

**Atmospheric Research  
and Monitoring Study of  
Hazardous Substances**

**Donald F. Gatz,  
Clyde w. Sweet**

**Illinois State Water Survey**

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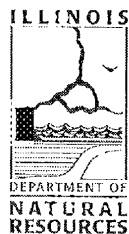
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**HAZARDOUS WASTE RESEARCH AND INFORMATION CENTER  
State Water Survey Division**

1808 Woodfield Drive  
Savoy, Illinois 61874

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**ATMOSPHERIC RESEARCH AND MONITORING STUDY  
OF HAZARDOUS SUBSTANCES**

*by*

*Donald F. Gatz and Clyde W. Sweet*

*Illinois State Water Survey*

October 1985



ATMOSPHERIC RESEARCH AND MONITORING STUDY  
OF HAZARDOUS SUBSTANCES

Progress Report

Chemical Substance Atmospheric Research Monitoring

Donald F. Gatz  
Clyde W. Sweet

Principal Investigator: Donald F. Gatz

Champaign, Illinois  
October 1985

Sponsored by  
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## EXECUTIVE SUMMARY

Production, handling, and disposal of hazardous wastes can result in emissions of toxic materials to the atmosphere. Airborne concentrations of such substances in Illinois are not well documented. Neither have they been characterized in terms of gas-solid partitioning or particle size distribution, two parameters important to understanding potential health and environmental effects.

This research effort was designed to provide information needed to assess possible health and environmental effects of airborne hazardous wastes. This first year's objectives included: 1) a review of hazardous waste incineration in Illinois, 2) a review of atmospheric sampling and analysis methods of the important hazardous waste-derived pollutants, and 3) a survey of current toxic airborne metals concentrations in Illinois. The following paragraphs review progress in these three areas.

### HAZARDOUS WASTE INCINERATION

Incineration of hazardous wastes will become more prevalent as landfilling becomes even more restricted over the next few years. Nineteen Illinois hazardous waste incineration facilities have filed, or are likely to file, RCRA Part B Applications for operative permits. Five of these either did not mention an incinerator in their application, or plan to close an existing incinerator. The others are believed to be currently operating incinerators under Interim Status. Most of these are in northern Illinois, clustered in or near Chicago. Three are in the industrial zone along the Mississippi River near East St. Louis.



Two of the active incinerators are commercially operated. One is a fixed hearth type and the other a rotary kiln. Both of these have liquid injection capability. The other three facilities which reported the type of incinerator they have are all liquid injection (only) types.

Only limited information is available on the nature of the waste streams burned. The two commercial incinerators take a wide variety of wastes, while the company-owned incinerators burn just the few hazardous wastes generated by their own facilities, often on-site.

Very little information is available on the composition of emissions from hazardous waste incinerators. However, in general two categories of compounds are of concern: 1) Principal Organic Hazardous Constituents (POHCs) present in the waste streams, and 2) Products of Incomplete Combustion (PICs) that can result from the combustion process. It appears likely that most hazardous waste incinerators can meet the standard of 99.99% destruction and removal efficiency\* required for an operating permit. Thus, stack emissions may be relatively inconsequential. Air quality should be measured in the vicinity of such facilities to verify this likelihood and also to detect possible fugitive emissions of toxic materials.

\*Destruction and Removal Efficiency (DRE) refers to the loss of a specific chemical compound and therefore can include anything from complete combustion to CO<sub>2</sub>, water and other simple compounds to a minor chemical change producing a new chemical compound which may or may not be hazardous itself.

## SAMPLING AND ANALYSIS OF TOXIC ORGANICS

Of the thousands of organic compounds that can be found in samples of ambient air, a relatively small number have a high enough toxicity and/or are present at a sufficient concentration to give rise to potential human health problems. Two classes of organic compounds which are important toxic components of hazardous waste streams and polluted atmospheres are the halogenated hydrocarbons and the aromatic hydrocarbons. Both of these classes include many large-volume industrial chemicals and have many members that are known or suspected carcinogens.

Sampling and analysis methods for organic compounds in air depend on the physical properties of the analytes. Vapor phase organics are usually preconcentrated by passing an air sample over a solid absorbent or a cold trap and subsequently desorbing the organics for analysis. For volatile compounds, the preferred analytical technique is separation of individual species by gas chromatography (GC) and quantitation using a specific detector or mass spectrometry (MS). Particle-bound organics are generally collected by filtration, extracted into a solvent, cleaned-up, and subjected to GC or GC-MS analysis after a clean-up procedure. Most particulate organics are difficult to analyze because they are present at low concentrations and are complex, high-molecular-weight compounds with many isomeric forms.

Two categories of potential target compounds for monitoring have been identified--volatile chlorinated hydrocarbons (e.g., chloroform, trichloroethylene), and volatile aromatic hydrocarbons (e.g., benzene, toluene). These compounds are important pollutants in terms of their

toxicity and their prevalence in urban atmospheres. They are relatively inert chemically and can be readily analyzed using available GC methodology. They also will be important components of the POHC's, PIC's and fugitive emissions from hazardous waste incinerators.

#### SAMPLING AND ANALYSIS OF TRACE ELEMENTS

A list of 19 trace elements which are found in air samples and which may pose a hazard to human health has been identified (see p. 38). Although all of these elements are toxic at levels much higher than found in ambient air, the health hazards of exposure to low levels are not well-understood; and safe levels for the general population have not been determined. At this time, lead (Pb) is the only metal for which an ambient air quality standard has been set ( $1.5 \text{ ug/m}^3$ ). Most of these elements occur as nonvolatile compounds and are associated with atmospheric particles. After collection by filtration, particulate samples are generally ashed, dissolