States are monomer and polymer production facilities. The estimated acrylonitrile emissions from these facilities are shown in Tables D-12 and D-13. Table D-14 gives spill hazards for acrylonitrile.

TABLE D-12. ESTIMATED ACRYLONITRILE EMISSIONS FROM MONOMER AND POLYMER PRODUCTION FACILITIES

Production facility	Estimated acrylonitrile emissions (Mg/yr)*
Monomer	802
ABS-SAN resin	1424
Acrylic and modacrylic fiber	1276
Nitrile elastomer	295
Adiponitrile	59
	3856

* Mg - millions of grams

Source: U.S. EPA 1982

TABLE D-13. MONOMER RESIDUE IN END-PRODUCTS OF ACRYLONITRILE

Product name	Usage	Monomer residue (ppm)
Acrylic and monacrylic fiber	Fabric	<1
Hycar	Rubber	0-100
Kralastic and paracril	Resin	50
UCAR-380	Latex	250
UCAR-4358	Latex	750
Acrylamide monomer	See Figure 1	50-100
Polyacrylamide	See Figure 1	1
ABS Resin	Packaging	24
SAN Resin	Containers	3-7
SAN Resin	Containers	2-5

Source: U.S. EPA 1982

Storage:

Outside or detached storage preferable

Inside storage in standard flammable liquids storage room or cabinet

Uninhibited acrylonitrile not to be stored under any condition

Outside tanks should be above-ground and surrounded by dikes of sufficient capacity to hold entire tank contents

Transport:

TABLE D-14. HAZARDS OF ACRYLONITRILE TRANSPORTATION*

Hazard parameter	Barge	Truck	Rail
Spill Pool radius (m)	61.0	17.1	31.7
Hazard radius (m)	122	38.4	68.3
Hazard area (m^2)	46,700† 5,460**	4,450#	13,400#
Relative exposure (%)-- urban/rural	8/92	23/77	27/73
Expected number of annual spills	0.0117	0.063	0.17
Probability of ignition following spill	0.30	0.25	0.40

* Calculations are based upon the assumption that each mode of transportation handles 100 percent of the quantity shipped, and that a total of 73,000 Mg per year of acrylonitrile is shipped between two points

† Area affected by spills into water which ignite. Assumes entire spill quantity contributes to burning pool

\# Area affected by spills on land which ignite. If no ignition occurs, the exposed land area is equivalent to the pool spill area (R^2 spill)

** For spills into water which do not ignite. The water toxicity hazard distance (meters) measured downstream from spill location for a 152 m wide, 3.05 m deep river flowing at 0.70 m/s. Assumes vertical dispersion rate at 0.30 m/min until uniform mixing is achieved throughout the entire depth of the river. Thereafter, plug flow is assumed with no synergistic or antagonistic reaction between the pollutant and the receiving body of water. For this situation, the entire spill quantity contributes to water

Source: U.S. EPA 1982

Disposition:

Acrylonitrile wastes are to be expected only in petrochemical plants and the frequently attached polymer production. Due to their quantity, they require special disposal provisions

Aqueous wastes with low contents are flushed into the sewerage system and biologically treated in sewage treatment plants. However, it will first have to be determined whether other constituents are present which could interfere with the degradation process. Undegraded remainders can be removed by filtration through activated charcoal

Concentrated wastes, which are mostly of a very complex nature, are turned over to special waste disposal facilities, if reproccessing appears uneconomical

Tables D-15 through D-17 give monitoring and analysis data for acrylonitrile

Sampling and Analytical Methods

1. NIOSH method P&CAM 202 "Acrylonitrile in Air"
   a. adsorption on Carbosieve 8
   b. desorption with methanol
   c. gas chromatographic determination

   Detection limits:
   40-1100 mg/m^3 in a 20 l sample

   Possible interferences:
   High humidity decreases loading capacity of the sorbent tube
   Any compound that has the same retention time as acrylonitrile

2. NIOSH method S156 for "Acrylonitrile"
   a. adsorption on charcoal
   b. desorption with methanol
   c. gas chromatographic analysis

   Detection limit:
   17.5-70.0 mg/m^3 with a 20 l sample
   Probable useful range is 4.5-13.5 mg/m^3

TABLE D-15. ATMOSPHERIC MONITORING DATA FOR ACRYLONITRILE

Site	Product	Distance (km) of Collection from Plant[a]	No. of Samples Collected[b]	Concentration of Acrylonitrile ($\mu g/m^3$)		
				High	Low	Maximal Average
American Cyanamid, New Orleans, LA	Acrylonitrile	0.6-1.8	5	13.6	<0.1	2.6
American Cyanamid, Linden, NJ	Acrylonitrile	0.5-1.8	6	15.9	<0.1	3.2
Monsanto, Texas City, TX	Acrylonitrile	0.7-2.6	7	8.9	<0.3	3.2
Monsanto, Decatur, AL	Acrylic and Modacrylic Fibers	1.3-5.0	5	4.2	<0.1	1.2
DuPont, Lugoff, SC	Acrylic Fibers	0.7-2.2	8	1.1	<0.1	0.3
DuPont, Waynesboro, VA	Acrylic and Modacrylic Fibers	0.3-0.9	6	7.0	<0.2	1.3
Borg-Warner, Washington, WV	ABS/SAN Resins	0.5-1.3	4	325.0	<0.2	84.0
Goodrich, Louisville, KY	Nitrile Elastomers > ABS/SAN Resin	0.4-3.0	4	4.3	<0.2	1.2
Monsanto, Addyston, OH	ABS/SAN Resins	0.3-1.0	5	1.1	<0.2	0.5
Uniroyal, Painesville, OH	Nitrile Elastomers	0.3-0.9	5	3.1	<0.1	1.0
Vistron, Lima, OH	Acrylonitrile > Acrylamide	0.2-0.6	5	148.0	<0.2	34.4

[a]The distances of sample collection points are obtained from Suta, 1979.

[b]Sometimes replicate samples were collected from the same sampling point.

Source: U.S. EPA 1982

TABLE D-16. DIRECT ANALYSIS OF ACRYLONITRILE

Sample	Sample Introduction into Detector Unit	Analysis Technique	Comfirmation Technique	Detection Limit
Simulated occupational air	Sample probe & pump	IR-microcomputer	None	0.2 ppm
Occupational air	Introduction of air from gas bag into evacuated cell	IR	None	0.5 ppm
Acrylonitrile in N_2	Introduction to a vacuum cell at 8 torr	IR lasers	None	0.03 ppm
Simulated air	Pump & rotometer	Detector tube	None	Range 1-120 ppm
Gases generated by heating ABS plastic	Forced air	Detector tube	GC-MS	---
Occupational air	Passive diffusion	Abcor GASBADGE™	None	Range 0.8-19 ppm
Simulated air	Direct injection	GC-NPD	MS	100 ppb
Occupational air	Direct injection	GC-FID	None	0.5 ppm

GC-MS = gas chromatography-mass spectrometry
GC-NPD = gas chromatography-nitrogen/phosphorus detectors
MS = mass spectrometry
GC-FID = gas chromatography-flame ionization detectors

Source: U.S. EPA 1982

TABLE D-17. VARIOUS SORBENTS AND TRAPPING MEDIA FOR COLLECTION OF ACRYLONITRILE IN AIR

Sample	Sorbent	Sampling Condition	Desorption Method	Analysis Technique	Confirmation Technique	Detection Limit
---	SiO_2	0.5 lpm[a] for 4-6 l	Water	Colorimetric	None	---
Plastic producing plant	Stiochrom-2 at -50°C	---	Thermal at 200°C	GC-FID[b]	None	---
Acrylic fiber factory	Silica gel	Personnal samplar for 100 min.	Water	GC-FID	None	0.1 ppm
Simulated air	Activated carbon	15 l in gas bag	2% acetone in CS_2	GC-FID	None	0.25-0.5 ppm
Plastic processing plant	Activated carbon	0.2 lpm for 8 hr.	2% acetone in CS_2	GC-FID	None	0.03-0.31 ppm
Eleven production plants	Activated carbon	1.0 lpm for ≈24 hr.	CS_2	GC-FID	None	< 0.3 $\mu g/m^3$
Simulated air	Porapak N	0.1 lpm for 3-5 l	Thermal at 200°C	GC-FID	None	< 1 ppb
Simulated air	Porapak N	0.1-0.15 lpm for 3-8 l	Thermal	GC-FID	None	< 0.26 ppm
Settling pond in acrylonitrile plant	Porous polymer Tenax GC(T)	≈0.07 m^3/hr. for 5-30 min.	Thermal	GC-FID	None	10 ng
Occupational air	Activated carbon	0.2 lpm for 20 l max	CH_3OH	GC-FID	None	Range 5-135 mg/m^3
Occupational air	Carbosieve B	1 lpm for 10-20 l	CH_3OH	GC-FID	None	Range 40-750 mg/m^3
--	95% ethanol	1 lpm	---	Polarographic	None	0.5-5 mg/50 ml
Grain fumigant air	Chilled water	0.03-0.33 lpm	---	Polarographic	None	1.08×10^{-5} M
---	Water	0.015 lpm for 1.5-3 l	---	Colorimetric	None	---
---	Water	---	---	Colorimetric	None	0.5 mg/m^3
Occupational air	Chilled water	1 lpm for 20-60 l	---	u.v.	None	Range 10-100 ppm
Acrylonitrile plant	Chilled water	1 lpm	---	GC-FID	None	50 ppb
---	Water	---	---	Colorimetric	None	1.0 $\mu g/ml$
---	H_2SO_4 & glass beads	0.4 lpm	---	Titrimetric	None	20-300 $\mu g/ml$
Rubber plant	1% H_2SO_4	---	---	Colorimetric	None	< 0.05 $\mu g/l$
---	1% H_2SO_4	---	---	Colorimetric	None	---
SAN plant	DMF	0.1-0.3 lpm	---	GC-FID	None	0.5 mg/m^3
---	25% methanol at -15°C	---	---	GC-FID	None	---

[a] lpm = liters per minute

[b] GC-FID = gas chromatography-flame ionization detectors

Source: U.S. EPA 1982

Possible interferences:
Humidity high enough to cause condensation in the charcoal tube will cause inefficient trapping of vapors
Any compound present which has the same retention time as acrylonitrile

3. Method B from Appendix A

a. Whole air collection in canister cryogenic concentration
b. Gas chromatographic/flame ionization detection (GC/FID)

Detection limit:
0.1 ppb for a 100 ml sample

Possible interferences:
Storage time greater than a week not recommended
Reactive and water-soluble compounds not readily analyzed
If possible, a fluid GC/FID should be used to avoid sample storage problems

4. Method F from Appendix A

a. Adsorption on carbon molecular seives
b. Thermal desorption into canister
c. Analysis by gas chromatography/flame ionization detection or gas chromatography/mass spectrometry

Detection limits:
0.01-1.0 ppb in a 20 l sample

Possible interferences:
High temperature (350° C) required for desorption may decompose labile compounds

5. Table D-18 lists recovery efficiency of alternate solvents to use of methanol

TABLE D-18. RECOVERY OF ACRYLONITRILE FROM VARIOUS SOLVENTS

Solvent	% Recovery
Methanol	ca. 50%
Acetone	73.5 ± 5.3%
2% acetone in CS_2	95.5 ± 7.9%
2% acetone in CS_2	94%
CS_2 (2 ml)	58%
CS_2 (4 ml)	75%

Source: U.S. EPA 1982

Materials Damage

Acrylonitrile may not be stored without polymerization inhibitors

Permissible Exposure Limits

	OSHA	NIOSH	ACGIH
TWA	2 ppm	4 ppm/10 hr	2 ppm (4.5 mg/m^3)
Ceiling	10 ppm/15 min		(human carcinogen)

Odor perception: 21.4 ppm

Human Toxicity

Acute Toxicity:

Occupational exposures of 16 to 100 ppm for 20 to 45 minutes produced nasal irritation, upper respiratory tract tightness

Acrylonitrile mixed with carbon tetrachloride caused toxic epidermal necrolysis

Chronic Toxicity:

Carcinogenesis--On test in FY1983 for carcinogenesis (U.S. DHHS 1981)

Occupational exposures may be associated with an excess of lung and colon cancer

Mutagenesis--Mutagenesis/genetic toxicity testing to be completed in FY1983 (U.S. DHHS 1981)

Other Chronic Toxicity:
On test for pulmonary toxicity in FY1983 (U.S. DHHS 1981)

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Chemical Name

Allyl Chloride

CAS Number

107-05-1

Chemical Classification

Organic halide

Synonyms

3-Chloro-1-propane, 3-chloro-propylene, chlorallylene, 3-chloroprene

Physical/Chemical Properties

Description:
Colorless to strawberry-colored liquid

Boiling point:
44.6° C

Melting point:
-134.5° C

Molecular weight:
76.5

Chemical formula:
C_3H_5Cl

Vapor pressure:
295 mm Hg 20° C
359 mm Hg 25° C

Refractive index:
1.416

Solubility:
Insoluble in water
0.36 wt % 20° C
Soluble in alcohol

Density:
0.94 g/cm^3

Vapor density:
2.64 (air = 1)

Chemical reactivity:
Very reactive and widely usable as a starting material and intermediate in organic synthesis

Transformation products in the atmosphere include 2-chloro-acetaldehyde and formaldehyde

Sources of Emissions

Production/processing:
Production in 1978 was estimated as 330 million lb

Process emissions (lb/year)	Producer	Location
516,000	Dow Chemical Co.	Freeport, TX
226,000	Shell Chemical Co.	Deer Park, TX
226,000	Base Chemicals	Norco, LA

Uses:
Allyl chloride is used as a monomer in the production of various plastics, resins, surface coatings, and as a chemical intermediate for glycerol, epichlorohydrin, and allyl alcohol

No emissions data were available

Storage emissions from storage operations have been estimated as 46,200 lb/year

Disposition:
With the exception of defective batches, no concentrated wastes are reported

Sampling and Analytical Methods

Sampling methods:
A known volume of air is drawn through a charcoal tube to trap the organic vapors present

NIOSH Manual of Analytical Methods number S116

Analytical methods:
The analyte is desorbed with benzene and an aliquot of the desorbed sample is injected into a gas chromatograph; NIOSH Manual of Analytical Methods number S116

Detection limits:
For a 100 l sample size, the detector sensitivity is 0.5 to 10 mg/m^3

Possible interferences:
1. High humidity causes inefficient trapping of organic vapors
2. Interference from the presence of the desorbant
3. Compounds present with the same column retention time

Permissible Exposure Limit

OSHA Standard
1 ppm (3 mg/m^3) TWA
NIOSH recommendation
3 ppm/15 min ceiling (9 mg/m^3)

Human Toxicity

Chronic Toxicity:

Carcinogenicity--There is inadequate evidence in humans, and in experimental animals tumors were not induced in a 6-month study (3 ppm, inhalation)

Mutagenicity--Allyl chloride was mutagenic in Salmonella TA 100 and TA 1535

Teratogenicity--Reproductive and developmental toxicity are on test in FY83

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Chemical Name

Arsenic

CAS Number

7440-38-2

Chemical Classification

Elemental metal

Synonyms

Arsen; arsenic black; grey arsenic; metallic arsenic

Physical/Chemical Properties

Description:
Grey to black brittle, crystalline or amorphous solid

Boiling point:
613° C (sublimes)

Melting point:
817° C

Atomic weight:
74.92

Atomic formula:
As

Solubility:
Insoluble in water; soluble in nitric acid

Photochemical reactivity:
No photochemical reactivity

Density:
5.727 g/cm^3 20° C

Chemical reactivity:
Metallic arsenic is stable in dry air; arsenic vapor does not combine directly with hydrogen to form hydrides. Metallic arsenic is not readily attacked by water, alkaline solutions or non-oxidizing acids

Sources of Emissions

Production:
Approximately 70 million lb of arsenic and inorganic arsenic compounds are produced in the United States annually. Table D-19 lists the location and companies producing arsenic compounds. Table D-20 lists the estimated arsenic emissions in the United States by source. Arsenic trioxide is the source of 97 percent of arsenic compounds

Uses:
Elemental arsenic and arsenic compounds are used in pesticides, glass, ceramics, paints, dyes, nonferrous alloys, wood preservatives, etc.

Emission factors for mining, industrial sources, processing and consumptive uses have been calculated as follows:

Source	Emission Factor
Mining	0.2 lb/ton arsenic in ore
Copper smelter	5 lb/ton of copper
Lead smelter	0.8 lb/ton of lead
Zinc smelter	1 lb/ton of zinc
Cast iron	0.01 to 0.02 lb/ton of metal charged
Nonferrous alloys	1 lb/ton of arsenic processed
Pesticide production	20 lb/ton of arsenic processed
Glass production	0.2 lb/ton of glass produced
Others (paint, pharmaceuticals, semiconductors, pyrotechnics, wood preservatives, etc.)	3 lb/ton of arsenic processed
Cotton ginning processing	4 lb/10^3 bales of cotton ginned

TABLE D-19. PRODUCTION OF ARSENIC COMPOUNDS

Location	Company
California	
Cucamunga	Will Ross (G. D. Searle)
Newark	" "
Santa Clara	Airco
South Gate	Los Angeles Chemicals
Georgia	
Morrow	Will Ross (G. D. Searle)
Fort Valley	Woolfolk Chemicals
Illinois	
Joliet	Will Ross (G. D. Searle)
North Chicago	Abbott Labs
Rockford	Apache Chemicals
Massachusetts	
Gloucester	Will Ross (G. D. Searle)
Missouri	
St. Peters	Monsanto
New Jersey	
Bayonne	Dimensional Pigments
Bayonne	Rona Pearl
Bound Brook	Blue Spruce
East Rutherford	Will Ross (G. D. Searle)
Jersey City	City Chemicals
Somerset	W. A. Cleary
Vineland	Vineland Chemicals
Oklahoma	
Miami	Eagle-Picher
Quapaw	"
Tulsa	Ozark-Mahoning (Pennwalt)
Pennsylvania	
Myerstown	Rohm and Haas
Tennessee	
Memphis	Osmose Wood Pres.
Texas	
Bryan	Pennwalt
Greens Bayou	Diamond-Shamrock
La Porte	Will Ross (G. D. Searle)
Washington	
Tacoma	Pennwalt
Wisconsin	
Marinette	Ansul

Source: Mason et al. 1979

TABLE D-20. ESTIMATED ARSENIC EMISSIONS IN U.S.--1974

Source	Number of Plants	Inorganic Arsenic Emissions kkg/Year	Percent Total Emissions
Copper smelters	15	2712	61.1
Lead smelters	6	63	1.4
Zinc smelters	6	73	1.6
Production of arsenical compounds	25	154	3.5
Application of inorganic arsenical pesticides	N/A	399*	9.0
Glass production	325	363	8.2
Coal burning - power plants above 25 megawatts	369	526	11.9
Other	-	109	2.5
Misc. (cotton gins, non-ferrous alloys, inorganic chemicals)	-	36*	.8
Total		4435	100.0%

Source: Mason et al. 1979

Coal-fired plants, pesticide production and use, and copper smelting are all significant sources of atmospheric arsenic. EPA reports that smelter emissions result in the most arsenic exposure by air to the greatest number of persons

Disposition:

Arsenic-containing wastes in the form of sludge occur during the metallurgical processing of arsenic-containing ores. Arsenic contamination of the environment occurs faster than it can be dissipated by natural processes. The emission factor for sewage and sludge containing arsenic has been calculated as 0.2 lb/ton. Airborne waste emissions were addressed under emission factors

Sampling and Analytical Methods

Particulate Arsenicals

Sampling methods:

Particulate arsenicals are collected on a 37 mm polytetrafluoroethylene-backed membrane filter at 1.5 lpm

Method number P&CAM 320

Analytical method:

The arsenicals are extracted ultrasonically and the arsenical species are separated chromographically. Hydrides of each species are generated and quantitated by AAS detection using quartz furnace atomization

Method number P&CAM 320

Detection limits:

This method was tested over the range of 5-20 $\mu g/m^3$ using a 300 l sample

Possible interferences:

Any arsenical compound with the same column retention time as the arsenical of interest is an interference

Additional methods for sampling and analysis of arsenic are:

Arsenic and compounds (as AS) in air (NIOSH Method number S309)

Inorganic arsenic in air (P&CAM 346)

Source: NIOSH Manuals of Analytical Methods

Permissible Exposure Limits

OSHA Standard
0.5 mg/m^3 8-hr TWA as arsenic (organic);
10 μg/m^3 8-hr TWA (inorganic)

Human Toxicity

Acute toxicity:
Acute arsenic poisoning can occur from accidental or intentional ingestion and can result in death of the victim

Chronic toxicity:

Carcinogenicity--there is sufficient evidence that skin cancer in humans is causually associated to inorganic arsenic compounds. Case reports have suggested an association between exposure to arsenic compounds and blood dyscrasias and liver tumors

Mutagenicity--humans who have been exposed to sodium arsenite have shown chromosomal defects

Teratogenicity--birth defects have been demonstrated in animals injected with arsenic. The evidence in humans is not available

Other chronic toxicity:

Neurological effects--arsenic exposure in humans can produce peripheral nerve damage and altered electrocardiograms

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Chemical Name

Asbestos

CAS Number

1332-21-4

Chemical Classification

Natural fibrous silicate

Synonyms

Asbestos fiber, asbestos fibre

Physical/Chemical Properties

Description:
Fibrous mineral that can be woven; good flexing and tensile strengths. There are two major groups of asbestos: serpentine (chrysotile) and amphibole. Chrysotile is the major type of asbestos used in the manufacture of asbestos products.

Properties of asbestos fibers:

Type	Name	CAS #	Formula
Serpentines	Chrysotile	12001-29-5	$Mg_3Si_2O_5(OH)_4$
Amphiboles	Amosite	12172-73-5	$(MgFe)_7Si_8O_{22}(OH)_2$
	Crocidolite	12001-28-4	$Na_2(MgFe)_5Si_8O_{22}(OH)_2$
	Anthophyllite	17068-78-9	$(MgFe)_7Si_8O_{22}(OH)_2$
	Tremolite	14567-73-8	$Ca_2Mg_5Si_8O_{22}(OH)_2$
	Actinolite	13768-00-8	$Ca_2(MgFe)_5Si_8O_{22}(OH)_2$

Other properties of asbestos fibers: See Table D-21

Synonyms:
Chrysotile: serpentine, 7-45 asbestos, Avibest C, Cassiar K, Calidria RG 144, Calidria RG 600
Amosite: mysorite
Crocidolite: --

TABLE D-21. PROPERTIES OF ASBESTOS FIBERS

	Chrysotile	Anthophyllite	Amosite (ferroanthophyllite)	Crocidolite	Tremolite	Actinolite
Structure	In veins of serpentine	Lamellar, fibrous asbestiform	Lamellar, coarse to fine fibrous and asbestiform	Fibrous in iron-stones	Long, prismatic and fibrous aggregates	Reticulated long prismatic crystals and fibers
Essential composition	Hydrous silicates of magnesium	Mg silicate with iron	Silicate of Fe and Mg, higher iron than anthophyllite	Silicate of Na and Fe with some water	Ca and Mg silicate with some water	Ca, Mg, Fe, silicates, water up to 5%
Crystal structure	Fibrous and asbestiform	Prismatic, lamellar to fubrous	Prismatic, lamellar to fibrous	Fibrous	Long and thin columnar with some water	Long and thin columnar to fibrous
Color	White, gray, green, yellowish	Grayish white, brown, gray or green	Ash gray, greenish or brown	Lavender, blue, greenish	Gray-white, greenish, yellowish, bluish	Greenish
Luster	Silky	Vitreous to pearly	Vitreous, somewhat pearly	Silky to dull	Silky	Silky
Specific gravity	2.4 - 2.6	2.85 - 3.1	3.1 - 3.25	3.2 - 3.3	2.9 - 3.2	3.0 - 3.2
Refractive index	1.50 - 1.55	1.61	1.64	1.7 pleochroic	1.61	1.63 weakly pleochroic
Flexibility	Very flexible	Very brittle, nonflexible	Good, less than chrysotile	Fair to good	Generally brittle, sometimes flexible	Brittle and nonflexible
Length	Short to long	Short	2" to 11" varies	Short to long	Short to long	Short to long
Acid resistance	Soluble up to approx. 57%	Fairly resistant to acids	Fairly resistant to acids	Fairly resistant to acids	Fairly resistant to acids	Relatively insoluble in HCl
Specific heat Btu/(lb °F)	0.266	0.210	0.217	0.201	0.212	0.217
Approx. smallest fiber diameter	0.01 μm	0.1 μm	0.1 μm	0.08 μm	0.1 μm	0.08 μm

Source: Kirk-Othmer 1963

Anthophyllite: Asbolen asbestos, ferroanthophyllite

Tremolite: Silicic acid, calcium magnesium salt (8:4)

Actinolite: --

Chemical reactivity:
Asbestos has a high fusion temperature; it is resistant to thermal degradation and chemical attack

Environmental Fate

Asbestos fibers are released into the environment from the natural occurrence of asbestos in the earth

Asbestos minerals are emitted into the atmosphere and water systems from the mixing and milling of asbestos ores

Atmospheric asbestos is limited because the mineral fibers and dust are quickly deposited by means of precipitation, becoming bound to soil or sediments

The general population is exposed to asbestos fibers from air, beverages, drinking water, food, pharmaceutical and dental preparations, and asbestos-containing consumer products. Families of asbestos workers have been exposed to high-fiber levels through contaminated clothing that was brought home for laundering

Sources of Emissions

Production:
Naturally, from asbestos ore and counterpart rock
Asbestos mining: run-off from waste tailings in dry mining
run-off from wet mining
iron ore mining
Approximately 200 million pounds were produced in 1979

Uses:
Asbestos cement products, manufactured by wet processes
Electrical insulation
Thermal insulation
Asphalt and vinyl flooring, adhesives

Papers, millboards, roofing felts

Asbestos textile industry, fireproof and acidproof fabrics

Brake linings, clutch facings and packings

Putties, molding compounds, roof coatings, welding rods, paints, calking compounds, fillers

For filtration (wines, juices, beers, whiskey)

For asphalt paving

In reinforcing plastics

Missile work--satellites, special packings in atomic energy equipment

Storage:

Milled asbestos fiber is usually stored and shipped in bags (which themselves become sources of emissions)

Transportation:

Emissions from open-truck movement of asbestos ore from mine to mill.

Emissions from shipment of milled asbestos fiber and asbestos-containing products

Disposition:

Emissions into run-off waters from asbestos mines, deposited in soils

Emissions from brakes lined with asbestos

Emissions from demolition of buildings with asbestos insulation

Emissions from manufacture and use of products containing asbestos

Asbestos-containing wastes occur as residues, collected dusts and sludges, and are often disposed of in open dump along with municipal wastes

Asbestos production, consumption, and exposure data are given in Tables D-22 through D-28

TABLE D-22. WORLD PRODUCTION OF ASBESTOS

Year	World production (million kg)	% Canada	% USSR
1960	2 210	45	29
1970	3 490	44	30
1973	4 093	41	31
1974	4 115	40	33
1975	4 560	23	48
1976	5 178	29	44

Source: IARC 1980

TABLE D-23. ASBESTOS DISTRIBUTION BY END USE, GRADE, AND TYPE IN THE U.S., 1974 (million kg)

	Chrysotile	Crocidolite	Amosite	Anthophyllite	Total
Asbestos cement pipe	168	33	0.9	0.18	202
Asbestos cement sheet	82		3.9		86
Flooring products	139				139
Roofing products	66		1.5		67
Packing & gaskets	26	0.09			26
Insulation, thermal	6.6		1.6		8
Insulation, electrical	4.2				4
Friction products	72			0.18	72
Coatings and compounds	34				34
Plastics	15	0.18		0.63	16
Textiles	18				18
Paper	57	0.18			57
Other	33	0.36	0.45		34
Total					763

Source: IARC 1980

TABLE D-24. LENGTHS OF ASBESTOS FIBERS IN AIR NEAR VARIOUS U.S. INDUSTRIES

Operation	Fibre type	Median length (μm)	% > 5 μm
Textile	chrysotile		
Fibre preparation & carding		1.4	4
Spinning, twisting, weaving		1.0	2
Friction	chrysotile		
Mixing		0.9	2
Finishing		0.8	2
Asbestos-cement pipe	chrysotile		
Mixing		0.9	2
Finishing		0.7	1
Pipe insulation	amosite		
Pipe forming		4.9	51

Source: IARC 1980

TABLE D-25. ASBESTOS PRODUCERS--1976

Location	Company	Comments
Alaska		
near Eagle	Tanana Asbestos	Drilling Operation in Progress
Arizona		
El Dorado Mine, Gila County	Jacquays Mining	
California		
Copperopolis	Calaveras Asbestos	
Fresno County	Atlas Asbestos	
San Benito County	Union Carbide	
North Carolina		
Newdale	Powhaten Mining	May be inactive, Anthophyllite asbestos
Vermont		
Lowell	Vermont Asbestos	

Notes - All asbestos mined is chrysotile except at the North Carolina location.

Source: Mason et al. 1979

TABLE D-26. ASBESTOS DISTRIBUTION BY TYPE, 1974 (Short tons)

	Crocidolite	Amosite	Anthophyllite	Total asbestos
Asbestos cement pipe	36,400	1,100	200	222,900
Asbestos cement sheet	—	4,300	--	94,800
Flooring products	—	--	--	153,500
Roofing products	--	1,700	--	75,500
Packing and gaskets	100	--	--	28,800
Insulation, thermal	—	1,800	—	9,100
Insulation, electrical	—	—	--	4,700
Friction products	—	—	200	79,500
Coatings and compounds	--	—	--	37,900
Plastics	200	--	700	17,600
Textiles	--	—	—	20,400
Paper	200	—	—	63,300
Other	400	500	--	37,300
Total	37,300	9,400	1,100	545,800

Source: Mason et al. 1979

TABLE D-27. ASBESTOS WORKERS EXPOSED

Asbestos mine and mill workers
Construction workers
Shipyard workers
Workers involved in the manufacture of:
- Asbestos textiles
- Insulation materials
- Acoustical products
- Asbestos cement, tile, cement powders

Source: Mason et al. 1979

TABLE D-28. SELECTED ASBESTOS CONSUMERS

Location	Company	Products
Alabama		
Ragland	CAPCO	Asbestos-concrete pipe
Arkansas		
Van Buren	CAPCO	Asbestos-concrete pipe
California		
Pittsburg	Johns-Manville	Asbestos paper
Connecticut		
Stratford	Raybestos-Manhatten	Textiles, friction materials*
Illinois		
Kankakee	Armstrong-Cork	Roofing and Tile
Louisiana		
New Orleans	National Gypsum	Asbestos-concrete sheet
Maine		
E. Walpole	Hollingsworth and Vose	Asbestos paper
Billerica	Johns - Manville	Asbestos-concrete sheet
Missouri		
St. Louis	Certain-Teed	Asbestos-concrete pipe
St. Louis	GAF	Asbestos-concrete sheet
New Hampshire		
Nashua	Johns - Manville	Asbestos-concrete sheet
Tilton	Johns - Manville	Asbestos paper
New Jersey		
Manville	Johns - Manville	Multi-products *
New York		
Fulton	Armstrong Cork	Asbestos paper
North Carolina		
Marshville	Raybestos - Manhatten	Textiles, friction materials
N. Charleston	Raybestos - Manhatten	Textiles, friction materials
Ohio		
Ravenna	Flintkote	Asbestos-concrete pipe *
Pennsylvania		
Ambler	Nicolet	Asbestos-concrete sheet
Erie	GAF	Asbestos paper *
Erie	GAF	Roofing and Tile
Whitehall	GAF	Asbestos paper *
Texas		
Denison	Johns - Manville	Asbestos-concrete pipe *

Source: Mason et al. 1979

Sampling and Analytical Methods

1. NIOSH method P&CAM 239 for "Asbestos Fibers in Air"
   a. Filter collection
   b. Microscopic count

   Detection limits:
   0.1 - 60 fibers/cm^3

   Possible interferences:
   In an atmosphere known to contain asbestos, all particulates with a length to diameter ratio of 3 to 1 or greater, and a length greater than 5 micrometers should, in the absence of other information, be considered to be asbestos fibers and counted as such.

2. NIOSH method P&CAM 309 for "Chrysotile"
   a. Collection on membrane filter
   b. Redisposition on silver membrane filters
   c. X-ray diffraction

   Detection limits:
   25 - 2500 $\mu g/m^3$ for an 800 l sample

   Possible interferences:
   Antigorite, the massive form of chrysotile, present in quantities >10%

   Chlorite interferes with both primary and secondary peaks of chrysotile unless the instrument has good resolution

   Kaolinite interferes with the primary peak of chrysotile so the secondary peak must be used.

   The presence of iron in sample results in X-ray fluorescense which can be avoided by using a diffracted beam monochromator

3. For "Chrysotile in Bulk Samples," see NIOSH method P&CAM 245

Permissible Exposure Limits

	OSHA	ACGIH
TWA	2 fibers longer than 5 µm/8 hr	amosite: 0.5 fibers >5 µm/cc chrysotile: 2 fibers >5 µm/cc crocidolite: 0.2 fibers >5 µm/cc other forms: 2 fibers >5 µm/cc
Ceiling	10 fibers longer than 5 µm/cc	

Human Toxicity

Chronic toxicity:

Asbestosis--Asbestos dusts and asbestos-containing dusts are among the fibrogenic dusts which, with the formation of connective tissue, can simultaneously cause pneumonoconiosis. Fibers of up to 250 µm in length can reach the alveoli. Longer fibers are always more dangerous than short ones

Sometimes the action of asbestos can cause irritation of the conjunctiva, gullet, and mucous membrane of the larynx. Fine asbestos fibers that reach the digestive tract are occasionally capable of penetrating the stomach and intestinal walls, reaching the blood stream and migating through the body with the flow of blood. They can even pass through the placenta

Carcinogenicity--Occupational exposure to chrysotile, amosite, anthophyllite, and mixtures containing crocidolite has resulted in a high incidence of lung cancer. A predominantly tremolitic material mixed with anthophyllite and small amounts of chrysotile has also caused an increased incidence of lung cancer. Pleural and peritoneal mesotheliomas have been observed after occupational exposure to crocidolite, amosite, and chrysotile asbestos. Gastrointestinal tract cancers were increased in groups exposed occupationally to amosite, chrysotile, or mixed fibers containing crocidolite. An excess of cancer of the larynx was also observed in exposed workers. Mesotheliomas have occurred in individuals living in the neighborhood of asbestos factories and crocidolite mines, and in persons living with asbestos workers. Both cigarette smoking and occupational exposure to asbestos fibers increase lung cancer incidence independently. When present together, they act multiplicatively

On test in FY1983 for biochemical/cellular/tissue effects, and for immunological and pulmonary toxicity, clinical toxicology and epidemiology (U.S. DHHS 1983)

Acute/chronic toxicity, biochemical/cellular/tissue effects, and immunological and pulmonary toxicity testing to be started in FY1983 (U.S. DHHS 1983)

Acute/chronic toxicity testing to be completed in FY 1983 (U.S. DHHS 1983)

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Chemical Name

Benzene

CAS Number

71-43-2

Synonym

(6)Annulene, benzene (DOT), benzin, benzine, benzol, benzole, benzolene, bicarburet of hydrogen, carbon oil, coal naphtha, cyclohexatriene, mineral naphtha, motor benzol, NCI-C55276, nitration benzene, phene, phenyl hydride, pyrob, pyrobenzol, pyrobenzole

Chemical Classification

Aromatic hydrocarbon

Physical/Chemical Properties

Description:
Colorless, volatile, highly flammable liquid, with a distinct odor, like gasoline

Boiling point:
80.1° C

Melting point:
5.5° C

Molecular weight:
78.11

Chemical formula:
C_6H_6

Vapor pressure:
74.6 mm Hg at 20° C

Refractive index:
Highly refractive; n_D^{29} 1.5016

Solubility:
Slightly soluble in H_2O (enough to be toxic to aquatic organisms); soluble in natural fats and fat soluble substances; miscible with acetone, alcohol, carbon disulfide, carbon tetrachloride, chloroform, ether, glacial acetic acid and oils

Octanol/water log partition coefficient:
2.28

Photochemical reactivity:
Not photoreactive

Density:
0.8737 g/ml at 25° C

Vapor density:
2.77 (air = 1)

Chemical reactivity:
Activity toward O_2: slowly reacts with oxidizing materials
Activity toward OH: half-life = 3 days
Undergoes substitution, addition and cleavage of the ring

Environmental Fate

Released into the atmosphere from both stationary and mobile sources, including from production, transportation, and storage of benzene

Benzene occurs in ambient air from 1-100 ppm, in drinking water at approximately 10 ppb, and in subsurface water at 10 ppm

Benzene is biodegradable

Sources of Emissions

Production:
An estimated 12 billion lb of isolated and non-isolated benzene (all grades) was produced in the United States in 1980

From petroleum:
Isolated from catalytic reformate
Isolated from pyrolysis gasoline
Direct from dealkylation of toluene
Direct from disproportionation of toluene

From coal:
- Isolated from coke oven light oil
- Isolated from further separation techniques in coke oven operations
- Distillation of coal tar

Uses:

Synthesis of other organic chemicals:
- Ethylbenzene (used in production of styrene)
- Cumene
- Cyclohexane
- Anilene
- Chlorobenzenes (for DDT and mothballs)
- Maleic anhydride
- Detergent alkylate

Emissions of benzene from the production of other chemicals have been estimated as 44,000-56,000 tons. Concentrations in air near U.S. chemical manufacturing companies were reported in the range of 2 to 109 $\mu g/m^3$

Solvent in chemical and drug industries

Gasoline additive
- Emissions from gasoline production have been estimated as 40,000-80,000 tons annually

Benzene is used in the manufacture of styrene and phenol, dyes, benzene hexachloride insecticides, fumigants, paint removers, rubber cement, anti-knock gasoline, synthetic detergents

Storage and transport:

Emissions from motor vehicle fueling and operation

Gasoline service station emissions

Bulk terminal (rail-tank-marine) loading/storage emissions

Oil spills emissions

Most of domestically shipped benzene goes by barge (79.6%), 14.8% by rail, and 5.6% by truck

Most pipeline shipment is restricted to benzene that is captively used by the producing plant

Disposition:

Wastes containing benzene are mainly distillation residues from petrochemistry, spent catalysts, residues from coking processes and spent solvents from petrochemistry, the reprocessing of which is frequently too expensive

Benzene is biodegradable. Diluted aqueous solutions, therefore, are drained into sewage treatment plants and decomposed there by anaerobic bacteria

Solvent mixtures and sludges of higher concentration are burnt in special waste incinerators if a recovery process is uneconomical

Tables D-29 through D-31 give benzene production, consumption, and emission data

Sampling and Analytical Methods

1. NIOSH method S311 for "Benzene"
   a. Adsorption on charcoal
   b. Desorption with carbon disulfide
   c. Gas chromatographic analyses

   Detection limits:
   13-51.8 ppm/2 l sample

   Possible interferences:
   High-humidity causes inefficient trapping and decreases breakthrough volume

   Any compound present which has the same retention time as benzene interferes with chemical identification

2. NIOSH method P&CAM 127, "Organic Solvents in Air"
   a. Adsorption on charcoal
   b. Desorption with carbon disulfide
   c. Gas chromatographic analyses

   Detection limits:
   0.01 mg/0.5 l to 55 l sample

TABLE D-29. ANNUAL EMISSIONS OF BENZENE TO AIR FROM VARIOUS SOURCES

Source	Emission (thousand tons)
Component of gasoline*	40.0 - 80.0
Production of other chemicals	44.0 - 56.0
Indirect production of benzene†	23.0 - 79.0
Production of benzene from petroleum	1.8 - 7.3
Solvents and miscellaneous sources	1.5
Imports of benzene	0.013

* Production, storage, transport, vending and combustion

† Coke ovens, oil spills, nonferrous metals manufacturing, ore mining, wood processing, coal mining, and textile industry

Source: IARC 1982

TABLE D-30. BENZENE CONSUMPTION (1976)

Product use	Percent
Ethylbenzene	50.0
Cumene	16.6
Cyclohexane	14.9
Aniline	4.3
Chlorobenzenes	3.5
Maleic anhydride	2.7
Detergent alkylate	2.6
Miscellaneous applications	3.0
Exports	2.4

Source: Ochsner, Blackwood, and Zeagler 1979

TABLE D-31. BENZENE EMISSION SOURCES

Emission source	1976 Estimated benzene emission rate, 10^6 kg/yr (11)	Number of sources	Mass emissions per source, kg/yr
Benzene production:			
Catalytic reforming	2.6	39	67,000
Toluene dealkylation	1.4	16	88,000
Toluene disproportionation	0.04	2	20,000
Pyrolysis gasoline	0.6	10	60,000
Coke-oven light oil	0.2	5	40,000
Coke-oven operations	0.2	6	33,000
Benzene consumption:			
Ethylbenzene/styrene	9.5	12	190,000
Cumene/phenol	2.4	9	270,000
Cyclohexane	7.8	8	975,000
Aniline	0.1	7	14,000
Chlorobenzenes	2.6	7	370,000
Maleic anhydride	2.0	9	220,000
Detergent alkylate	0:01	5	2,700
Surface coatings (paints)	3.2	8,745	370
Degreasing	73.1	1,300,000	56
Nitrobenzene	3.4	9	380,000
Fumaric acid	0.3	6	50,000
Acrylonitrile	0.2	6	33,000
Other sources:			
Automobile tank loading	5.9	226,500	26
Service station tanks	0.2	226,500	80
Bulk terminal loading/storage	0.04	30,900	1
Motor vehicles	450	130,000,000	3
Oil spills	10	787	12,000
TOTALS	576	131,800,000	

Source: Ochsner, Blackwood, and Zeagler 1979

Materials Damage

Fire hazard; explosion hazard

Permissible Exposure Limits

	OSHA	ACGIH
TWA	10 ppm 8-hr	10 ppm (30 mg/m^3)
Ceiling	25 ppm	25 ppm (75 mg/m^3)
PEAK	50 ppm/10 min.	

Human Toxicity

Acute toxicity:
- Blood effects
- Aplastic anemia
- Narcotic action on CNS

Chronic toxicity:

Carcinogenicity--There is sufficient evidence that benzene is carcinogenic to humans. Several case reports as well as an epidemiological case control study establish a relationship between benzene exposure and leukemia

Mutagenicity--The evidence of mutagenicity in short-term tests is limited. Benzene has induced chromosomal abnormalities in occupationally exposed people

Other chronic effects:
- Estrus cycle disorder
- Liver, kidney and lung damage
- Hormone alteration
- Bone marrow hyperplasia

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Chemical Name

Benzyl chloride

CAS Number

100-44-7

Chemical Classification

Aromatic halogen

Synonyms

Alpha-tolylchloride; chloromethyl-benzene; alpha-chloromethyl-benzene; alpha-chlorotoluene

Physical/Chemical Properties

Description:
Benzyl chloride is a colorless to light yellow liquid, moderately volatile and a strong lacrimator

Boiling point:
179° C at 760 mm Hg

Melting point:
-39° C

Molecular weight:
126.6

Chemical formula:
$C_7 H_7 Cl$

Vapor pressure:
1.4 mm at 25° C
10 mm at 60.8° C
100 mm at 114.2° C

Refractive index:
$n_T^D = 1.5412$

Solubility:
Slightly soluble in water (49.3 mg/100 ml); soluble in lipids

Photochemical reactivity:
No photochemical degradation

Density:
1.026 at 18° C

Vapor density:
4.36 (air = 1)

Chemical reactivity:
Benzyl chloride undergoes Friedel-Crafts condensation reactions in the presence of such metals as iron, copper, zinc, aluminum, magnesium and tin. The compound hydrolyzes slowly in boiling water. The reactions of benzyl chloride involve

a. the reaction of the side chain containing the halogen, and
b. the reaction of the aromatic ring

Environmental Fate

Benzyl chloride decomposes slowly in the presence of water. The half-life for the hydrolysis of benzyl chloride at pH7 25° C is 15 hours, at 60° C hydrolysis is 45 times faster

Sources of Emissions

Production:
There are currently three producers of benzyl chloride at four locations. An estimated 115 million lb was produced in 1978. Table D-32 lists the plant locations and the estimated production

TABLE D-32. BENZYL CHLORIDE PRODUCERS

Company	Location	1978 Capacity (10^6 lb/yr)	1978 Production (10^6 lb/yr)
Monsanto	Bridgeport, NJ	80	52.5
	Sauget, IL	80	52.5
Stauffer	Edison, NJ	12	8.0
UOP, Inc.	E. Rutherford, NJ	3	2.0
	Total	175	115.0

Source: Mannsville Chemical Products 1978

Total estimated emissions (including process, storage, and fugitive) were 59,000 lb/year in 1978

Uses:

The major end uses for benzyl chloride are butyl benzyl phthalate (75%) benzyl alcohol (7%), quarternary ammonium compounds (10%), and miscellaneous uses (8%) (1978 data)

Table D-33 lists benzyl chloride emissions from producers and users

Transportation/storage:

Benzyl chloride is shipped in glass carboys, phenolic-lined steel or nickel drums, tank cars and tank trucks. The chemical has an effective storage life of 2 to 3 months at normal temperatures. The emission factor from storage and handling has been estimated as 0.000025 to 0.00040 lb lost for lb produced and used

Disposition:

No data available

Sampling and Analytical Methods

Sampling method:

A known volume of air is drawn through a charcoal tube to trap the organic vapors present

NIOSH Manual of Analytical Methods: Method No. S115

Analytical method:

The sample is desorbed with carbon disulfide and the desorbed sample is injected into a gas chromatograph for analysis

NIOSH Manual of Analytical Methods: Method No. S115

Detection limits:

For a 10 l sample (25° C 744 mm Hg), the detection range is 2-8 mg/m^3

TABLE D-33. BENZYL CHLORIDE EMISSIONS FROM PRODUCERS AND USERS

Company	Location	Source	Emissions (lb/yr)			Total Emissions	
			Process	Storage	Fugitive	(lb/yr)	(g/sec)
Monsanto	Bridgeport, NJ	Production	20,633	1785	3833	26,250	0.378
	Sauget, IL	Production	20,633	1785	3833	26,250	0.378
Stauffer	Edison, NJ	Production	4,000	344	744	5,088	0.073
UOP	E. Rutherford, NJ	Production	1,000	86	186	1,272	0.018
Monsanto	Bridgeport, NJ	BBP	10,178	1078	2329	13,584	0.196
	Sauget, IL	BBP	10,178	1078	2329	13,584	0.196
Velsicol	Chattanooga, TN	Benzyl alcohol	945	108	297	1,350	0.019
Orbis	Newark, NJ	Benzyl alcohol	280	32	88	400	0.006
Norda	Boonton, NJ	Benzyl alcohol	280	32	88	400	0.006
Akzona	McCook, IL	QAC	322	46	92	460	0.007
	Morris, IL	QAC	322	46	92	460	0.007
Lonza	Mapelton, IL	QAC	322	46	92	460	0.007
Hexcel	Lodi, NJ	QAC	322	46	92	460	0.007
Witco	Houston, TX	QAC	322	46	92	460	0.007
Ashland	Janesville, WI	QAC	322	46	92	460	0.007
Gulf Oil	Jersey City, NJ	QAC	322	46	92	460	0.007
Rohm & Haas	Philadelphia, PA	QAC	322	46	92	460	0.007
Sterling	Cincinnati, OH	QAC	322	46	92	460	0.007
National Starch	Salisbury, NC	QAC	322	46	92	460	0.007
Total			71,347	6788	14,647	92,778	

Source: SAI 1980

Possible interferences:

1. High humidity
2. Compounds with the same column time retention will interfere with analysis

Permissible Exposure Limits

1 ppm (5 mg/m^3) OSHA standard

Human Toxicity

Chronic toxicity:

Carcinogenicity--There are no case reports or epidemiologic studies available in humans; however, benzyl chloride is carcinogenic in experimental rats. There is a long-term animal bioassay on test in FY83 by the National Toxicology Program

Mutagenicity--Benzyl chloride was weakly mutagenic to Salmonella typhimuiium (1975). Further microbial testing is on test for mutagenesis and genetic toxicity in FY83 by the National Toxicology Program

Other chronic toxicity:

Air concentrations of 32 ppm were reported to cause severe irritation of the eyes and respiratory tract of humans

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Chemical Name

Beryllium

CAS Number

7440-41-7

Chemical Classification

Chemical element, rare metal

Synonyms

Beryllium-9, glucinium, glucinum

Physical/Chemical Properties

Description:
Hard, noncorrosible grey metal of alkaline earth family: lightest structural metal known. Beryllium is available as powder, beads, electrolytic flakes, ingot, strip, sheet, plate, foil, wire, rod, bar, tube, castings, and fabricated parts

Boiling point:
2970° C

Melting point:
1284-1300° C

Atomic weight:
9.01

Chemical formula:
Be

Solubility:
Soluble in acids or alkalis

Atmospheric reactivity:
Two radioactive isotopes of Beryllium, Be^{7} and Be^{10}, are formed in the upper atmosphere as a result of intense cosmic-ray activity

Density:
1.85 g/cm^3 (20° C)

Chemical reactivity:
Reacts with hot water, alkali, and dilute acids; oxidation resistant; good transparency to X-rays; high heat capacity and thermal conductivity

Sources of Emission

Production:
From beryl ore or from bertrandite ore: In recovering the metal from the usual ores (beryl and bertrandite), the sulfate process and the fluoride process produce beryllium oxide or hydroxide. This step is followed either by a thermal reduction or an electrolytic process. Thermal reduction involves the magnesium reduction of a halide, generally beryllium fluoride. The electrolytic process requires conversion to the chloride for the fused-salt bath and produces Be of higher purity. Approximately 74,000 lb of beryllium were produced in 1977

Uses:
To form alloys with copper, nickel, and aluminum with emissions of approximately 55,000 lb/year

In manufacture of ceramics and vitreous enamel

To make refractory crucibles as moderator and reflecting material in nuclear reactors

To make gas mantles

As a window material for X-ray tubes

To produce a heat sink material in low-weight, high performance aircraft brakes, and to make mirror components of satellite optical systems

To make electrical components

Storage and transport:
Usually stable during transport. Shipped in steel and fiber drums. Should be stored in dry place away from

acids, caustics, and chlorinated hydrocarbons. Kept separate from oxidizing materials

Disposition:

Emission losses at production sites are kept down by reusing beryllium occurring in production and processing (powder, chips, beryllium compounds)

Emission dusts can be controlled by use of filters and scrubbers at production and processing sites

Liquid or solid waste with too low a beryllium concentration to warrant recovery is disposed of in special dumps, but prior to disposal, the beryllium compound involved must be converted to the relatively inert oxide

Beryllium emissions occur during the combustion of fossil fuels which represents the major source of non-occupational exposure

Some sources of beryllium emissions are given in Tables D-34 through D-38

Sampling and Analytical Methods

1. NIOSH method P & CAM 121 for "Beryllium in Air" for use on air, settled dust, ore, and swipe samples

   a. Air samples can be collected by using a cellulose membrane filter, an electrostatic precipitator, or a chemically clean impinger containing 10% HNO_3 solution
      Settled dust and ore samples can be collected directly in chemically clean jars
      Swipe samples should be collected on Whatman filter paper
   b. Air samples are ashed with nitric acid, treated with 1:1 hydrochloric acid, and dissolved in a weak hydrochloric acid solution
      Ore and settled dust samples are ground in a mill to pass a U.S. Standard 200-mesh sieve
         -dust samples are ashed with nitric acid
         -ore samples are fused without ashing
   c. The samples are analyzed by atomic absorption spectrophotometry

   Detection limits:
   0.03-8.0 µg/ml

TABLE D-34. SOURCES OF BERYLLIUM EMISSIONS

Source
Mica, feldspar mining
Gray iron foundry
Cupola
Ceramic coatings
Beryllium alloys and compounds
Beryllium fabrication
Power plant boilers
Pulverized coal
Stoker coal
Cyclone coal
All oil
Industrial boilers
Pulverized coal
Stoker coal
Cyclone coal
All oil
Residential/commercial boilers
Coal
Oil

Source: Sittig 1975

Table D-35. SOURCES OF BERYLLIUM FROM INDUSTRIAL AND SOLID WASTE INCINERATION EMISSIONS

Source
Mining
Production of beryllium metal and its compounds
Cement plants
Dry process
Feed to raw mill
Wet process
Kiln
Clinker cooker
Clinker cooler
Processing or uses of beryllium and its compounds
Beryllium alloys (stamped and drawn)
Beryllium alloys (molding)
Uncontrolled
After a baghouse
Ceramics
Rocket propellants
Beryllium metal fabrication

TABLE D-36. SOURCES OF BERYLLIUM EMISSIONS FROM FUEL COMBUSTION, COAL

Source
Power plants
Kansas
South Carolina
Illinois
Michigan
Coal beds
Maryland
Ohio
Pennsylvania
Alabama
Georgia
Kentucky-east
Kentucky-west
Tennessee
Virginia
West Virginia
Illinois
Indiana
Arkansas
Iowa
Missouri
Oklahoma
Montana
North Dakota
Wyoming
Colorado
Utah

Source: Sittig 1975

TABLE D-37. SOURCES OF BERYLLIUM EMISSIONS FROM FUEL COMBUSTION, OIL

Source
Residual oil
Power plant, Connecticut
Residual No. 6

Source: Sittig 1975

TABLE D-38. SOURCES OF BERYLLIUM EMISSIONS FROM WASTE INCINERATION

Source
Sewage sludge incinerator Multiple hearth, after wet scrubber Fluidized bed, after wet scrubber
Municipal incinerator, uncontrolled
Municipal incinerator, after electrostatic precipitator

Source: Sittig 1975

Possible Interferences:
High concentrations of aluminum, silicon, and magnesium depress the sensitivity of beryllium determination

2. NIOSH method P & CAM 173 for "General Procedure for Metals"
Same as method P & CAM 121 above

3. NIOSH method P & CAM 288 for "Beryllium and Beryllium Compounds (as Be)"
   a. filter collection
   b. ashing of samples with nitric acid and sulfuric acids; sample is solubilized in 3% sulfuric acid with 2% sodium sulfate added
   c. graphite furnace atomic absorption analyses

   Detection limits:
   0.5-10.0 $\mu g/m^3$

   Possible interferences:
   Calcium's effect is masked by 3% sulfuric acid
   Sodium, potassium, and ammonium enhance the absorbance of beryllium
   Perchloric, phosphoric, and hydrofluoric acids produce interferring non-atomic peaks

4. NIOSH method P & CAM 351 for "Trace Elements"
   a. filter collection
   b. acid digestion
   c. inductively coupled plasma atomic emission spectroscopy (ICR-AES)

   Detection limits:
   5-2000 $\mu g/m^3$, in a 500 l air sample

   Possible interferences:
   Changes in density and viscosity of different acids and acid concentrations affect the sample uptake rate

   Chemical interferences:
   Molecular compound formation
   Ionization effects
   Solute volatilization effects

   Spectral interferences

5. NIOSH method S 339 for "Beryllium and Beryllium Compounds (as Be)"
   a. filter collection
   b. acid digestion
   c. flameless atomic absorption

   Detection limits:
   2.68-11.84 ug/m^3

   Possible interferences:
   None known

6. Tentative Method of Analysis for Beryllium Content of Atmospheric Particulate Matter
   a. cellulose, glass fiber, or membrane filter collection
   b. ash sample
   c. measure fluorescence of an aqueous beryllium solution with ultra violet light in the presence of morin

   Detection limits:
   0.01-1.0 ug Be/10 ml aqueous beryllium solution

   Possible interferences:
   Presence of zinc may interfere slightly

7. Analytical Methods for Beryllium and Beryllium Compounds: See Table D-39

Permissible Exposure Limits:

	OSHA	ACGIH
TWA	2 ug/m^3	2.0 ug/m^3 (0.002 ppm)
Ceiling	5 ug/m^3	
Peak	25 ug/m^3/30 min	

Human Toxicity:

Acute Toxicity:
Inhalation of beryllium vapor causes acute "metal-fume fever" (foundryman's fever), which can be the preliminary stage of beryllium pneumonia

Inhalation of beryllium dust can also cause pneumonia

Beryllium slivers or dusts that penetrate the skin can produce poorly healing sores

TABLE D-39. ANALYTICAL METHODS FOR BERYLLIUM AND COMPOUNDS

Sample matrix	Sample preparation	Assay procedure	Sensitivity or limit of detection
Bulk chemical	Add solutions of uramil-*N,N*-diacetic acid, acetate buffer and water	UV (267 nm)	-
	Add solutions of chromal blue G, cetyltrimethylammonium chloride and acetate buffer; dilute; allow colour to develop	Spectrophotometry (626 nm)	-
	Add hydroxynaphthol blue solution; allow to stand 5 min	Spectrophotometry	2.7 µg
Formulations			
β-Alumina ceramics	Grind; dissolve in strong phosphoric acid solution	AAS	0.02 mg/kg
Technological solution		Aerosol-Spark spectrography	0.001 mg/l
Copper-beryllium alloy	Make complex with sodium (ethylenedinitrilo) tetraacetate; precipitate beryllium as phosphate; ignite; weigh as pyrophosphate	Gravimetry	-
	Add ammonium aurintricarboxylate to form a red lake	Photometry	-
Air	Dissolve collection filter matrix in hydrofluoric acid; add nitric acid and water; boil ; dilute	FAAS AAS	0.05 ng/m^3 2.5 ng/m^3
	Dry collection filter; add nitric and sulphuric acids and distilled, deionized water; reflux at 80°C for 7 hrs ; add EDTA-buffer solution and sodium hydroxide to pH 6; add trifluoroacetylacetone:benzene solution (1:1); decant chelate; wash with sodium hydroxide	GC/EC	
	Extract filter with sulphuric acid; add chrome Azurol S solution, gum arabic solution and EDTA; adjust pH to 2.0; add cetylpyridinium bromide and hexamine solution; adjust to pH 5	Spectrophotometry (605 nm)	-
	Ash collection filter strips; reflux with mixture of nitric and hydrochloric acids containing 55.5 µg/ml indium and yttrium; concentrate extraction liquid; add nitric acid; centrifuge; add 40% lithium chloride solution containing 20% nitric acid and 200 µg/ml indium and yttrium	Optical emission spectroscopy	5.3 mg/m^3

Source: IARC 1980

Chronic Toxicity:

Carcinogenesis--Suspected human carcinogen. There is sufficient evidence of carcinogenicity of some beryllium compounds in experimental animals

Other Chronic Toxicity:
On test in FY 83 for biochemical/cellular/tissue effects, for pulmonary toxicity, and for acute/chronic toxicity (U.S. DHHS 1983)

Industrially used beryllium metal and its compounds cause chronic respiratory disease (beryllium disease or berylliosis)

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Chemical Name

Cadmium

CAS Number

7440-43-9

Chemical Classification

Elemental metal

Synonyms

C.I. 77180

Physical/Chemical Properties

Description:
Soft blue-white malleable metal or grey powder

Boiling point:
767° C

Melting point:
321° C

Atomic weight:
112.4

Atomic formula:
Cd

Vapor pressure:
0 at 20° C

Density:
3.65

Refractive index:
1.13

Solubility:
Insoluble in water; soluble in dilute acids

Photochemical reactivity:

Retention time in the atmosphere is dependent on particle size and meteorological parameters. Cadmium found in the air is usually in particulate form as the oxide, chloride or sulfate

Environmental Fate

About 85 percent of cadmium aerosols were found to be soluble. Cadmium which is emitted to the air is ultimately deposited in the soil and water. The half-life of cadmium in humans has been calculated to be as long as 38 years

Sources of Emission

The primary metals industry (mining and processing), waste disposal by incinerator, fertilizer processing, and the burning of fossil fuels are the principal man-made stationary sources of cadmium emissions to air. Cadmium vaporization occurs at fairly low temperatures, approximately 767° to 907° C, and therefore is readily emitted by processes such as ore roasting, pyrosmelting, steel scrap melting, incineration of wastes and burning of fossil fuels. Total estimated emissions of cadmium from stationary sources are 3,260,000 lb/year and mobile sources add approximately 70,000 lb/year for a total of 3,326,000 lb/year. Some estimates of cadmium emissions by source are presented in Table D-40

Production:

The 1980 domestic production of cadmium and eight high volume cadmium compounds was about 17 million lb and 2 million lb were imported

Uses:

Cadmium and certain cadmium compounds are widely used commercially in electroplating, alloys, solders, plastic stabilizers, batteries, fungicides, and in phosphors and pigments for television tubes, inks, artists' colors, glass, ceramics, textiles, paper, and fertilizers. Emission sources for cadmium from consumptive uses, industrial sources, and processes are presented in Tables D-41 to D-43

TABLE D-40. CADMIUM EMISSIONS

Source	Amount in Tons	% This Pollutant
Copper Mining	NEG	NEG
Zinc Mining	<1	0.01
Lead Mining	NEG	NEG
Primary Copper		
Roasting	229	7.59
Reverberatory Furnace	94	3.12
Converters	270	8.95
Material Handling	59	1.96
Primary Zinc		
Roasting	666	22.07
Sintering	284	9.41
Distillation	90	2.98
Material Handling	NEG	NEG
Primary Nickel	NEG	NEG
Primary Lead		
Sintering	66	2.19
Blast Furnace	19	0.63
Reverberatory	3	0.10
Material Handling	NEG	NEG
Secondary Copper		
Sweating Furnace	70	2.32
Blast Furnace	55	1.82
Iron & Steel		
Blast Furnace	1,000	33.14
Non-Ferrous Alloys		
Furnaces	3	0.10
Material Handling	NEG	NEG
Cadmium Paint Pigments	11	0.36
Cadmium-Barium Plastic Stabilizers	3	0.10
Cadmium-Nickel Batteries	<1	0.01
Miscellaneous Cadmium Products	<1	0.02
Use of Pesticides, Herbicides and Fungicides	<1	0.01
Fertilizer Application	<1	0.02
Incinerators	95	3.15
TOTAL	3,018	100.06

Source: Sittig 1975

TABLE D-41. EMISSION FACTORS FOR CONSUMPTIVE USES OF CADMIUM

Source[a]	Emission factors
Rubber tire wear	0.003 kg/10^6km (0.01 lb/10^6 vehicle miles)
Fungicides	0.02 kg/10^3 liters (0.05 lb/10^3 gal.) of spray
Superphosphate fertilizers	0.0001 kg/10^3kg (0.0002 lb/ton) of fertilizer
Motor oil consumption (in vehicle)	0.0006 kg/10^6km (0.002 lb/10^6 vehicle miles)
Cigarettes	16.0 μg/20 cigarettes

[a] All sources are uncontrolled.

Source: Sittig 1975

TABLE D-42. EMISSION FACTORS FOR CADMIUM FROM INDUSTRIAL SOURCES

Source[a]	Emission Factor
Mining of zinc-bearing ore	0.0005 kg/10^3kg (0.001 lb/ton) of Zn or 0.1 kg/10^3kg (0.2 lb/ton) of Cd mined
Zinc smelters	150 kg/10^3kg (300 lb/ton) of Cd charged or 1.0 kg/10^3kg (2.0 lb/ton) of Zn produced
Copper smelters	650 kg/10^3kg (1300 lb/ton) of Cd charged or 0.4 kg/10^3kg (0.07 lb/ton) of Cu produced
Lead smelters	650 kg/10^3kg (1300 lb/ton) of Cd charged or 0.1 kg/10^3kg (0.2 lb/ton) of Pb produced
Cadmium refining units	13 kg/10^3kg (25 lb/ton) of Cd produced
Secondary copper	2 kg/10^3kg (4 lb/ton) of Cu scrap
Secondary lead	
Reverberatory furnace	0.05 kg/10^6kg (0.1 lb/10^3 tons) of Pb[i]
Reverberatory furnace	0.2 kg/10^6kg (0.4 lb/10^3 tons) of Pb
Steel scrap (galvanized metal)	0.001 kg/10^3kg (0.003 lb/ton) of steel
Cement plants	
Dry process	
Kiln	0.2 kg/10^6kg (0.3 lb/10^3 tons) of feed
Raw mill	0.00005 kg/10^6kg (0.0001 lb/10^3 tons) of feed
Air separator after raw mill	0.0005 kg/10^6kg (0.0009 lb/10^3 tons) of feed
Feed to raw mill	0.0002 kg/10^6kg (0.0003 lb/10^3 tons) of feed
Feed to finish mill	0.003 kg/10^6kg (0.0005 lb/10^3 tons) of feed
Wet process	
Kiln	0.1 kg/10^6kg (0.2 lb/10^3 tons) of feed
Raw mill	0.01 kg/10^6kg (0.02 lb/10^3 tons) of feed
Clinker cooler	0.00005 kg/10^6kg (0.0001 lb/10^3 tons) of feed

[a] In this table, sources are controlled unless otherwise specified.

Source: Sittig 1975

TABLE D-43. EMISSION FACTORS FOR PROCESSES INVOLVING CADMIUM

Source [a]	Emission factor, kg/10^3kg (lb/ton) of cadmium charged
Pigments	8 (15)
Plastic stabilizers	3 (6)
Alloys and solders	5 (10)
Batteries (Ni-Cd)	1 (2)
Miscellaneous (x-ray screens, cathode ray tubes, nuclear reactor components, etc.)	1 (2)

[a] Emission are uncontrolled unless otherwise specified.

Source: Sittig 1975

Disposition:
Emission factors for cadmium from waste incineration have been estimated in the range of 0.003 lb/10^3 tons to 0.8 lb/10^3 tons depending on source. These emission factors are presented in Table D-44

Sampling and Analytical Methods

Cadmium dust--NIOSH Manual of Analytical Methods; Method number S 312

Sampling method:
Sample containing filters are wet-ashed with nitric acid and the sample is solubilized in hydrochloric acid

Analytical method:
The sample solution is aspirated into an atomic absorption spectrophotometer. The absorbance is proportional to the cadmium concentration

Detection limits:
This method was validated in the range of 0.12 to 0.98 mg/m^3 using a 2.5 l sample

TABLE D-44. EMISSION FACTORS FOR CADMIUM FROM WASTE INCINERATION

Source [a]	Emission factor
Sewage sludge incinerators	
Multiple hearth [c,d]	0.004 kg/10^3kg (0.007 lb/ton) of solid waste incinerated [g]
Fluidized bed [c]	0.0002 kg/10^3kg (0.003 lb/10^3 tons) of solid waste incinerated
Municipal incinerator	
Refuse only [c]	0.4 kg/10^6kg (0.8 lb/10^3 tons) waste incinerated
Refuse and sludge [c]	0.3 kg/10^6kg (0.6 lb/10^3 tons) waste incinerated
Overall value for uncontrolled solid waste incineration (municipal) [e]	0.0002 kg/10^3kg (0.003 lb/ton) of solid waste incinerated
Lubricating oil [f]	0.0002 kg/10^3 liters (0.002 lb/10^3 gal.) of oil

[a] In this table, emissions are controlled unless otherwise specified.

Source: Sittig 1975

Possible interferences:
There are no known spectral line interferences for this assay

Cadmium fume--NIOSH Manual of Analytical Methods; Method number S313

The method is simple and specific for cadmium, but will not distinguish between cadmium dust and cadmium fume

Permissible Exposure Limits

OSHA Standard
0.1 mg/m^3 8-hr TWA (fumes)
0.3 mg/m^3 ceiling (fumes)
0.2 mg/m^3 8-hr TWA (dust)
0.6 mg/m^3 ceiling (dust)

Human Toxicity

Acute Toxicity:
About 1 mg/m^3 of cadmium inhaled over an 8-hour period gives rise to clinical symptoms such as pulmonary congestion and edema; an air level of cadmium of 5 mg/m^3 inhaled over the same period can be lethal

Chronic Toxicity:

Carcinogenicity--The evidence of carcinogenicity in humans is limited; studies have suggested that occupational exposure to cadmium (possibly the oxide) increases the risk of prostate, respiratory, and genitourinary cancers in humans. The evidence for the carcinogenicity of cadmium and certain cadmium compounds in experimental animals is sufficient

Mutagenicity--There is conflicting evidence with regard to the production of chromosomal aberrations in humans exposed to cadmium

Teratogenicity--There is no evidence that cadmium is teratogenic in humans. Teratogenic effects have been demonstrated in animals using very high doses

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Chemical Name

Carbon Tetrachloride

CAS Number

56-23-5

Chemical Classification

Halogenated hydrocarbon

Synonyms

Benzinoform; carbon chloride; carbona; flukoids; freon 10; halon 104; methane tetrachloride; methane, tetrachloro-necatorina; perchloromethane; tetrachlorocarbon; tetrachloromethane; tetrafinol; tetraform; tetrasol

Physical/Chemical Properties

Description:
Clear, colorless heavy liquid

Boiling point:
76.75° C

Melting point:
-22.8° C

Molecular weight:
153.8

Chemical formula:
CCl_4

Vapor pressure:
91 mm Hg 20° C
113 mm Hg 25° C

Vapor density:
5.32 (air = 1)

Refractive index:
1.4607 20° C

Solubility:
Miscible in organic liquids. Solubility in water 0.08 g/100 ml water at 25° C.

Log partition coefficient (octanol/water):
2.64

Photochemical reactivity:
CCl_4 is stable in the troposphere and there is apparently an absence of physical or biological removal mechanisms. Therefore, CCl_4 would be expected to be a precursor of stratospheric ozone-destroying chlorinations

Chemical reactivity:
Chemically not reactive; not easily hydrolyzed

Environmental Fate

CCl_4 is stable in air and water and tends to bioaccumulate. It has a half life of about 10 years

Sources of Emissions

Production:
U.S. production of CCl_4 was estimated as over 1 billion lb in 1974 and dropped to an estimated 717 million lb in 1981
Production emissions for 1978 are presented in Table D-45

Uses:
The major end-use for CCl_4 is in the production of fluorocarbon gases. The remaining CCl_4 production is used in solvent applications as an oil, wax and fat extractant; in rubber cement; in polishes, paints and lacquers; in printing inks and stains; and in pesticide manufacturing. Estimated end use consumption; nationwide emissions and point sources are presented in Tables D-46 and D-47 and Figure D-3

Storage:
Storage emission factors were reported from two site visits as 0.000442 and 0.00374 lb per lb used

TABLE D-45. 1978 CARBON TETRACHLORIDE PRODUCTION EMISSIONS

Company	Location	Process Vent Emissions (lb/yr)	Process Vent Emissions (g/sec)[b]	Storage Vent Emissions (lb/yr)	Storage Vent Emissions (g/sec)[b]	Fugitive Emissions (lb/yr)	Fugitive Emissions (g/sec)[b]	Total Emissions (lb/yr)	Total Emissions (g/sec)[b]
Allied Chemical	Houndsville, WV	20	Nil	510	0.007	290	0.004	820	0.012
Dow Chemical	Freeport, TX	370	0.005	8,880	0.128	5,030	0.072	14,280	0.206
	Pittsburg, CA	350	0.005	70,140	1.010	20,580	0.296	91,070	1.311
	Plaquemine, LA	550	0.008	108,550	1.563	31,850	0.459	140,950	2.029
Dupont	Corpus Christi, TX	1,790	0.026	355,710	5.121	104,370	1.503	461,870	6.649
FMC	South Charleston, WV	1,560,000	22.458	530,400	7.636	93,600	1.347	2,184,000	31.441
Stauffer	Lemoyne, AL	1,040,000	14.972	353,600	5.091	62,400	0.898	1,456,000	20.961
	Louisville, KY	150	0.002	30,060	0.433	8,820	0.127	39,030	0.562
Vulcan	Geismar, LA	400	0.006	78,490	1.130	23,030	0.332	101,920	1.467
	Wichita, KA	260	0.004	51,770	0.745	15,190	0.219	67,220	0.968
Total		2,603,890		1,508,110		365,160		4,557,160	

[b]Based on 8760 hr/yr operation.

Source: Systems Applications, Inc. 1980

TABLE D-46. 1978 CARBON TETRACHLORIDE CONSUMPTION BY END USE

End Use	Percent of Total Consumption	End Use Consumption (M lb)
Dichlorodifluoromethane (F-12)	55	412.5
Trichlorofluoromethane (F-11)	34	255.0
Solvents and miscellaneous	8	60.0
Export	3	22.5
Total	100	750.0

Source: Systems Applications, Inc. 1980

TABLE D-47. 1978 ESTIMATED CARBON TETRACHLORIDE NATIONWIDE EMISSION LOSSES

Source	Estimated National Emission (M lb/yr)
Production	4.56
Dichlorodifluoromethane (F-12) Trichlorofluoromethane	0.47
Solvents, miscellaneous	60.0
Export	0
Total	65.03

Source: Systems Applications, Inc. 1980

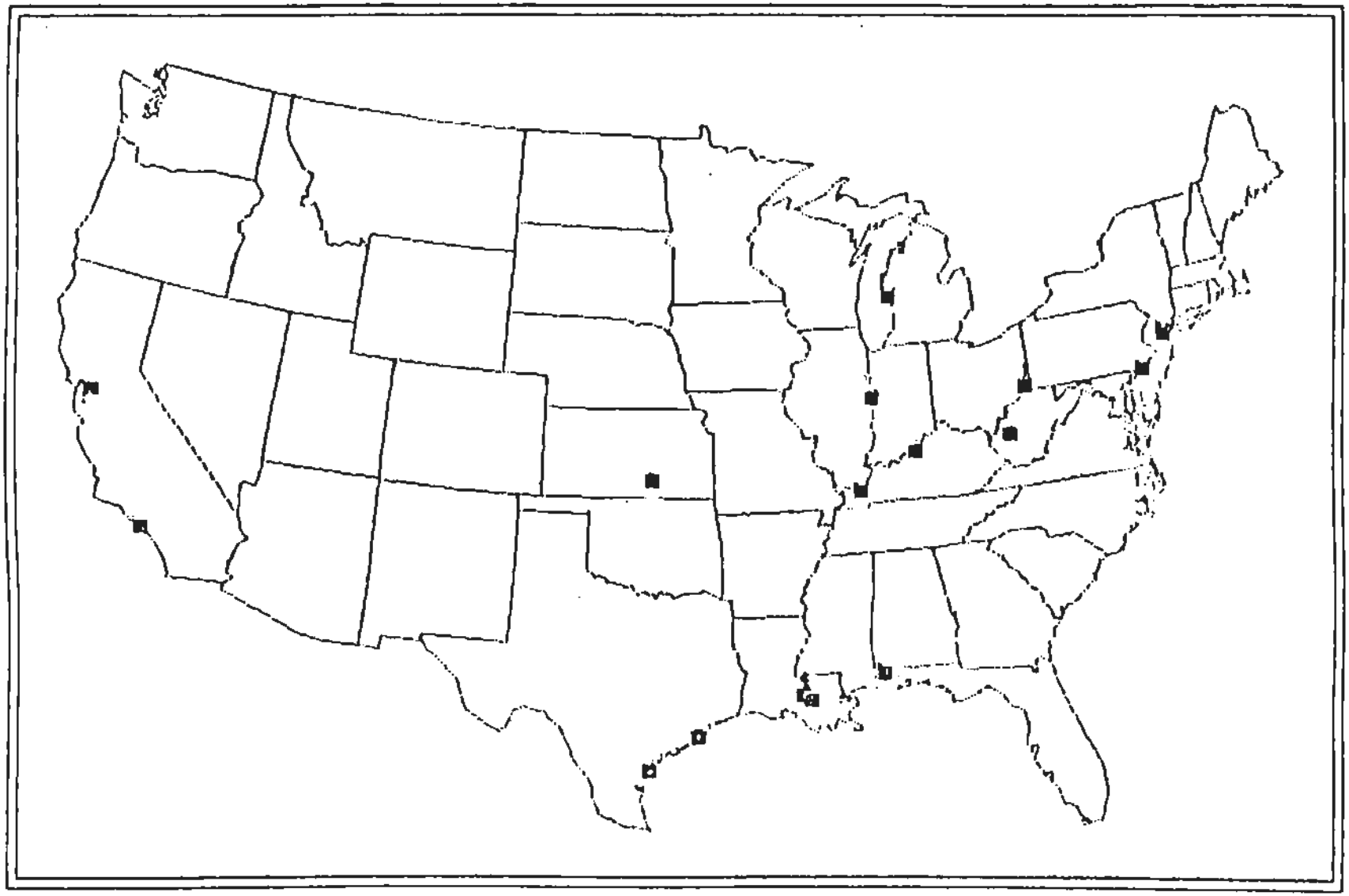

Figure D-3. Specific point sources of carbon tetrachloride emissions.

Source: Systems Applications, Inc. 1980

Disposition:
Emissions data from disposition were not available. Most large-scale consumers recover impure solvents by distillation. Residues from recovery operations are waste dumped or burnt in special waste incinerators

Sampling and Analytical Methods

NIOSH Manual of Analytical Methods--Method Number S 314

Sampling method:
A known volume of air is drawn through a charcoal tube to trap the organic vapors present

Analysis method:
An aliquot of the sample that has been desorbed with carbon disulfide is injected into a gas chromatograph

Detection limits:
The working range of this method is 16-480 mg/m^3 for a 15 l sample size

Possible interferences:
1. High humidity
2. Compounds present in the sample with the same column retention size

Materials Damage

Reacts sometimes exposively with aluminum and its alloys

Permissible Exposure Limits

OSHA Standard
10 ppm 8-hr TWA
25 ppm ceiling
200 ppm maximum peak for 5 min in any 4-hr period

Human Toxicity

Acute Toxicity:
Humans exposed to 14,000 ppm for 50 s were rendered unconscious. CCl_4 can produce coma and death from respiratory arrest or circulatory collapse

Chronic Toxicity:

Carcinogenesis--There are suggestive case reports of liver cancer in humans. There is sufficient evidence that CCl_4 is carcinogenic in experimental animals

Mutagenicity--There is no evidence that CCl_4 is mutagenic

Teratogenicity--CCl_4 is fetotoxic in experimental animals. There were no data available in humans. Biochemical, cellular tissue effects, and systemic organ toxicity are on study in FY83 (U.S. DHHS 1983)

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Chemical Name

Chlorobenzene

CAS Number

108-90-7

Chemical Classification

Halogenated cyclic hydrocarbon

Synonyms

Monochlorobenzene, phenyl chloride, chlorobenzol, MCB, benzene chloride

Physical/Chemical Properties

Description:
Colorless liquid, very refractive, highly volatile

Boiling point:
131.7° C

Melting point:
-45.6° C

Molecular weight:
112.56

Chemical formula:
C_6H_5Cl

Vapor pressure:
12.14 mm at 25° C

Density:
1.1058 at 20° C (rel. water at 4° C)

Vapor density:
3.88 (air = 1)

Refractive index:
1.5216 (25° C) highly refractive

Solubility:
Insoluble in water

Log partition coefficient (octanol/H_2O):
2.84

Photochemical reactivity:
No photochemical degradation

Chemical reactivity:
At ordinary temperatures and pressure, chlorobenzene is unaffected by the presence of air, moisture or light. At moderate temperatures, chlorobenzene is also nonreactive

Sources of Emissions

Production/processing:
Commercially important chlorobenzenes are mono-chlorobenzene and the two dichlorobenzenes, ortho and para. In 1978 an estimated 355 million lb of monochlorobenzene was produced, 59 million lb of ortho-dichlorobenzene and 55 million lb of para-dichlorobenzene. Tables D-48 through D-50 present the producers, location, and estimated production. Tables D-51 through D-53 present the estimated emissions at these sites from process, storage and fugitive (emissions from plant leaks)

Uses:
The end-use distribution of chlorobenzenes is presented in Table D-54

Estimated emissions from end-uses are presented in Table D-55

Disposition:
Chlorobenzenes should be disposed of by atomizing in a combustion chamber equipped with appropriate effluent gas cleaning devices. Chlorobenzenes have been detected at hazardous waste sites. Emissions data from disposition were not located

Sampling and Analytical Methods

NIOSH Manual of Analytical Methods: Method number S133

Sampling methods (monochlorobenzene):
A known volume of air is drawn through a charcoal tube to trap the organic vapors present

Analysis:
Desorb sample with carbon disulfide and analyze by gas chromography

TABLE D-48. MONOCHLOROBENZENE PRODUCERS

Source	Location	1978 Estimated Production (10^6 lb/yr)	1978 Estimated Capacity (10^6 lb/yr)
Dow	Midland, MI	101	220
ICC	Niagara Falls, NY	5	10
Monsanto	Sauget, IL	69	150
Montrose	Henderson, NV	32	70
PPG	New Martinsville, WV	79	172
Standard Chlorine	Delaware City, DE	69	150
Total		355	772

Source: Systems Applications, Inc. 1980

TABLE D-49. o-DICHLOROBENZENE PRODUCERS

Source	Location	1978 Estimated Production (10^6 lb/yr)	1978 Estimated Capacity (10^6 lb/yr)
Dow	Midland, MI	12	30
Monsanto	Sauget, IL	6	16
PPG	New Martinsville, WV	15	38
Standard Chlorine	Delaware City, DE	19	50
Specialty Organics	Irwindale, CA	1	2
Montrose	Henderson, NV	3	7
ICC	Niagara Falls, NY	3	8
Total		59	151

Source: Systems Applications, Inc. 1980

TABLE D-50. p-DICHLOROBENZENE PRODUCERS

Source	Location	1978 Estimated Production (10^6 lb/yr)	1978 Estimated Capacity (10^6 lb/yr)
Dow	Midland, MI	9	30
Monsanto	Sauget, IL	4	12
PPG	New Martinsville, WV	13	40
Standard Chlorine	Delaware City, DE	24	75
Specialty Organics	Irwindale, CA	1	2
Montrose	Henderson, NV	2	7
ICC	Niagara Falls, NY	2	8
Total		55	174

Source: Systems Applications, Inc. 1980

TABLE D-51. MONOCHLOROBENZENE EMISSIONS FROM PRODUCTION SITES

Company	Location	Emissions (lb/yr)			Total Emissions[a]	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)[b]
Dow	Midland, MI	208,060	45,450	69,690	323,200	4.65
ICC	Niagara Falls, NY	10,300	2,250	3,450	16,000	0.23
Monsanto	Sauget, IL	142,140	31,050	47,610	220,800	3.18
Montrose	Henderson, NV	65,920	14,400	22,080	102,400	1.47
PPG	New Martinsville, WV	162,740	35,550	54,510	252,800	3.64
Standard Chlorine	Delaware City, DE	142,140	31,050	47,610	220,800	3.18
Total		731,300	159,750	244,950	1,136,000	

[a]Based on the following emission factors (lb emitted per lb produced).

Process	0.00206	A -	(derived from site visit data)
Storage	0.00045	A -	(derived from site visit data)
Fugitive	0.00069	A -	(derived from site visit data)
Total	0.00320		

[b]Based on 8760 hr/yr operation.

Source: Systems Applications, Inc. 1980

TABLE D-52. o-DICHLOROBENZENE EMISSIONS FROM PRODUCTION SITES

Company	Location	Emissions (lb/yr)			Total Emissions[a]	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)[b]
Dow	Midland, MI	27,840	5,640	9,120	42,600	0.61
Monsanto	Sauget, IL	13,920	2,820	4,560	21,300	0.31
PPG	New Martinsville, WV	34,800	7,050	11,400	53,250	0.77
Standard Chlorine	Delaware City, DE	44,080	8,930	14,440	67,450	0.97
Specialty Organics	Irwindale, CA	2,320	470	760	3,550	0.05
Montrose	Henderson, NV	6,960	1,410	2,280	10,650	0.15
ICC	Niagara Falls, NY	6,960	1,410	2,280	10,650	0.15
Total		136,880	27,730	44,840	209,450	

[a]Based on the following emission factors (lb emitted per lb produced).

Process	0.00232	A	- (derived from site visit data)
Storage	0.00047	A	- (derived from site visit data)
Fugitive	0.00076	A	- (derived from site visit data)
Total	0.00355		

[b]Based on 8760 hr/yr operation.

Source: Systems Applications, Inc. 1980

TABLE D-53. p-DICHLOROBENZENE EMISSIONS FROM PRODUCTION SITES

Company	Location	Emissions (lb/yr)			Total Emissions[a]	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)[b]
Dow	Midland, MI	52,290	3,690	9,180	65,160	0.94
Monsanto	Sauget, IL	23,240	1,640	4,080	28,960	0.42
PPG	New Martinsville, WV	75,530	5,330	13,260	94,120	1.35
Standard Chlorine	Delaware City, DE	139,440	9,840	24,480	173,760	2.50
Specialty Organics	Irwindale, CA	5,810	410	1,020	7,240	0.10
Montrose	Henderson, NV	11,620	820	2,040	14,480	0.21
ICC	Niagara Falls, NY	11,620	820	2,040	14,480	0.21
Total		319,550	22,550	56,100	398,200	

[a]Based on the following emission factors (lb emitted per lb produced).

Process	0.00581	A -	(derived from site visit data)
Storage	0.00041	A -	(derived from site visit data)
Fugitive	0.00102	A -	(derived from site visit data)
Total	0.00724		

[b]Based on 8760 hr/yr operation.

Source: Systems Applications, Inc. 1980

TABLE D-54. CHLOROBENZENES END-USE DISTRIBUTION 1978

Source	Usage (million lb/yr)	Usage (%)
Monochlorobenzene	355	100
Pesticide/degreasing solvents	174	49
Nitrochlorobenzene	107	30
DDT	25	7
Diphenyl oxide	28	8
Miscellaneous, others	21	6
o-Dichlorobenzene	59	100
3,4 dichloroaniline	38	65
Toluene diisocyanate solvent	9	15
Miscellaneous solvents (paint removers, engine cleaners, etc.)	6	10
Dye manufacturing	3	5
Pesticide intermediate	3	5
p-Dichlorobenzene	55	100
Space deodorant	27.5	50
Moth control	22	40
Pesticide intermediate	5.5	10

Source: Systems Applications, Inc. 1980

TABLE D-55. 1978 NATIONWIDE EMISSIONS OF CHLOROBENZENES

Source	Nationwide Emissions (lb/yr)
Monochlorobenzene	
Production	1,136,000
Pesticide/degreasing solvents	174,000,000
Nitrochlorobenzene	171,200
DDT	12,500
Diphenyl oxide	28,500
Miscellaneous, other	27,930
Sub-total	175,376,130
o-Dichlorobenzene	
Production	209,450
3,4-Dichloroaniline	57,000
Toluene diisocynnate solvent	9,000,000
Miscellaneous solvents	6,000,000
Dye manufacturing	1,500
Pesticide intermediate	1,500
Sub-total	15,269,450
p-Dichlorobenzene	
Production	398,200
Space deodorant	27,500,000
Moth control	22,000,000
Pesticide intermediate	2,750
Sub-total	49,900,950
Total - all chlorobenzenes	240,546,530

Source: Systems Applications, Inc. 1980

Detection limits:

This method has been validated over the range of 183-736 mg/m^3 (25° C 761 mm Hg) using a 10 l sample

Possible interferences:

1. High humidity
2. Compounds present with the same column retention time.

Materials Damage

Liquid chlorobenzene may attack some forms of plastics, rubber, and coatings

Permissible Exposure Limit

OSHA Standard

75 ppm (345 mg/m^3)

The immediately dangerous to life or health (IDLH) concentration is 2400 ppm

Human Toxicity

Chronic Toxicity:

Carcinogenicity--No adequate animal or human epidemiological studies are available for evaluation. However, a long-term animal carcinogenesis bioassay is being completed in FY83 by the National Toxicology Program for monochlorobenzene; a long-term animal carcinogenesis bioassay for p-dichlorobenzene is being initiated in FY83 (U.S. DHHS 1983)

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Chemical Name

Chloroform

CAS Number

67-66-3

Chemical Classification

Halogenated unsaturated hydrocarbon, halogenated methane, chlorinated aliphetic hydrocarbon, halocarbon

Synonyms

Chloroform (DOT), chloroform (BCI), formyl trichloride, freon 20, methane trichloride, methane, trichloromethenyl chloride, methenyl trichloride, methyl trichloride, NCI-C02686, R 20, R 20 (refrigerant), R 20 (van), trichloroform, trichloromethane

Physical/Chemical Properties

Description:
Heavy, water-white, volatile liquid with a pleasant, non-irritant odor; nonflammable

Boiling point:
61.25° C

Melting point:
-63.5° C

Molecular weight:
119.39

Chemical formula:
$CHCl_3$

Vapor pressure:
200 mm Hg at 25.9° C; 246 mm Hg at 30° C

Refractive index:
1.4467 at 20° C

Solubility:
Miscible with principal organic solvents; slightly soluble in water (8.0 g/l)

Octanol/water log partition coefficient:
1.17

Photochemical reactivity:
Highly reactive in the troposphere and will undergo thermal tropospheric reactions
When exposed to air and light, chloroform breaks down to phosgene, HCl, and chlorine
half-life = <1 year (OH) atmospheric loss
0.9% loss/day (12 sun hrs)

Vapor density:
4.12

Chemical reactivity:
Reacts with strong caustics, chemically active metals (aluminum, magnesium powder, sodium, potassium)

Environmental Fate

Degrades easily in the atmosphere to phosgene and chlorine monoxide with a half life of ~2-3 months
Found less frequently than other chlorinated hydrocarbons. Chloroform is an ubiquitous material in the atmosphere at trace amounts, due to industrial emissions, release from end use applications and to formation due to reaction of chlorine and methanol in the atmosphere

Sources of Emissions

Production:
176 million lb in 1977
chlorination of methane
hydrochlorination of methanol or methyl chloride chlorination
reduction of carbon tetrachloride

Uses:

In production of chlorodifluoromethane

To produce fluorocarbon 22, a refrigerant and aerosol propellant, to make fluorocarbon resins (used 107,250 tons in 1975 or ~80% of chloroform production)

As an industrial solvent; to make pharmaceuticals or pesticides (leads to a population exposed to ~300,000 lb/year of chloroform)

As a laboratory solvent

Heat transfer medium

As a fire extinguisher

Storage and Transport:

Should be stored in sealed containers in a cool place; glass containers should be dark green or amber

Technical grade chloroform can be stored in lead lined or mild steel containers of all welded construction

Technical grade is shipped in galvanized steel drums, tank trucks, or tank cars

Dispostion:

Production losses to air

Emissions from bleaching of paper pulp using chlorine

Decomposition of perchloroethylene may be a source of chloroform in the atmosphere

Occurs in leachate of sanitary landfills

Tables D-56 through D-58 and Figure D-4 present chloroform production, end use, and emissions data

Sampling and Analytical Methods

1. NIOSH method S 351 for chloroform
   a. adsorption on charcoal
   b. desorption with carbon disulfide
   c. gas chromatography

   Detection limits:
   0.10 mg/0.5 to 13 l sample

TABLE D-56. PRODUCTION OF CHLOROFORM

Source	Location	1978 Estimated Production (10^6 lb/yr)	Process
Allied Chemical Corp.	Moundsville, WV	19	A,B
Diamond Shamrock	Belle, WV	26	A
Dow Chemical	Freeport, TX	64	B
	Plaquemine, LA	64	A
Stauffer Chemical Co.	Louisville, KY	49	A
Vulcan Materials Co.	Geismar, LA	38	A
	Wichita, KS	70	A,B
Total		330	

(A) - Methanol hydrochlorination process or methyl chloride chlorination process.
(B) - Methane chlorination process.

Source: Systems Applications, Inc. 1980

TABLE D-57. 1978 CHLOROFORM CONSUMPTION BY END-USE

End Use	Percent of Total Consumption	End Use Consumption (M lb)
Chlorodifluoromethane (F-22) refrigerants	61	201.3
Chlorodifluoromethane (F-22) resin intermediates	25	82.5
Export	7	23.1
Solvent/miscellaneous	7	23.1
Total	100	330.0

Source: Systems Applications, Inc. 1980

TABLE D-58. 1978 CHLOROFORM PRODUCTION EMISSIONS

Company	Location	Process Vent Emissions (lb/yr)	Process Vent Emissions (g/sec)[b]	Storage Vent Emissions (lb/yr)	Storage Vent Emissions (g/sec)[b]	Fugitive Emissions (lb/yr)	Fugitive Emissions (g/sec)[b]	Total Emissions (lb/yr)	Total Emissions (g/sec)
Allied Chemical	Moundsville, WV	140	0.002	17,870	0.257	4,630	0.067	22,640	0.326
Diamond Shamrock	Belle, WV	200	0.003	25,350	0.365	6,420	0.092	31,970	0.460
Dow Chemical	Freeport, TX	260	0.004	18,470	0.266	11,500	0.166	30,230	0.435
	Plaquemine, LA	480	0.007	62,400	0.898	15,810	0.228	78,690	1.133
Stauffer	Louisville, KY	370	0.005	47,780	0.688	12,100	0.174	60,250	0.867
Vulcan	Geismar, LA	290	0.004	37,050	0.533	9,390	0.135	46,730	0.673
	Wichita, KA	500	0.007	63,450	0.913	16,820	0.242	80,770	1.163
Total		2,240		272,370		76,670		351,280	

Source: Systems Applications, Inc. 1980

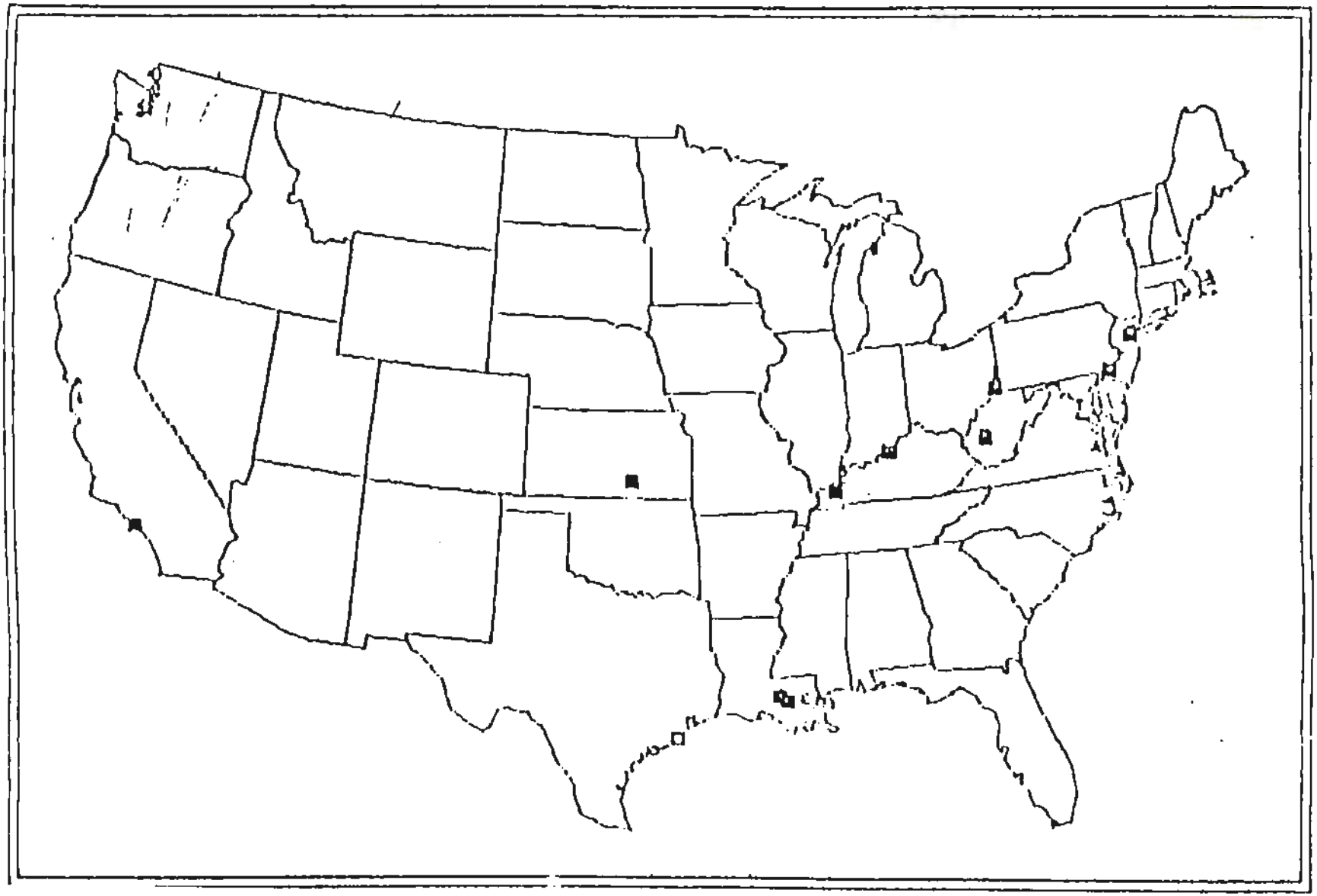

Figure D-4. Specific point sources of chloroform emissions.

Source: Systems Applications, Inc. 1980

Possible interferences:
High humidity (decreases breakthrough volume)
Presence of other solvents
Presence of other compounds with same retention time as chloroform

2. Method B (Appendix A): C_2-C_{18} hydrocarbons and other nonpolar organics with a boiling point -100 to 175° C

Whole air collection in canister
Cryogenic concentration
Gas chromatography/flame ionization detection

Detection limits:
0.1 ppb per 100 ml sample

Possible interferences:
Reactive and water soluble compounds are not readily analyzed

3. Method C (Appendix A): C_6-C_{12} hydrocarbons and other nonpolar organics with boiling point between 60 and 200° C

Adsorption on tenax
Thermal desorption
Gas chromatography/mass spectrometry analysis

Detection limits:
1-200 ppt for a 20 l sample

Possible interferences:
Blank levels usually limit sensitivity
Artifacts due to reactive components (O_3, NO_x) can be a problem
Sample can be analyzed only once

4. Method D (Appendix A): C_6-C_{12} hydrocarbons and other nonpolar organics with boiling point of 60-200° C

Adsorption in Tenax
Thermal desorption into canisters
Gas chromatography/flame ionization detection, or gas chromatography/mass spectrometry analyses

Detection limits:
0.01-1 ppb for a 20 l sample

Possible interferences:
Blanks and artifact problems as in method C, above

Materials Damage

Liquid chloroform will attack some forms of plastics, rubber, and coatings

Permissible Exposure Limits

	OSHA	NIOSH	ACGIH
TLV	50 ppm (240 mg/m^3)		10 ppm (50 mg/m^3)
Ceiling		2 ppm/1 hour	50 ppm (225 mg/m^3)

Human Toxicity

Acute Toxicity:

Chloroform vapor is a central nervous system depressant and is toxic to the liver and kidneys

Chronic Toxicity:

Carcinogenicity--There is sufficient evidence for the carcinogenicity of chloroform in experimental animals

Mutagenesis--Chloroform failed to produce mutagenetic changes in the Chinese hamster

Teratogenesis--Chloroform appears to be somewhat teratogenic and highly embryotoxic in animals

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Chemical Name

Chloroprene

CAS Number

126-99-8

Chemical Classification

Halogenated hydrocarbon

Synonyms

2-chloro-1,3-butadiene; chlorobutadiene; beta-chloroprene

Physical/Chemical Properties

Description:
Colorless volatile liquid with an ether-like odor

Boiling point:
58.9° C

Melting point:
-130° C

Molecular weight:
88.5

Chemical formula:
C_4H_5Cl

Vapor pressure:
179 mm Hg at 20° C
215.4 mm Hg at 25° C

Vapor density:
3 (air = 1)

Refractive index:
n_D^{20} 1.4583

Solubility:
Partially soluble in water; soluble in most organic solvents

Photochemical reactivity:
Resistant to sunlight

Chemical reactivity:
Reacts with oxygen to form peroxides. Enters into addition reactions with halogens. Forms high molecular weight elastomeric polymers

Sources of Emissions

Production/processing:
EPA reports domestic production of chloroprene at 1 billion lb by four producers in one region (public record, TSCA Inventory). EPA/OAQPS has estimated that within 20 km of manufacturing sites exposure to chloroprene is at median concentrations of <0.05 to >0.025 $\mu g/m^3$

Uses:
Most of the chloroprene is used in the production of polychloroprene elastomers. Airborne concentrations at a chloroprene polymerization plant ranged from 14-1400 ppm in the make-up area, 130-6800 ppm in the reactor area, and 110-250 ppm in the latex area

Storage and transport:
Chloroprene has to be stored and transported cooled to -10° C under an inert gas. Emissions are probably minimal

Disposition:
Due to high reactivity and volatility chloroprene and chloroprene-containing wastes cannot be dumped. Wastes have to be destroyed in special waste incinerators

Sampling and Analytical Methods

NIOSH Manual of Analytical Methods. Method number S 112

Sampling method:
A known volume of air is drawn through a charcoal tube containing activated coconut charcoal to trap chloroprene vapors

Analytical method:
Chloroprene is desorbed from the charcoal with carbon disulfide and the sample is analyzed by GC

Detection limits:
This method was validated over the range of 44 to 174 mg/m^3 at 21° C 760 mm Hg using a 3 l sample

Possible interferences:
Any compound having the same column retention time under the same analytical operating conditions could cause interference of chemical identity

Permissible Exposure Limits

OSHA Standard:
25 ppm (90 mg/m^3)

NIOSH recommendation:
1 ppm/15 min ceiling

Human Toxicity

Acute toxicity:
High concentrations (no exact data) lead to collapse and death from acute pulmonary edema

Chronic toxicity:

Carcinogenicity--Inadequate evidence

Mutagenicity--Epidemiological evidence consistent with experimental evidence that chloroprene is mutagenic in humans

Other chronic toxicity:
Reproductive toxicity supported by epidemiological evidence

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Chemical Name

Chromium

CAS Number

7440-47-3

Synonym

Chrome

Chemical Classification

Elemental metal

Physical/Chemical Properties

Description:
Silver, blue-white, hard, brittle lustrous metal

Boiling point:
2672° C

Melting point:
1857 ±20° C

Atomic weight:
51.9

Atomic formula:
Cr

Vapor pressure:
Essentially 0 at 210° C

Solubility:
Insoluble in water; some chromium salts are very soluble in water

Density:
7.2 g/cm^3 at 28° C

Chemical reactivity:
Not oxidized by air even in the presence of moisture; reacts with dilute hydrochloric and sulfuric acids; attacked by caustic alkalies and alkali carbonates

Environmental Fate

Under environmental conditions, when oxygen is present, chromium exists as elemental, trivalent or hexavalent chromium

Source of Emissions

Production/processing:
Chromite ore consists of varying percentages of chromium, iron, aluminum and magnesium oxides. Current U.S. mine production is believed negligible. In 1978, 17,705 million lb of chromite ore were imported

The 1980 domestic production of chromium and ten important chromium compounds was an estimated 750 million lb. Approximately 100 million lb were imported in 1980

Uses:
Chromium metal and metal alloys are used primarily in stainless, alloy and heat resisting steel. Other chromium compounds are used in chemical processing, refining, plating and a number of specialty uses. Table D-59 presents sources and estimates of chromium emissions for 1970

Disposition:
The galvanizing and metal processing industries are a major source of chromate waste

Chromium-containing sludges or residues cannot be disposed of in incinerators as the trivalent chromium is reoxidized to the toxic hexavalent chromium with heat. Emissions data from disposition were not available

TABLE D-59. SOURCES AND ESTIMATES OF CHROMIUM-CONTAINING EMISSIONS IN 1970

Source	Uncontrolled Emission Factor lb/ton	Uncontrolled Emission Factor kg/10^3 kg	Reliability Code	Production Level (tons/yr)	Percent Cr in Emissions	Emissions of Cr Before Controls (tons/yr)	Estimated Level of Emission Control	Emissions of Cr After Controls (tons/yr)
Mining								
None in U.S.A.						0		0
Refining								
Ferrochromium								
Electric furnace	(200-830) 500[a]	(100-415) 250[a]	C	375,500	22	20,600	40%	12,360
Material handling	10	5	B	375,500	65	1,220	32%	830
Electrolytic chromium	0.048	0.024	C	9,000	51	neg	95%	neg
Refractory								
Nonclad	150	75	C	60,300	b	4,500	64%	1,630
Electric cast	225[a]	112	C	6,700	b	754	77%	173
Chemical Processing								
Dichromate	30	15	C	61,000	b	920	90%	92
Other chemicals	-	-	-	-	-	-	-	24
Steel and Alloys								
Chromium steels	25	12	C	189,000	b	2,362	78%	520
Cast iron	75	38	C	5,000	b	188	99%	2
Super alloys and alloys	25	12	C	12,000	b	150	78%	33
General steel making	N.A.	N.A.		N.A.	N.A.	N.A.	N.A.	100[c]
Inadvertent Sources								
Coal combustion	N.A.	N.A.		33,800,000[e]	0.026	8,700	82%	1,564
Oil combustion	N.A.	N.A.		287,000[d]	0.13	370	0	370
Cement production	N.A.	N.A.		934,000[d]	0.03	N.A.	N.A.	280
Incineration	N.A.	N.A.		931,000[d]	0.017	N.A.	N.A.	158
Asbestos	N.A.	N.A.		6,579	0.15	10	99%	0
Total						39,774	54%	18,136

[a] Intermediate value
[b] Emission factor multiplier equal to tons of Cr processed or handled annually.
[c] Needs further investigation
[d] Emissions, after control
[e] Emissions, before control

Sampling and Analytical Methods

1. Total particulate chromium sampling method

   NIOSH Manual of Analytical Methods. Method number P&CAM 152

   Sampling:
   Atmospheric samples are obtained by drawing a measured volume of air through a 0.8 μm filter

   Analysis:
   The filter is wet-ashed and analyzed for chromium by atomic absorption spectroscopy

   Detection limit:
   The working range in air is from 0.1 mg/m^3 to 0.4 mg/m^3 using a sample of 100 l of air

   Possible interferences:
   A number of metallic elements may interfere with the atomic absorption analysis

2. Chromium, metal and insoluble compounds

   NIOSH Manual of Analytical Methods. Method number S352

   Sampling:
   A known volume of air is drawn through a cellulose ester membrane filter to collect the analyte

   Analysis:
   Samples are ashed to destroy the filter and other organic compounds in the sample, and the chromium metal and other insoluble chromium compounds are dissolved in nitric acid. The solution of sample is aspirated into the flame of an atomic absorption spectrophotometer for analysis

   Detection limits:
   A 90 l sample has a working range of 0.05 to 2.5 mg/m^3 at 26° C 761 mm Hg

   Possible interferences:
   1. Soluble chromium compounds
   2. Iron and nickel present in the sample

Permissible Exposure Limit

OSHA standard:
0.1 mg/m^3 ceiling (chromic acid and chromates);
0.5 mg/m^3 8-hr TWA (soluble chromic or chromous salts);
1 mg/m^3 8-hr TWA (metal and insoluble salts)

Human Toxicity

Chronic toxicity:

Carcinogenicity--There is sufficient evidence for the carcinogenicity of chromium and certain chromium compounds both in humans and experimental animals. There is sufficient evidence for increased incidence of lung cancer among workers in the chromate-producing industry, and possibly among chromium platers and alloy workers

Mutagenicity--An increased frequency of chromosomal aberrations has been observed in workers exposed to chromium (VI) compounds

Teratogenicity--Some teratogenic effects in animals have been reported with chromium (III) and chromium (VI) compounds using very high doses. No human data are available

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Chemical Name

2,3,7,8-Tetrachlorodibenzo-para-dioxin (TCDD)

CAS Number

1746-01-6

Chemical Classification

Polychlorinated dioxin. There are 75 chlorinated dibenzo-para-dioxins identified of which 2,3,7,8-TCDD is the most toxic

Synonyms

Dioxin, TCDBD, TCDD, 2,3,7,8-Tetrachlorodibenzodioxin; 2,3,7,8-Tetrachlorodibenzo-1,4-dioxin; 2,3,7,8-Tetrachlorodibenzo(b,3)(1,4)dioxin

Physical/Chemical Properties

Description:
Colorless needles

Melting point:
305°-306° C

Molecular weight:
322.96

Chemical formula:
$C_{12}H_4Cl_4O_2$

Solubility:

Solvent	Solubility, g/l
ortho-dichlorobenzene	1.4
chlorobenzene	0.72
benzene	0.57
chloroform	0.37
acetone	0.11
n-octanol	0.05
methanol	0.01
water	2×10^{-7}

Photochemical reactivity:
In studies exposing nanogram quantities of TCDD to sunlight, 50 percent degradation occurred in 5 to 6 hours. The chlorinated dibenzo-para-dioxins when dissolved in methanol are easily degraded by strong sunlight

Chemical reactivity:
The chlorinated dioxins are extremely stable and persistent compounds. TCDD is a very stable chemical that resists breakdown by other chemicals

Atmospheric reactivity:
Some data indicate that the chemical can be photodegraded

Environmental fate

Soil:
TCDD has been reported as immobile in soil samples of varying textures. In a study conducted by the U.S. Air Force, levels up to 1.5 µg/kg were found in soil 10 to 12 years following aerial spraying of herbicides containing TCDD. The microbial degradation of TCDD is reported to be relatively rare in nature

Sources of Emissions

Production:
The chlorodibenzo-para-dioxins are not manufactured commercially

Byproduct sources:
TCDD forms as a hazardous byproduct during the preparation of 2,4,5-trichlorophenol, a major intermediate in the manufacture of several herbicides, fungicides, and wood preservatives

Byproduct sources:
Estimated emission rates by specific plants (SAI 1980)

Company	Site	Type of production*	Emission rate* (mg/sec)
Dow	Midland, MI	1	0.003298
		2	0.018000
		3	0.042480
PBI-Gordon	Kansas City, KA	1	0.003298
Riverdale	Chicago Heights, IL	1	0.003298
Union Carbide	Ambler, PA	1	0.003298
Union Carbide	Fremont, CA	1	0.003298
Union Carbide	St. Joseph, MO	1	0.003298
Vertac	Jacksonville, FL	1	0.003298
		2	0.018000
Monsanto	Sauget, IL	3	0.042480
Reichhold	Tacoma, WA	3	0.042480
Vulcan	Wichita, KA	3	0.042480

* Estimated nationwide emissions (lb/yr) during 1978 are as follows (SAI 1980):
Type 2 Trichlorophenol production 2.5
Type 1 2,4,5-T production 1.6
Type 3 Pentachlorophenol production 11.8
These were allocated equally among the sites over 8,760 hours

Contaminant sources:
The following materials are known to contain trace amounts of TCDD as an impurity:
1,3,4,5-tetrachlorobenzene
2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and its esters
hexachlorophene
pentachlorophenol
2,4,5-trichlorophenoxypropionic acid (silvex)
2,4-dichlorophenoxyacetic acid (2,4-D)
clophen
Agent Orange: 50:50 mixture of 2,4,5-T and 2,4-D
Locust bean gum (food stabilizer)

The following emissions are estimated to result from use of these materials in 1978 (SAI 1980):
2,4,5-T applications 6.5 lb
Pentachlorophenol as wood preservative 42.3 lb

Combustion sources:

Trace levels of dioxins (including TCDD) may be present in fly ash and flue gases from the following sources:

- Incinerated waste material containing grass clippings and wood previously treated with contaminated herbicides
- Particulate emisions from incinerators, powerhouse boiler stacks, and fireplaces
- Emissions from the combustion of chlorinated organic chemicals such as polychlorinated benzenes, polychlorinated phenols, and polyvinyl chloride plastics
- Emissions from fires in transformers containing chlorinated benzenes and polychlorinated biphenyls
- Emissions from the combustion of gasoline, diesel fuel, and cigarettes resulting in air levels of 0.001 to 1100 ppb

The estimated emissions of TCDD during 1978 due to combustion processes are as follows (SAI 1980):

Source	Particulate Emissions (tons/yr)	Total Emissions (lb/yr)*
Open burning	2,161,142	8.6
Agriculture	1,433,712	5.7
Forest fires	526,843	2.1
Refuse open burning	212,211	0.8
Conical burners	193,500	0.8
Coal burning--all sources	108,952	0.4
Oil burning--all sources	72,389	0.3
Incineration, municipal domestic	30,123	0.1
Total		18.8

* Based on a TCDD emission concentration in particulate matter of 2 ppb

Uses:

TCDD is not used commercially. This compound has been tested for use in flameproofing polymers, and against insects and wood-destroying fungi, but these uses are not known to have been exploited commercially

TCDD has no reported use other than as a test chemical in basic research

Storage:
Not applicable

Transportation:
Not applicable

Disposition:
Abandoned dump sites which contain wastes from herbicide manufacturing, particularly 2,4,5-TCP, are major sources of TCDD

Under the Resource Conservation and Recovery Act (RCRA), TCDD has been designated by the EPA as a hazardous constituent of waste, which subjects the chemical to special handling and recordkeeping requirements. Under the Toxic Substances Control Act, Section 6, the EPA restricts the removal of TCDD in wastes except with EPA approval in compliance with RCRA requirements

Sampling and Analytical Methods

1. Commercial chlorophenols analysis for chlorodibenzo-para-dioxins
   a. Analysis on an aluminum oxide column
   b. Detection by gas chromatography with electron capture
   c. Confirmation by mass spectroscopy

   Detection limits:
   20 ug/kg

   Possible interferences:
   Presence of other compounds with the same column retention time

2. Analysis of samples of unknown origin
   a. Use of an ion-exchange resin column to remove chlorophenoxyphenols
   b. Determination of the dioxins by gas chromatography and mass spectrometry using multiple-ion detection

   Detection limits:
   0.05 mg/kg for TCDD

   Possible interferences:
   Presence of other compounds with the same column retention time

3. Analysis for TCDD contained in 2,4,5-T
   a. Use of gas chromatography
   b. Identification by mass fragmentography

   Detection limits:
   50 to ug/kg
   Recovery 80 to 100 percent

   Possible interferences:
   Presence of other compounds with the same column retention time

4. Dioxins from photochemical and thermochemical decomposition of chlorophenoxyphenols
   a. Use of gas chromatography
   b. Detection with flame ionization and mass spectometry

   Possible interferences:
   Presence of other compounds with the same column retention time

Permissible Exposure Limits/Threshold Limit Values

Under study by OSHA

Materials Damage

Chemical reactivity low, probability of materials damage low

Toxicity

Acute toxicity:
In animal tests, TCDD has been demonstrated to be the most acutely toxic compound made

Chronic toxicity:

Carcinogenicity--TCDD caused cancer in oral and dermal studies in animals. When the chemical was administered by gavage, exposure caused thyroid tumors in male rats and liver tumors in female rats. TCDD painted on the skin of mice was carcinogenic for female mice

Mutagenicity--TCDD produced mutagenic effects in some short-term microbial bioassays

Teratogenicity--TCDD is embryotoxic and teratogenic in mice and rats. No human data are available. Positive results in these studies demonstrate that the chemical is carcinogenic for animals and that exposure is a potential hazard to humans

Other chronic toxicity:
Chloracne
Neurological effects
Liver toxicity
Anemia and other blood disorders
Kidney dysfunction
Impairment of the immune system

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U.S. Environmental Protection Agency. 1981. Dioxins. Toxic Information Series. OPTS, Washington, D.C.

Chemical Name

Epichlorohydrin

CAS Number

106-89-8

Chemical Classification

Epoxide fibrous silicate

Synonyms

2-(chloromethyl) oxirane; 3-chloro-1,2-propylene; 3-cholro-1-oxacyclobutane; gamma-chloropropylene oxide; alpha-epichlorohydrin; 1,2-epoxy-3-chloropropane; chloropropylene oxide; glycerol epichlorohydrin; glycerol epichlorhydrin; 3-chlorooxetane; 3-chloro-1,2-exoxypropane; (chloromethyl) ethylene oxide; 3-chloro-1,2-propylene oxide; 1-chloro-2,3-epoxy propane; epichlorohydrine; oxirane (chloromethyl); 2,3-epoxypropyl chloride; glycidyl chloride

Physical/Chemical Properties

Description:
Colorless liquid

Boiling point:
117.9° C

Melting point:
-25.6° C

Molecular weight:
92.53

Chemical formula:
C_3H_5ClO

Vapor pressure:
16.8mm at 2.5° C

Vapor density:
3.29

Physical/Chemical Properties

Refractive Index:
N_D^{25} 1.4359

Solubility:
5.48 percent soluble in water; soluble in most organic solvents

Photochemical reactivity:
Potential for air pollution is high; however, no data are available on photochemical reactivity

Chemical reactivity:
By suitable adjustment of reaction conditions, epichlorohydrin can be an intermediate in the synthesis of a wide variety of products.

Epichlorohydrin emits highly toxic fumes when heated to decomposition

The reactivity of the compound is characterized by the terminal chlorine atom and the epoxy group

Environmental Fate

Indications of accumulative effects; however, biodegradation may occur

Sources of Emissions

Production:
Approximately 312 million lb of epichlorohydrin were produced in 1978. The total production emissions including process, storage and fugitive was estimated as 146,600 lb/yr in 1978

lb lost/lb produced

Process	0.00042-from state files
Storage	0.00001-from state files
Fugitive	0.00004-engineering estimate

Plants and locations:

Dow Chemical	Freeport, TX
Shell	Deer Park, TX
	Norco, LA

Uses/storage/fugitive:

The ordinary end uses of epichlorohydrin are for the manufacture of epoxy resins (53%) and synthetic glycerin (25%). Other uses include the production of epichlorohydrin elastomers, glycidol ethers, surfactants, etc. End use consumption is presented in Table D-60. Epichlorohydrin emissions from epoxy resin production including process, storage and fugitive emissions total an estimated 250,800 lb/yr (1978 data). Table D-61 presents plant locations and emissions. Table D-62 presents nationwide emission losses of allyl chloride (consumed in epichlorohydrin production) and epichlorohydrin

Disposition:

The largest quantities of epichlorohydrin containing wastes originate in the production of epoxy and phenolic resins. It is expedient to destroy concentrated wastes in special incinerators to avoid the formation and emission of toxic fumes. No data are available on emissions from disposition

Sampling and Analytical Mehtods

NIOSH Method Number S 118: Epichlorohydrin

Sampling method:

A known volume of air is drawn through a charcoal tube to trap the organic vapors present

Analytical method:

The analyte is desorbed with carbon disulfide, and the desorbed sample is injected into a gas chromatograph

Detection limits:

A sample size of 210 l yielding a 1 mg sample has a working range of 2-60 mg/m^3

Possible interferences:

1. High humidity
2. Compounds with the same column retention times

TABLE D-60. 1978 EPICHLOROHYDRIN CONSUMPTION BY END-USE

End-Use	Percent of Total Consumption	End-Use Consumption (M lb)
Glycerin	25	78
Unmodified epoxy resins	53	165
Miscellaneous products	15	47
Epichlorohydrin elastomers	2	6
Export	5	16
Total	100.0	312

Source: Systems Applications, Inc. 1980

TABLE D-61. 1978 EPICHLOROHYDRIN EMISSIONS FROM EPOXY RESIN PRODUCTION

Company	Location	Process Emissions (lb/yr)	Process Emissions (g/sec)[b]	Storage Emissions (lb/yr)	Storage Emissions (g/sec)[b]	Fugitive Emissions (lb/yr)	Fugitive Emissions (g/sec)[b]	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Celanese	Linden, NJ	15,960	0.230	1,400	0.020	3,920	0.056	21,280	0.306
	Louisville, KY	10,260	0.148	900	0.013	2,520	0.036	13,680	0.197
Ciba-Geigy	Toms River, NJ	25,080	0.361	2,200	0.032	6,160	0.089	33,440	0.481
Dow	Freeport, TX	69,540	1.001	6,100	0.088	17,080	0.246	92,720	1.335
Reichhold	Andover, MA	3,420	0.049	300	0.003	840	0.012	4,560	0.066
	Azusa, CA	3,420	0.049	300	0.003	840	0.012	4,560	0.066
	Detroit, MI	3,420	0.049	300	0.003	840	0.012	4,560	0.066
	Houston, TX	3,420	0.049	300	0.003	840	0.012	4,560	0.066
Shell	Deer Park, TX	41,040	0.591	3,600	0.052	10,080	0.145	54,720	0.788
Union Carbide	Bound Brook, NJ	4,560	0.066	400	0.004	1,120	0.016	6,080	0.088
	Taft, LA	7,980	0.115	700	0.010	1,960	0.028	10,640	0.153
Total		188,100		16,500		46,200		250,800	

[a]Emission factor for epichlorohydrin emissions (lb lost per lb used).

Process	0.00114	B - From state files
Storage	0.00010	B - From state files
Fugitive	0.00028	B - From state files
Total	0.00152	

[b]Assumes 8760 hr/yr operation.

Source: Systems Applications, Inc. 1980

TABLE D-62. 1978 ESTIMATED ALLYL CHLORIDE AND EPICHLOROHYDRIN NATIONWIDE EMISSION LOSSES

Source	Estimated National Emissions	
	Allyl Chloride (M lb/yr)	Epichlorohydrin (M lb/yr)
Production (allyl chloride, epichlorohydrin, and glycerin)	1.11	0.147
Unmodified epoxy resins - use		0.251
Chemical intermediate - use		0.081
Export	0	0
Total	1.11	0.479

*Based on emission factor of 0.00152 lb lost per lb used derived for epoxy resin manufacture.

Source: Systems Applications, Inc. 1980

Materials Damage

Epichlorohydrin can pit steel and attack rubber and leather. Containers used for storage and transport require special precautions

Permissible Exposure Limits

OSHA standard
5 ppm as an 8 hr TWA
NIOSH recommendation
0.5 ppm TWA 10 hr/40 hr week
Ceiling
5 ppm 15 min

Human Toxicity

Chronic toxicity:

Carcinogenicity--The evidence for carcinogenicity to humans is inadequate. One epidemiological study in workers showed an excess of respiratory cancer. The evidence of carcinogenicity in animals is sufficient

Mutagenicity--The evidence in humans is insufficient; the evidence in short term tests is sufficient

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Chemical Name

Methyl chloroform

CAS Number

71-55-6

Chemical Classification

Chlorinated aliphatic hydrocarbon

Synonyms

1,1,1-Trichloroethane; alpha-Trichloroethane; chloroethene; methyl trichloromethane

Physical/Chemical Proterties

Description:
Colorless mobile volatile liquid, chloroform-like odor

Boiling point:
74° C

Melting point:
-32.6° C

Molecular weight:
133.41

Chemical formula:
$CH_3 CCl_3$

Vapor pressure:
100 mm Hg 20° C
127 mm Hg 25° C

Solubility:
0.44 g/100 g water at 25° C, soluble in ethyl ether and ethyl alcohol

Refractive index:
1.44 at 20° C

Vapor density:
4.6 (air = 1)

Chemical reactivity:
- Liquid methyl chloroform will attack some forms of plastics, rubber and coatings. Contact with strong caustics, strong oxidizers and chemically active metals may cause fires and explosions

Sources of Emissions

Production/processing:
630 million lb were estimated as produced in 1976. The release rate from production has been estimated as 284.5 million lb/year

Uses:
Methyl chloroform has been a preferred solvent for cleaning electrical machines, electronic devices and precision instruments. It is also used as a dry cleaning agent, aerosol propellant additive, a constituent of rubber adhesives and as an additive to metal cutting oils. The environmental level of emissions for these industrial uses have been reported as <1 to 400 ppm (Data from Health Hazard Evaluation Reports, NIOSH)

Transport:
Methyl chloroform is shipped in 5 and 55 gal steel drums, tank cars, and tank trucks. Loading and unloading operations would be possible sources of high emission concentrations

Sampling and Analytical Methods

NIOSH Method number S328

Sampling method:
A known volume of air is drawn through a charcoal tube to trap the methyl chloroform present

Analytical method:
The desorbed sample is analyzed by gas chromatography

Detection limits:
Using a sample size of 3 l the detection sensitivity ranges from 190 to 5700 mg/m^3

Possible interferences:
1. High humidity
2. Compounds with the same retention times will interfere with results

Permissible Exposure Limits

The OSHA standard is 350 ppm (1900 mg/m^3)

Human Toxicity

Acute toxicity:
A number of fatalities have been reported due to deliberate or accidental exposures

Chronic toxicity:

Carcinogenicity--The available data does not permit an evaluation of the carcinogenicity of methyl chloroform in humans. A long term animal bioassay is being completed by the National Toxicology Program in FY83

Mutagenicity--Methyl chloroform has been reported as mutagenic in Salmonella typhimurium. Additional testing is to be completed in FY83 by the National Toxicology Program

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Chemical Name

Nickel

CAS Number

7440-02-0

Chemical Classification

Metal

Synonyms

Carbonyl nickel powder, nickel catalyst, nickel sponge, raney alloy, raney nickel

Physical/Chemical Proterties

Description:
Silvery gray metallic, odorless powder

Boiling point:
2732° C

Melting point:
1453° C

Atomic weight:
58.7

Chemical formula:
Ni

Vapor pressure:
Essentially zero at 20° C

Solubility:
Insoluble in water

Density (specific gravity):
8.9

Chemical reactivity:

Nickel is a divalent metal with characteristic divalent metal chemistry, although it does not readily form chloro- or sulfate complexes under environmental conditions

Environmental Fate

Atmospheric reactivity--nickel carbonyl decomposes readily to form nickel oxide in dry air and/or nickel carbonate in moist air. These products are more likely to be atmospheric pollutants than is nickel carbonyl

Nickel subsulfide occurs in air in particulate form and is subject to settling, impaction, rainout and washout. It is not believed to be a significant atmospheric or water pollutant

The form of nickel in air and its possible reactions have not been extensively studied. Due to the industrial importance of nickel carbonyl, the possibility of nickel entering the atmosphere as nickel carbonyl does exist. Although nickel carbonyl is recognized as a hazard in industrial hygiene, there is a scarcity of information regarding the amount of nickel carbonyl that escapes to the atmosphere. In the atmosphere nickel is unreactive toward OH and O_3

Table D-63 presents average nickel concentrations at 30 urban National Air Surveillance Network Stations from 1957-1968

Sources of Emissions

Production:

U.S. nickel mining operations produce about 30 million lb of Nickel annually and imports are approximately 330 million lb

In 1977 there were two major nickel producers in the U.S.; the Hanna Mining Co., Riddle, Oregon, and AMAX, Inc., at Port Nickel, Louisiana. Production emissions are estimated at 500,000 lb/year

Uses:

The principal use of nickel is as an alloying agent. Nickel emissions from melting and alloying are in the form of nickel oxide or complex oxides. Other than direct use sources nickel may be released from coal and oil fired boilers, coke ovens,

TABLE D-63. AVERAGE CONCENTRATIONS OF SUSPENDED PARTICLES AND NICKEL AT 30 URBAN AIR SURVEILLANCE NETWORKS STATIONS, 1957-1960, 1961-1964, AND 1965-1968

Station	Nickel Concentration, $\mu g/m^3$			
	1957-1960	1961-1964	1965-1968	Average
Atlanta, Ga.	0.021	0.012	0.007	0.013
Baltimore, Md.	0.057	0.071	0.051	0.060
Boise, Idaho	0.037	0.006	0.003	0.015
Boston, Mass.	0.171	0.076	0.090	0.112
Chattanooga, Tenn.	0.024	0.018	0.012	0.018
Charleston, W. Va.	0.058	0.040	0.015	0.038
Chicago, Ill.	0.044	0.048	0.033	0.042
Cincinnati, Ohio	0.024	0.018	0.013	0.018
Cleveland, Ohio	0.035	0.027	0.015	0.026
Columbus, Ohio	0.045	0.024	0.019	0.029
Denver, Colo.	0.021	0.028	0.007	0.19
Des Moines, Iowa	0.016	0.010	0.007	0.011
Detroit, Mich.	0.037	0.020	0.033	0.030
East Chicago, Ind.	0.202	0.123	0.070	0.031
El Paso, Tex.	0.015	0.015	–	0.015
Indianapolis, Ind.	0.023	0.036	0.021	0.027
Los Angeles, Calif.	0.055	0.041	0.031	0.042
Milwaukee, Wis.	0.029	0.023	0.011	0.021
New Orleans, La.	0.025	0.022	0.034	0.027
Newark, N.J.	0.057	0.084	0.066	0.069
Oklahoma City, Okla.	0.013	0.014	0.003	0.010
Omaha, Nebr.	0.018	0.013	0.005	0.012
Philadelphia, Penn.	0.082	0.074	0.077	0.078
Phoenix, Ariz.	0.038	0.019	0.011	0.023
Pittsburgh, Penn.	0.042	0.028	0.031	0.034
Saint Louis, Mo.	0.018	0.013	0.012	0.014
San Francisco, Calif.	0.029	0.023	0.023	0.025
Seattle, Wash.	0.079	0.059	0.037	0.058
Tacoma, Wash.	0.051	0.038	–	0.045
Washington, D.C.	0.049	0.040	0.021	0.037
AVERAGE	0.047	0.036	0.026	0.037

Source: Sittig 1975

diesel fuel burning and gray iron foundries. Emission sources have been estimated as follows:

Source	Pounds/Year
Iron and steel industry	231,000
Ferro alloy manufacturing	828,000
Gray iron foundries	186,000
Nonferrous alloy manufacturing	143,000
Electric utility power plants	8,456,000
Coke ovens	123,000
Diesel fuel use	1,785,000
Industrial boilers	6,518,000
Heating boilers	3,863,000
TOTAL	22,133,000

(OAQPS 1980)

Disposition:

Nickel scrap is a significant source of the nickel supply. Essentially all nickel scrap is returned to mills, smelters, refineries and foundries. Nickel alloy scrap is usually exported to Japan or Germany for recycling

Sampling and Analytical Methods

NIOSH Method number S 206

Sampling method:

A known volume of air is drawn through a cellulose membrane filter to collect the analyte

Analytical method:

The sample solution is aspirated into the oxidizing air-acetylene flame of an atomic absorption spectrophotometer

Detection limits:

At 26.5° C 745 mm Hg the working range of an 85 l sample is estimated to be 0.4 to 8 mg/m^3

Interferences:

There are no known interferences for the nickel atomic absorption spectrophotometer assay

Permissible Exposure Limit

OSHA standard:
1 mg/m^3 8 hour TWA (as nickel metal and soluble nickel compounds)

NIOSH recommended standard:
0.015 mg/m^3 10 hr TWA

Human Toxicity

Chronic toxicity:

Carcinogenicity--Workers in nickel refineries have increased incidences of nasal, lung, and larynx cancer. It is not possible to state with certainty which specific nickel compounds are carcinogenic to humans

Other chronic toxicity:
Pharmacokinetics, metabolism and nutritional studies for nickel are on test in FY83 sponsored by the Division of Research Resources, NIH

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Chemical Name

Nitrobenzene

CAS Number

98-95-3

Chemical Classification

Nitroaromatic compound

Synonyms

Nitrobenzol, oil of mirbane, mononitrobenzene

Physical/Chemical Properties

Description:
Yellow oily liquid, yellow crystals in solid state

Boiling point:
210.8° C at 760 mm

Melting point:
5.7° C

Molecular weight:
123.11

Molecular formula
$C_6H_5NO_2$

Vapor pressure:
0.340 mm at 25° C

Density:
1.2037 at 20° C (water at 4° C)

Refractive index:
1.5529 - highly refractive

Solubility:
Slightly soluble in water

Octanol/water log partition coefficient:
1.88

Photochemical reactivity:
Undergoes photoreduction when irradiated with UV

Chemical reactivity:
Undergoes nitration, halogenation and sulfonation and is a strong oxidizing agent. These reactions are not likely to occur under environmental conditions

Sources of Emissions

Production/processing:
In 1978 there were 5 companies producing nitrobenzene at 7 locations

An estimated 850 million lb were produced in 1978

The following producers and processors of nitrobenzene have been reported:

Company	Location
American Cyanimid	Bound Brook, NJ Willow Island, WV
Du Pont	Beaumont, TX Deepwater, NJ Gibbstown, NJ
First Chemicals	Pascagoula, MS
Mobay Corporation	New Martinsville, WV
Rubicon	Geismar, LA
BASF Wyandotte	Wyandotte, MI
Dow	Midland, MI
Hercules	Brunswick, GA Harbor Beach, MI Hopewell, VA Parlin, NJ
H. Kohnstaum	Camden, NJ Clearing, IL
MAK Chemical	Muncie, IN

Company	Location
Procter and Gamble	Memphis, TN
Union Carbide	Institute, WV
Eastman Kodak	Rochester, NY
Monsanto	Luling, LA
Toms River Chemicals	Toms River, NJ

Production and process emissions:
263,500 lb (1978)

Uses:
The total number of estimated sites where nitrobenzene is used is 279

Most of (98%) nitrobenzene is used captively to produce aniline (1978 estimate)

Nitrobenzene is used as a solvent in the petroleum industry and in cellulose ether manufacture

Nitrobenzene is used as a chemical intermediate

Emissions from use:

Use	Emissions
Solvent applications	12.75 million lb
Production and analine manufacture	275,000 lb
Chemical Intermediate	6,000 lb

Total nationwide emissions of nitrobenzene in 1978:

13 million lb

Emissions from storage:
Storage emissions represent total losses from surge, final product, feed storage tanks, and loading and handling. Emissions range from 300-18,000 lb per year (from site visit data)

Disposition:
Atmospheric concentrations of nitrobenzene adjacent to production or processing sites are believed low. Atmospheric nitrobenzene is not monitored by industry. High concentrations of wastes should be incinerated. Caution: poisonous nitrous gases can be produced

Sampling and Analytical Methods

NIOSH Method number S 217

Sampling method:
A known volume of air is drawn through a silica gel tube

Analytical method:
An aliquot of the desorbed sample is analyzed by GC

Detection limits:
Method validation in range of 3.11-12.45 mg/m^3 (23° C 765 mm) using 55 l of sample

Possible interferences:
Vapors may not be trapped efficiently during periods of high humidity

Compounds with the same column retention time as nitrobenzene can interfere with the analysis

Permissible Exposure Limit

OSHA Standard
1 ppm (5 mg/m^3)

Human Toxicity

Acute toxicity:
A few ml of nitrobenzene liquid can be lethal to humans

Chronic toxicity:

Carcinogenicity--On test in FY83 for long term carcinogenesis animal bioassay (National Toxicology Program)

Mutagenicity--On test in FY83 for mutagenesis/genetic toxicity testing (National Toxicology Program)

Other chronic toxicity:
On test in FY 1983 for pharmacokinetics/metabolism studies (University of California)

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Chemical Name

Nitrosomorpholine

CAS Number

59-89-2

Chemical Classification

N-nitroso compound

Synonyms

morpholine, 4-nitroso-, N-nitrosomorpholine, 4-nitrosomorpholine, NMOR

Physical/Chemical Proterties

Description:
Yellow crystals

Boiling point:
225° C 747 mm

Melting point:
29° C

Molecular weight:
116.1

Chemical formula:
$C_4H_8N_2O_2$

Solubility:
Soluble in water, and soluble in organic solvents

Photochemical reactivity:
Photochemically reactive, light sensitive, especially to UV

Chemical reactivity:
Resistant to hydrolysis. Strong oxidants oxidize NMOR to the corresponding nitramine

Sources of Emissions

Production/processing:

NMOR is not produced commercially and there are no reports of past commercial production

Uses:

No reported uses. NMOR has been detected as a contaminant in analytical grade dichloromethane and chloroform, in morpholine and in a rubber accelerator. Rubber or tire manufacturing workers may be exposured in the range of 9-130 µg/day

Sampling and Analytical Methods

Sampling methods:

Samples should be stored in opaque containers because of the light sensitivity of NMOR

Analytical methods:

Gas chromatography recommended for analysis of NMOR using either an electron-capture detector or alkali flame ionization detector. Confirmation should be made with a mass spectrometer or thin layer chromatography

Possible interferences:

Any compound which has the same retention time as the analyte is a potential interference. Compounds containing phosphorous or nitrogen could be sources of interference

Human Toxicity

Chronic toxicity:

There are no case reports or epidemiologic studies available

Carcinogenicity--There is sufficient evidence for the carcinogenic effect of NMOR in experimental animals and the chemical should be regarded as carcinogenic to humans

Mutagenicity--There is evidence of the mutagenic effect of NMOR in experimental animals. NMOR has been selected for further mutagenesis/genetic toxicity testing by the National Toxicology Program

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Chemical Name

Polychlorinated biphenyls, a generic term for 209 possible isomers of chlorinated biphenyls

CAS Numbers

13-36-36-3, generic
11097-69-1, Aroclor 1265
11096-82-5, Aroclor 1260

Chemical Classification

Halogenated aromatic hydrocarbon

Synonyms

PCB, chlorinated biphenyl, chlorinated diphenyl, chlorinated diphenylene, chloro biphenyl, polychlorinated polyphenyls

Trade Names

Akarel, Aroclor, Clophen, Chlorextol, Dykanol, Interteen, Kanechlor, Noflanol, Phenochlor, Pyralene, Pyranol, Sovol, Therminol

Physical/Chemical Properties

Description:
Variable appearance. Lower chlorinated Aroclors are colorless mobile oils. Increased chlorinated of the biphenyl results in increasing yellow colorations and compound viscosity

Boiling point:
Aroclor 1254, 365° C
Aroclor 1260, 390° C

The boiling points for the PCBs increase with increased chlorination

Melting point:
2-chlorobiphenyl, 54° C
decachlorobiphenyl, 310° C

Melting points for the PCBs increase with the chlorination of the biphenyl. The PCBs do not crystallize upon heating or cooling, but at specific temperatures defined as pour points, they form resinous compounds

Molecular weight:
Exact molecular weights of the PCBs are unknown

Chemical formula:
The PCBs most frequently occur as mixtures; exact chemical formulas are unknown

General formula: $C_{12}Cl_xH_x$ (x = 1 to 10)

Log partition coefficient (octanol/H_2O):
10,000 to 20,000 for representative tri-, tetra-, and pentachlorobiphenyls

Refractive index:
Aroclors, 1.617-1.640 at 20° C
Kaneclors, 1.623-1.690 at 25° C

Solubility:
The PCBs are generally considered insoluble in water

Aroclor 1254, 0.1 µg/l

Chlorobiphenyls are freely soluble in nonpolar organic solvents and lipids

Density:
1.495 to 1.505

Vapor pressure:
1 mm at 25° C

Photochemical reactivity:
Transformation products--
Reactivity toward OH: 5% butane
Reactivity toward O_3: no reaction
Photolysis: free radicals can form that may result in the formation of the contaminant chlorodibenzofurans

Chemical reactivity:

PCBs are considered inert to most of the typical chemical reactions. These compounds do not undergo oxidation, reduction, addition, or elimination except under extreme conditions

Environmental fate

Due to their chemical stability, environmental persistence, and tendency to bioaccumulate, the PCBs have continued to present an environmental hazard despite regulatory actions

Air:

Vaporized PCBs can be adsorbed onto particulates and transported with the prevailing wind. Ultimately they will be deposited on land or water

Water:

PCBs found in water are mainly adsorbed to particulate matter and sediment. Because of their low aqueous solubility, PCBs discharged into water bodies will accumulate and redissolve very slowly. Fish can bioaccumulate 10^5 times more PCBs than are found in surrounding waters

Soil:

The primary source for PCBs in soil is atmospheric fallout
Estimated half-life in soil: 5 years
Estimated residence time: 35 years
Large fractions of PCBs in soil may leach into adjacent water bodies

Sources of Emissions

Production:

Except for limited research and development applications, the PCBs are no longer produced domestically, and no importation or exportation of the compounds has been permitted since July 1979. United States production peaked in 1970 when greater than 80 million pounds was manufactured principally in Illinois

Uses:

PCBs are no longer used or consumed for any kind of end use in the United States, and end use is no longer a source of PCB emissions

Prior common uses have been in transformer and capacitor fluids, electrical insulations, plasticizers, hydraulic fluids, epoxy paints, carbonless reproduction papers, and certain lubricants. These prior uses have continued to be sources for environmental and human exposure

Storage:

The loss of PCBs by evaporation or leakage when stored in closed systems such as in transformers and capacitors is not believed to be a significant emissions source.

EPA regulations specify the types of containers that can be used for the storage of liquid containing PCBs prior to incineration

Transportation:

Not significant

Disposition:

The only significant sources of PCB emissions to the atmosphere are from the disposal of PCB-containing transformers and capacitors. When PCBs and PCB-containing products are disposed of, disposal must be undertaken in accordance with EPA regulations. In 1980 there were the following existing and proposed incineration sites:

*Bridgeport, NJ	Chicago, IL
*Deer Park, TX	Sandusky, OH
*Baton Rouge, LA	Atlanta, GA
San Francisco, CA	Richmond, VA
Los Angeles, Ca	Waterford, NY
Denver, CO	El Dorado, AR

* Designates incinerator site existing in 1980

Annual emissions of PCBs if all 12 sites are operational is estimated to be between 3,000 and 30,000 lb/yr

The concentration of PCBs in PCB-containing wastes determines the disposition. Wastes that contain PCBs greater than 500 ppm require incineration. Chemical landfill disposal is permitted for specified wastes provided all free-flowing PCBs have been drained for incineration

Sampling and Analytical Methods

1. Polychlorinated Biphenyls in Air--Method Number P&CAM 244
   a. Adsorption of Florisil
   b. Hexane desorption
   c. Gas chromatography with electron capture detection

   Detection limits:
   The estimated range of detection for this method is 0.01 to 10 mg/m^3. The minimum detectable quantity of PCB from a standard curve was determined as 32 pg per injection. Field samples analyzed by this method ranged from 0.1 to 1.5 mg/m^3

   Possible interferences:
   Compounds with nearly the same retention time as the PCB sample on the GC column. The chlorinated pesticides such as DDT, DDE, etc., have been reported to interfere with determinations, and sulfur-containing compounds in petroleum products have been reported as interferences

2. Polychlorinated Biphenyls in Air--Method Number P&CAM 253
   a. Adsorption in Florisil
   b. Hexane desorption
   c. Perchlorination
   d. Gas chromatography with electron capture detection

   Detection limits:
   The estimated useful range of this method is 0.01 to 10 mg/m^3. The minimum detectable limit of decachlorobiphenyl, the perchlorination product, is 10 pg per injection

   Possible interferences:
   Compounds with the same column retention time or nearly same. Chlorinated pesticides, sulfur-containing compounds in petroleum products, and biphenyl, if present in the PCB mixture

Permissible Exposure Limits/Threshold Limit Values

PEL: 1 mg/m^3, 8-hour Time Weighted Average (42 percent chlorine)
0.5 mg/m^3, 8-hour Time Weighted Average (54 percent chlorine)

TLV: 1 mg/m^3, 8-hour Time Weighted Average (42 percent chlorine)
0.5 mg/m^3, 8-hour Time Weighted Average (54 percent chlorine)

Toxicity

Acute toxicity:

Acute toxicity studies are on test in FY83 by the Division of Research and Resources, National Institutes of Health. The acute toxicity grams per kilogram of the PCBs increases with chlorination, as shown in the following results:

	Aroclor										
	1221	1232	1242	1248	1260	1262	1268	4465	5442	5460	2565
Rats, Oral LD_{50}*	3.9†	4.5†	8.7†	11.0†	10.0§	11.3§	10.9§	16.0§	10.6§	19.2#	6.3#
Rabbits, Skin MLD	>2.0† <3.2†	>1.3† <2.0†	>0.8† <1.3†	>7.9† <1.3†	>1.3§ <2.0§	>1.3§ <3.2§	-- <2.3§	>2.0§ <3.2§	>1.3§ <2.0§	>7.9# --	>2.0# <3.3

* LD_{50} is lethal dose to 50 percent of recipients, and MLD is mean lethal dose.
† Undiluted
§ Administered as 50 percent in corn oil.
# Administered as 33.3 percent corn oil

Chronic toxicity:

Carcinogenicity--The evidence for the carcinogenicity of PCBs in humans is inadequate. The evidence for the carcinogenicity of PCBs in mice and rats is sufficient for certain PCBs when the compounds are administered in their diets

Mutagenicity--Short-term mutagenicity testing has not produced dominant lethal mutations or chromosomal abberations. No data on humans are available

Teratogenicity--Data available are inadequate; however, teratogenic effects have been noted in several species of animals, including humans

Other Chronic effects:

Chloracne
Strong chronic irritant when inhaled, skin-absorbed, or ingested
Liver ailments in humans
Increased eye discharge and eyelid swelling
Jaundice

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Chemical Name

Toluene

CAS Number

108-88-3

Chemical Classification

Aromatic hydrocarbon, alkylbenzene

Synonyms

Methacide, methylbenzene, methylbenzol, phenylmethane, toluol

Physical/Chemical Properties

Description:
Colorless, volatile, flammable liquid at ambient temperatures; very refractive; noncorrosive; sweet odor, similar to benzene, but milder

Boiling point:
110.6° C

Melting point:
-95.0° C

Molecular weight:
92.15

Chemical formula:
C_7H_8

Vapor pressure:
24 mm Hg at 25° C; 22 mm Hg at 20° C; 36.7 mm Hg at 30° C

Log partition coefficient (Octanol/H_2O):
2.80

Refractive index:
N_D: 1.49693 at 30° F
1.49414 at 77° F

Solubility:
Slightly soluble (4.7 g/l H_2O); sol. in alcohol and ether

Density:
0.86694 g/ml at 20° C
0.86230 g/ml at 25° C

Vapor density:
3.1 (air = 1)

Photochemical reactivity:
Effective ambient air decay rate: 2.8×10^{-5} s^{-1} (daytime)
Reactivity toward: OH is 2X butane
No reactivity toward O_3 or photolysis

Chemical reactivity:
Reacts with oxidizing materials

Environmental fate

Can persist in atmosphere. Its high volatility and low solubility in water enables it to volatilize from water surfaces to the atmosphere

Sources of Emissions

Production:
An estimated 67,000 million lb of toluene was produced in 1978

Several petroleum or petrochemical processes:
a. from catalytic reformate from refineries (principal method in U.S.) an estimated 64,875 million lb was produced in 1978
b. hydrocracking
c. steam cracking
d. catalytic cracking

By-product sources:

a. from coal carbonization, an estimated 175 million lb of toluene was produced in 1978
b. as BTX (Benzene, Toluene, Xylene) from petroleum-derived pyrolysis gasoline, an estimated 1,560 million lb was produced in 1978 from this source
c. from olefin manufacturing during cracking of hydrocarbons
d. from styrene manufacturing, 320 million lb of toluene was produced in 1978
e. from coal-derived BTX, 175 million lb of toluene was produced in 1978

Uses:

Toluene isolated from BTX:

a. Chemical intermediate:
   benzene manufacturing (by dealkylation)
   toluene diisocyanate products
   xylenes (via disproportionation)
   benzoic acid manufacturing
   benzl chloride
   vinyl toluene
   benzaldehyde
   p-cresol
   backblending into gasoline
b. solvent
   paints
   rubber
   plastics
   coatings
   pharmaceuticals
c. in manufacturing of artificial leather, photogravure inks

All toluene produced as BTX and not isolated is blended into gasoline

Tables D-64 through D-67 and Figure D-5 present toluene production, consumption, and emission data

TABLE D-64. 1978 TOLUENE PRODUCTION AND CONSUMPTION

Source	Isolated Toluene (M lb)	Toluene in BTX (M lb)	Total Toluene Produced (M lb)
	Production		
Catalytic reformate	8,000	56,875	64,875
Pyrolysis gasoline	830	730	1,560
Coal derived	145	30	175
Styrene by-product	220	100	320
Total	9,195	57,735	66,930

Source: Systems Applications, Inc. 1980

TABLE D-65. END-USE CONSUMPTION

End Use	Isolated Toluene Used (%)	Toluene Used (M lb/yr)
Gasoline as BTX		57,735
Gasoline isolated (back blended)	35.1	3,230
Benzene dealkylation	40.2	3,693
Paints and coating solvent	6.3	579
Adhesives, inks, pharmaceuticals solvent	3.2	291
Toluene diisocyanate	4.8	440
Xylenes (disproportionation)	2.3	216
Benzoic acid	1.6	144
Benzyl chloride	0.8	79
Vinyl toluene	0.6	55
Benzaldehyde	0.2	18
p-Cresol	0.1	14
Miscellaneous others	0.6	53
Net export	4.2	383
Total	100.0	66,930

Source: Systems Applications, Inc. 1980

TABLE D-66. TOTAL NATIONWIDE 1978 TOLUENE EMISSIONS

Source	Toluene Emissions (lb/yr)
Toluene production - catalytic reformate	6,487,500
Toluene production - pyrolysis gasoline	1,404,000
Toluene production - coal-derived	218,750
Toluene production - styrene by-product	243,200
Paint and coatings solvent	579,000,000
Adhesives, inks, pharmaceutical solvent	247,000,000
Benzene production	738,600
Toluene diisocyanate production	563,200
Benzoic acid production	216,000
Benzyl chloride production	79,000
Vinyl toluene production	55,000
Benzaldehyde production	27,000
p-Cresol production	28,000
Xylene disproportionation production	43,200
Other/miscellaneous uses	20,140
Gasoline - marketing evaporative loss	38,492,000
Gasoline - automobile evaporative loss	35,400,000
Gasoline - automobile exhaust emissions	1,300,147,000
Coke ovens	25,680,000
Total	2,235,842,590

Source: Systems Applications, Inc. 1980

TABLE D-67. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF TOLUENE

Region	Toluene Production (Catalytic Reforming)*		Gasoline Marketing		Coke Oven	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0	0	0.00245	11,105	6.062	0
Middle Atlantic	0.535	17	0.00245	28,383	6.062	15
East North Central	0.510	28	0.00245	42,270	6.062	25
West North Central	0.227	16	0.00245	23,304	6.062	3
South Atlantic	0.250	5	0.00245	37,286	6.062	4
East South Central	0.422	8	0.00245	16,313	6.062	9
West South Central	0.634	71	0.00245	28,336	6.062	2
Mountain	0.116	23	0.00245	12,815	6.062	2
Pacific	0.429	33	0.00245	26,647	6.062	1

* This includes both the nonisolated toluene (as BTX) producers and the isolated toluene producers.

Source: Systems Applications, Inc. 1980

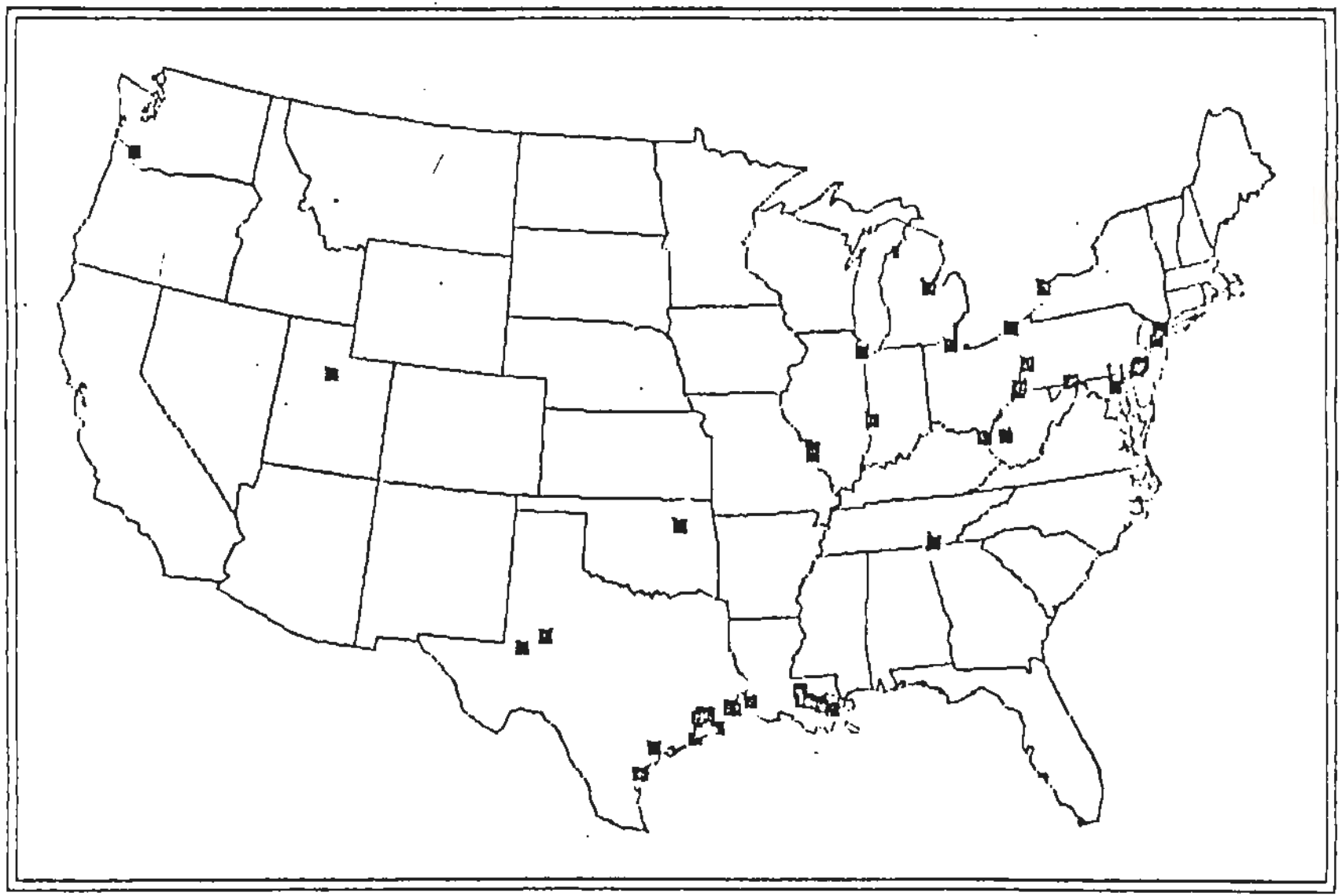

Figure D-5. Specific point sources of toluene emissions.

Source: Systems Applications, Inc. 1980

Storage:

Outside/detached storage or inside in standard flammable liquids storage room/cabinet. Separate from oxidizing materials

Transportation:

In glass bottles, cans, drums, tank cars, tank trucks, or tank barges

Disposition:

Toluene wastes originate mainly in petrochemical plants as well as plants which use toluene as a raw material for synthesis of the above-mentioned compounds. Further sources of waste are installations which blend fuels and plants which utilize toluene as a solvent.

When discharging wastes of low toluene content into the sewer system, the local discharge regulations have to be observed. Solvent wastes from which toluene cannot be recovered and toluene-containing sludges are burnt. Distillation residues and toluene-containing sludges are disposed of in special waste incinerators

Sampling and Analytical Methods

1. EPA "Preferred Method"
   a. Tenax GC sorbent collection (gives pre-concentrated samples)
   b. Thermal elution
   c. Gas chromatographic/flame ionization detector determination

Detection limits: (depend on sample volume)

0.1 ppb with capillary column and flame ionization detector--25 l sample on sorbent trap

0.3 ppb with gas chromatographic/photoionization detector directly injected--1 ml sample

Possible interferences:

High humidity
Interfering compounds possibly also present in the air
Any compound with the same column retention time

2. NIOSH Method S 343 for Toluene
   a. Adsorption on charcoal
   b. Desorption with carbon disulfide
   c. Gas chromatographic analyses

   Detection Limits:
   0.01 mg/0.5 l for a 22 l sample at 16x1 attenuation on a gas chromatograph fitted with a 10:1 splitter

   Possible interferences:
   High humidity
   Other solvents in air
   Presence of other compounds with same retention time

3. See Appendix A
   Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/PID is a useful determinative technique

Materials Damage

Toluene will attack some forms of plastics, rubber, and coatings. Containers may burst at elevated temperatures

Permissible Exposure Limits/Threshold Limit Values

	OSHA	NIOSH	ACGIH
TWA	200 ppm	100 ppm	100 ppm (375 mg/m^3)
Ceiling	300 ppm	200 ppm/10 min	150 ppm (560 mg/m^3)
Peak	500 ppm/10 min		

Odor perception: TLV 40 ppm

Human Toxicity

Acute toxicity:
Inhalation: 200 ppm TC_{LO} - central nervous system
100 ppm TC_{LO} - psychotrophic

Chronic toxicity:

Carcinogenicity--On test for carcinogenicity in FY83 (U.S. DHHS 1983)

Mutagenicity--On test for mutagenesis/genetic toxicity in FY83 (U.S. DHHS 1983)

Teratogenicity--Tests to be completed in FY83 for reproductive/developmental toxicity (U.S. DHHS 1983)

Other chronic toxicity:
- Blood abnormalities
- Bone marrow chromosome damage
- Metabolic effects
- Enzymatic effects
- Increased liver microsomal enzymes
- Neurological/behavioral toxicity testing to be completed in FY83 (U.S. DHHS 1983)
- Pharmacokinetics/metabolism testing to be started in FY83 (U.S. DHHS 1983)

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Chemical Name

Trichloroethylene

CAS Number

79-01-6

Chemical Classification

Chlorinated Hydrocarbon

Synonyms

Acetylene trichloride; 1-chloro-2,2-dichloroethylene; 1,1-dichloro-2-chloroethylene; ethinyl trichloride; ethylene trichloride; TCE; Tri; trichlorethylene; 1,1,2-trichloroethylene

Physical/Chemical Proterties

Description:
Colorless liquid, volatile, nonflammable

Boiling point:
87° C

Melting point:
-73° C

Molecular weight:
131.4

Chemical formula:
C_2HCl_3

Vapor pressure:
77 mm Hg at 25° C

Solubility:
Miscible with H_2O (0.1% w/v at 20° C); miscible with acetone, ethanol, diethyl ether, chloroform and oils.

Log Partition Coefficient (Octanol/H_2O):
2.29

Photochemical reactivity:
High photochemical reactivity; oxidative breakdown of atmospheric oxygen, greatly accelerated by elevation of temperature and exposure to light, especially UV

Chemical reactivity:
Slowly oxidized by O_3 and RO_2, products are phosgene, HCl, CO, trichloroethylene oxide and dichloroacetylchloride; unreactive toward OH

Density:
1.4642 at 20° C (4° C water)

Environmental Fate

Not expected to accumulate in atmosphere due to low solubility and reactivity. Half-life in air range from 157 minutes to 8 hours, longer in water

Sources of Emissions

Production/processing:
From acetylene (high manufacturing cost)

By chlorination of ethylene

By oxychlorination of ethylene or dichloroethane (perchloroethylene is a byproduct)

Uses:
In industrial metal fabricating industry for vapor degreasing and cleaning operations

Solvent/solvent base for adhesives, sealants, lubricants, and dip-painting processes

Textiles

Low temperature heat transfer fluid

Component in spot remover and cleaning fluids for rugs, etc.

Pharmaceutical grade used as general anesthetic and an analgesic

Tables D-68 to D-72 present estimated production, end uses, and emission losses

TABLE D-68. PRODUCTION OF TRICHLOROETHYLENE

Source	Location	1978 Estimated Production (million pounds)	1978 Estimated Capacity (million pounds)	Geographic Coordinates
Dow Chemical	Freeport, TX	89.0	120	28°, 59', 15 N. Latitude 95°, 24', 45 W. Longitude
Ethyl Corporation	Baton Rouge, LA	37.0	50	30°, 18', 0(N. Latitude 91°, 08', 0(W. Longitude
PPG Industries	Lake Charles, LA	164.0	220	30°, 13', 14 N. Latitude 93°, 16', 54 W. Longitude
Total		290	390	

Source: Systems Applications, Inc. 1980

TABLE D-69. TRICHLOROETHYLENE END USES 1978

End Use	% of Total Consumption	End-Use Consumption (M lb)
Vapor degreasing	80	232
Solvent	4	11.6
Export	16	46.4
Total	100	290

Source: Systems Applications, Inc. 1980

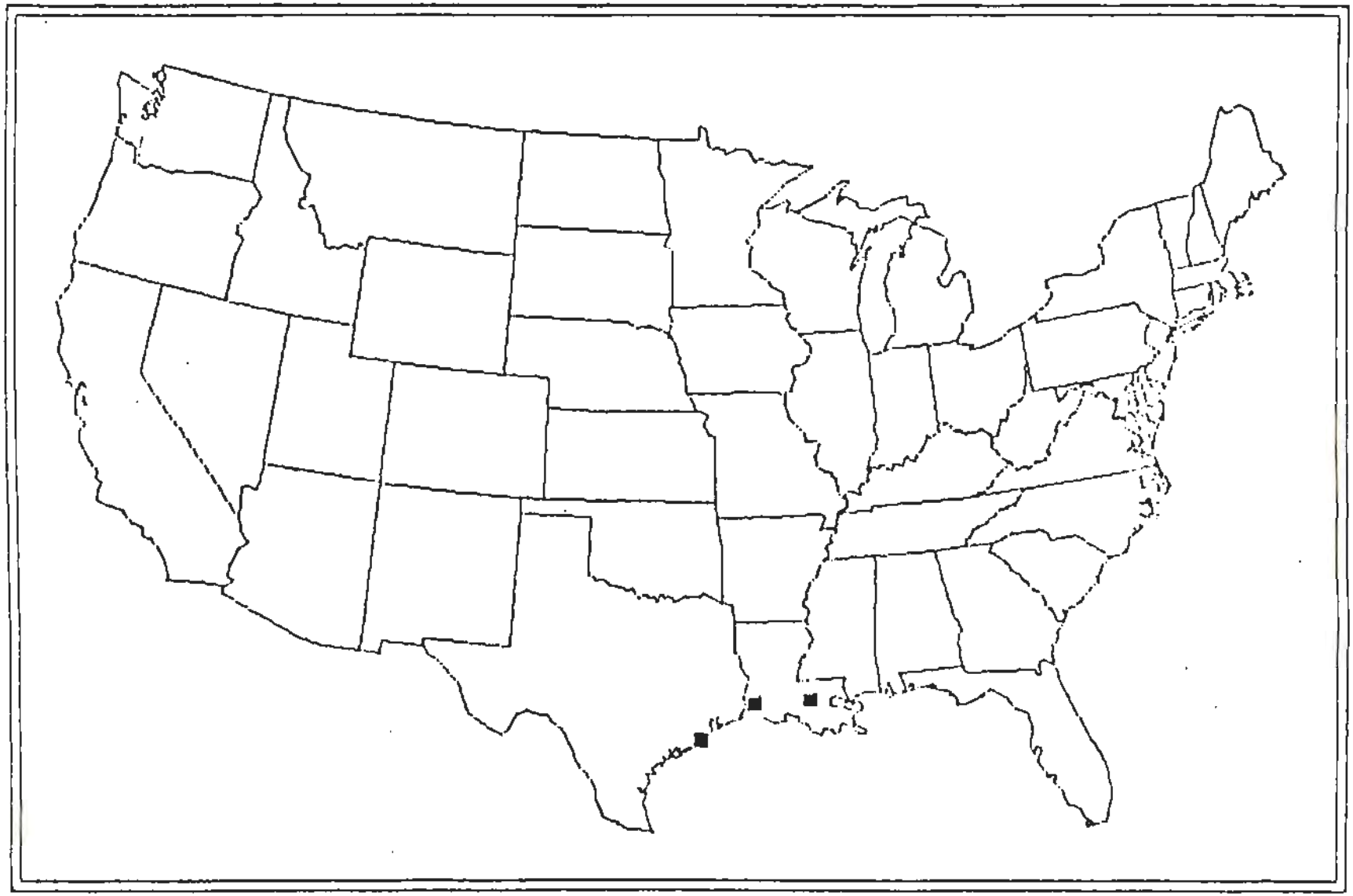

Figure D-6. Specific point sources of trichloroethylene emissions.

Source: Systems Applications, Inc. 1980

TABLE D-70. TRICHLOROETHYLENE

Emission source	Extent of problem: Total emission quantity, 10^1 metric tons/yr	Extent of problem: Population exposed	Control methods[a]	Regulation
Production:				
Acetylene-based		Produced only at Taft, Louisiana by this process	Incineration (95% efficiency) Treatment of aqueous waste streams	Workplace exposure limit of 100 ppm at 8 hr (OSHA)
Reactor reflux condenser vent	[b]			
Tail gas absorber vent	[b]			
Ethylene-based: None identified	[b]	Produced at Deer Park and Freeport, Texas, and Baton Rouge and Lake Charles, Louisiana by this process	Incineration (95% efficiency) Treatment of aqueous waste streams	Trichloroethylene is designated a priority pollutant under Federal Water Pollution Control Act
Transportation:				
Loading	[b]	[b]	Proper operating practices	[b]
Transfer	[b]	[b]		
Accidental spills	[b]	[b]		
Industrial use:		Number of operations:		
Cold cleaners	19.5	149,715	Proper design and operation of equipment (25% - 60% efficiency) Carbon absorption (95% - 100% efficiency) Incineration Liquid absorption Waste solvent reclamation (90% efficiency) Waste solvent landfills	Workplace exposure limit of 100 ppm in 8 hr (OSHA)
Open top vapor degreasers	63.5	11,440		
Conveyorized vapor degreasers	25.9	1,713		
Fabric scouring	7.5	693		
Food processing	[b]			
Miscellaneous	[b]			
Consumer use of end products:				
Public exposure due to use of products	[b]	[b]	[b]	The FDA is considering a ban on use in foods, drugs, and cosmetic products. Present FDA limits on trichloroethylene in decaffeinated instant coffee, decaffeinated ground coffee, and spices are 10 ppm, 25 ppm, and 30 ppm, respectively.

[a] Extent of use is unknown.

[b] Information not known.

Source: Blackwood, Micheletti, and Ochsner 1979

TABLE D-71. ESTIMATED 1978 TRICHLOROETHYLENE NATIONWIDE EMISSION LOSSES

Source	Estimated National Emission (million lb/yr)
Production	0.6
Cold cleaners	32.9
Vapor degreasers	195.6
Solvent	11.6
Export	0
Total	240.7

Source: Systems Applications, Inc. 1980

TABLE D-72. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF TRICHLOROETHYLENE

Region	Cold Cleaning		Open Top Vapor Degreasing (OTVD)		Conveyorized Vapor Degreasing (CVD)	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0.00952	2,991	0.288	560	0.857	113
Middle Atlantic	0.00952	7,760	0.288	1,158	0.857	244
East North Central	0.00952	13,179	0.288	1,742	0.857	405
West North Central	0.00952	4,362	0.288	452	0.857	80
South Atlantic	0.00952	6,005	0.288	465	0.857	84
East South Central	0.00952	2,944	0.288	265	0.857	52
West South Central	0.00952	4,832	0.288	398	0.857	68
Mountain	0.00952	1,806	0.288	174	0.857	21
Pacific	0.00952	5,893	0.288	896	0.857	165

Source: Systems Applications, Inc. 1980

Storage and Transport:

Stored in cool dry places, well-ventilated, away from sunlight and heat. Shipped in 5 and 55 gal steel drums, tank cars and tank trucks, barges.

Disposition:

60% of world's annual production is released to environment with most to the atmosphere. Disposal methods include:

- Incineration
- Aqueous waste
- Waste solvent reclammation
- Waste solvent landfills.

Sampling and Analytical Methods

1.

Sample Type	Extraction/Clean-Up	Detection	Limit of Detection
Air			
Ambient	Trap in Drechsel flask fitted with rubber septum, sample with gas syringe	GC/ECD	1 $\mu g/m^3$
Ambient	Analyze directly	GC/ECD	10 mg/m^3
Rural	Trap on porous polymer, desorb, by heating, retrap in line on GC column	GC/ECD; GC/MS	160 ng/m^3 (30 ppt)
Atmosphere	Analyze directly	GC/MS	27 ng/m^3 (5 ppt)
Ambient	Analyze directly	Carbon dioxide laser	1.8 $\mu g/m^3$ (0.7 ppb)
Ambient	Analyze directly	Carbon dioxide laser	23 $\mu g/m^3$ (4.2 ppb)

Source: IARC 1979

2. NIOSH method S 336 for trichloroethylene
   a. Adsorption on charcoal
   b. Desorption with carbon disulfide
   c. Gas chromatographic analyses

   Detection limits:
   0.01 mg/0.5-22 l of sample

   Possible interferences:
   High humidity (decreases breakthrough volume)
   Two or more solvents present of different polarities
   Two or more solvents present with same retention time as trichloroethylene

3. Methods B, C, or D from Appendix A
   Cryogenic trapping or Tenax adsorption appear to be the best approaches. GC/PID is a useful determinative technique

Materials Damage

Trichloroethylene will attack the common metals, even in the presence of moisture

Permissible Exposure Limits

	OSHA	NIOSH	ACGIH
TWA	100 ppm	100 ppm	50 ppm (150 mg/m^3)
Ceiling	200 ppm	150 ppm/15 min	150 ppm (805 mg/m^3)
Peak	300 ppm/5 min in any 2 hrs		

Human Toxicity

Acute toxicity:
Inhalation of 160 ppm (83 minutes) = TC_{LO} for central nervous system effects

Chronic toxicity:

Carcinogenesis--testing to be completed in FY83 (U.S. DHHS 1983)

Mutagenicity--mutagenesis/genetic toxicity testing ongoing in FY83 (U.S. DHHS 1983)

Teratogenicity--selected for reproductive/developmental toxicity testing, date not determined

Other chronic toxicity:
Kidney, spleen, and liver damage
Metabolic and enzymatic effects
Hypertension
Decreased ATP level
Reduces antibody formation

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Chemical Name

Vinyl chloride

CAS Number

75-01-4

Chemical Classification

Halogenated unsaturated hydrocarbon

Synonyms

Chlorethene, chlorethylene, chloroethene, chloroethylene, ethylene monochloride, monochloroethene, monochlorethylene, Trovidur, VC, VCM, vinyl chloride C monomer, vinyl chloride monomer

Physical/Chemical Properties

Description:
Colorless gas (pure substances)

Boiling point:
-13.37° C

Melting point:
-153.8° C

Molecular weight:
62.5

Chemical formula:
C_2H_3Cl

Vapor pressure:
2530 mm at 20° C

Refractive index:
n_D^{20} 1.3700

Solubility:
Slightly soluble in water, 0.11/100 g at 25° C; soluble in ethanol; very soluble in ether, carbon tetrachloride, and benzene

Density:
0.9106 at 20° C (water at 4° C)

Vapor density:
2.2 (air = 1)

Photochemical reactivity:
Vinyl chloride undergoes atmospheric reactions in the presence of nitrogen oxides and solar radiation. The reaction rate is slower than other atmospheric hydrocarbons that have been studied. Reaction products of vinyl chloride photo-oxidation include carbon monoxide, formaldehyde, formic acid, formyl chloride, and hydrogen chloride. The half-life of vinyl chloride in laboratory experiments was reported as 6 hours. No data were available on the half-life of vinyl chloride in the ambient atmosphere

Chemical reactivity:
On treatment with strong alkalis at high temperatures, vinyl chloride loses hydrogen chloride. Reacts with hydrogen peroxide, oxides of nitrogen, sulfuric acid, and ozone in ambient air

Environmental fate

Vinyl chloride should disappear significantly in its transport over long distances; however, in the immediate vicinity of emission sources, it is considered a stable pollutant. Vinyl chloride is so volatile that it does not bioaccumulate or transfer appreciably through food chains. Vegetational damage around manufacturing or processing plants has not been documented. The polyvinyl chloride products made from vinyl chloride are not readily biodegradable

Sources of Emissions

Production:
The annual production of vinyl chloride in the United States is approximately 7 billion lb. The total emissions from the 10 vinyl chloride monomer production sites operated in 1975 were estimated to be 30 million lb/yr, based on an emission rate of 0.45 percent of production

Byproduct sources:

Polyvinyl chloride plants use an estimated 95 percent of the vinyl chloride produced. Vinyl chloride emissions in 1975 from U.S. polyvinyl chloride polymer plants were approximately 240 million lb. This figure represents extrapolated figures based on estimated emissions of 4 percent vinyl chloride during polymer production and recovery, and full capacity operation. The location of vinyl chloride and polyvinyl chloride plants is presented in Figure D-7.

Maximum 24-hour air concentrations around plants ranged from 0.32 to 10.6 ppm. Fabrication plants produced lower vinyl chloride emissions than production plants.

NESHAP addressed vinyl chloride emissions from vinyl chloride monomer production and polymerization. The imposed engineering controls have been shown to reduce emissions by 95 percent over precontrol levels.

Uses:

The principal use of vinyl chloride is in the production of vinyl chloride homopolymer and copolymer plastics. The remainder is used in the synthesis of several chemicals.

Vinyl chloride was formerly used as a component of aerosol propellants. This use was banned by EPA, FDA, and CPSC in 1975.

Storage:

During bulk polymerization, intermittent storage losses of vinyl chloride were reported as high as 20 percent. Intensive maintenance is capable of reducing these sources of fugitive emissions 50 to 75 percent.

Transportation:

Monomer loading and unloading are potential sources of intermittent vinyl chloride emissions. Special controls have been suggested, such as vapor collection adapters with recycling, thermal level detectors with recycling, and magnetic gauges to limit loading area losses.

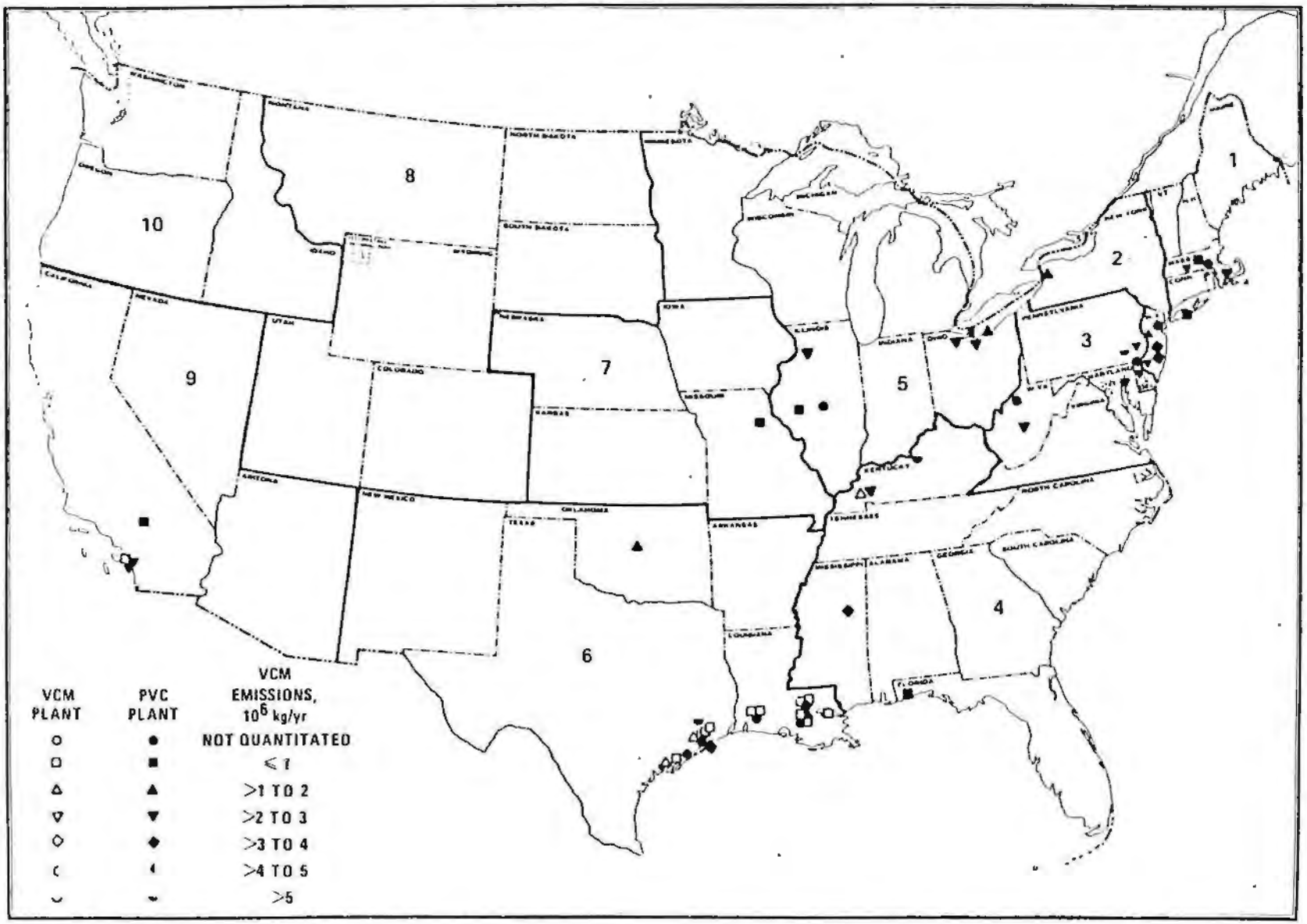

Figure D-7. Location of vinyl chloride and polyvinyl chloride plants. EPA Regions are delineated.

Source: Systems Applications, Inc. 1980

Disposition:

Limited data are available on the levels of vinyl chloride emissions from the incineration of plastics. Emissions from incineration are expected to vary as a function of temperatures and types of plastic incinerated. The following are representative:

Temperature (°C)	25-280	280-350	350-430	430-510
Emissions (mg/g)	0.04	0.25	0.17	0.02

Sampling and Analytical Methods

1. Method Number P&CAM 178 Matrix Air
   a. Adsorption on activated carbon
   b. Desorption with carbon disulfide
   c. Gas chromatographic detection

Detection limits:

The detection limit of the method was determined as 0.008 mg/m^3 in a 5-liter air space sample. The minimum detectable amount of vinyl chloride was 0.2 ng per injection (1 x 1 attenuation on a gas chromatograph)

Possible interferences:

a. High humidity decreases the adsorption capacity of activated carbon
b. Compounds with the same column retention time as vinyl chloride will interference in determinations

Materials Damage

Vinyl chloride is an extremely volatile gas, and appropriate precautions must be taken in handling this human carcinogen

Permissible Exposure Limits/Threshold Limit Values

OHSA

1 ppm 8 hour Time Weighted Average
5 ppm/15 minutes Time Weighted Average Ceiling

Toxicity

Acute toxicity:

Vinyl chloride is of low order acute toxicity. Produces anesthetic effects accompanied by cardiac irregularities and pulmonary edema

Chronic toxicity:

Carcinogenicity--There is sufficient evidence that vinyl chloride monomer is a human carcinogen. Its target organs are the liver, brain, lung, blood and lymphatic systems

Mutagenicity--Vinyl chloride induces mutagenicity in short-term cellular testing. Chromosomal aberrations were induced in workers exposed to levels of 25 ppm. No chromosomal aberrations were induced when exposure to vinyl chloride was reduced to 15 ppm

Teratogenicity--Studies indicate increased rates of birth defects among children residing in communities where vinyl chloride production and polymerization plants are located. Further investigation of its teratogenicity is needed

Other Chronic toxicity:

Low grade liver and kidney damage
Degeneration of finger bones associted with direct physical contact with high levels of the monomer
Hypertension following chronic exposures
Circulatory system disturbances such as fibrosis in arteries

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Chemical Name

Vinylidene chloride

CAS Number

75-35-4

Chemical Classification

Vinyl halide

Synonyms

1,1-Dichloroethene; 1,1-dichloroethylene; 1,1-DCE; VDC

Physical/Chemical Proterties

Description:
Highly volatile, clear liquid

Boiling point:
32° C

Melting point:
-122.1° C

Molecular weight:
97.0

Chemical formula:
$C_2 H_2 Cl_2$

Vapor pressure:
400 mm at 14.8° C

Refractive index:
n_D^{20} 1.424

Solubility:
Insoluble in water (0.4% wt/vol at 20° C)

Photochemical reactivity:
Photooxidizes rapidly

Vapor density:
3.4 (air = 1)

Chemical reactivity:
Easily polymerized at temperatures above 0° C

Environmental Fate

VDC emissions to the atmosphere are estimated to be shortlived. The half life is in the order of several hours

Sources of Emissions

Production/Process:
Domestic production was reported as 386,000,000 lb by Five producers in two regions (public record, TSCA Inventory)

The following companies reported production to EPA in 1977:

Producer	Location
Dow Chemical Co.	Freeport, TX Plaquemine, LA
PPG Industries, Inc.	Lake Charles, LA
Continental Oil Co.	West Lake, LA

VDC emission losses during production are in the range of 1.2 to 3.1 g/kg produced

Most of the VDC emissions are process losses. Estimated annual emissions from processing are presented in Table D-73. New control technologies since 1974 have probably reduced the total emissions

Uses:
VDC has two main commercial uses: the production of 1,1,1-trichloroethane and the synthesis of various polymers used in food packaging; coatings; resins, latexes; films and extruded fibers. There are scant data available on the migration of VDC monomer from products

Storage/transport:
Storage, transfer and filling operations have been estimated to account for about 25% of the total environment VDC emissions

TABLE D-73. ESTIMATED ANNUAL EMISSIONS OF VINYLIDENE CHLORIDE (VDC) IN THE U.S. IN MONOMER AND POLYMER SYNTHESIS AND POLYMER PROCESSING (1974)

Process	Annual VDC Emissions		VDC Consumption	% of Total U.S. Emissions
	1000 kg	1000 lbs		
Monomer Synthesis	1523[2]	3355[2]		82.6
Polymer Synthesis	308	679	112	16.7
- Latex for Barrier Coatings	55	120	20	
- Latex for Miscellaneous Coating	68[3]	150[3]	15	
- Synthetic Fibers	73[3]	160	16	
- Coating Resin for Cellophane	82	182[4]	25	
- Extrusion Resin (Emulsion Process)	12	27[5]	21	
- Extrusion Resin (Suspension Process)	18	40[6]	15	
Fabrication or Polymer Processing	13.7	30.4		0.7
- Coating Cellophane	0.7	1.6		
- Coating Plastics, Paper & Glassine	7.3	16.4		
- Extrusion	0.2	0.4		
- Miscellaneous Coating	5.5[3]	12.0[3]		
Total	1845.0	4064.0		100.0

1 This VDC emission inventory does not include emissions of VDC from the conversion of vinylidene chloride into 1,1,1-trichloroethane.

2 New emission-control technology will be installed in one of the plants during the latter part of 1975. On this basis, the annual VDC emissions should drop to 611,000 lbs (277,000 kg).

3 While all emissions listed in this table are estimates, the degree of certainty varies. These estimates are based on minimal data and are, therefore, more uncertain.

4 These products result in vinyl chloride emissions. The annual emissions are 1800 lbs.

5 These products result in vinyl chloride emissions. The annual emissions are 105,120 lbs. or 47,700 kg.

6 These products result in vinyl chloride emissions. The annual emissions are 43,435 lbs. or 19,700 kg.

Source: Arthur D. Little 1976

Disposition:
VDC (primarily in polymerized form) is disposed of in landfills. No data are available on emissions from this source

Sampling and Analytical Methods

NIOSH Method number P&CAM 266

Sampling:
A known volume of air is drawn through a charcoal tube to trap the VDC present

Analysis:
An aliquot of the sample desorbed with carbon disulfide is analyzed by gas chromatography

Detection limits:
The lowest quantifiable limit was determined as 7 ug of VDC per sample

Possible interferences:
1. Stability of sample
2. Humidity
3. Presence of other substances in the sample with the same column retention times as VDC

Threshold limit Values

U.S. TLV 10 ppm (40 mg/m^3)

Human Toxicity

Chronic Toxicity:

Carcinogenicity--The available epidemiological studies do not permit an assessment of human carcinogenicity. VDC does produce malignant tumors in experimental animals

Mutagenicity--VDC is mutagenic in S. typhimurium and E. coli; no data are available for humans

Teratogenicity--Fetotoxicity and embryotoxicity have been demonstrated in animals; no adequate data for humans

Other chronic toxicity:
Additional biochemical cellular, tissue effects and pulmonary toxicity testing is to be started in FY83 (National Heart, Lung, and Blood Institute)

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16. ABSTRACT

Procedures for selecting air monitoring sites are provided and discussed. A significant amount of information regarding 43 selected noncriteria pollutants is also presented. The document is a useful guideline for systematically setting priorities, identifying siting areas, and selecting specific sites that will meet the data needs for air monitoring responsibilities. The characteristics of each of the selected noncriteria pollutants are presented, including physical properties, sources of emissions, emission estimates, sampling and analysis methods, and toxicity. The siting procedures deal with a range of representative spatial scales varying from less than 100 m to 50 km.

17. KEY WORDS AND DOCUMENT ANALYSIS

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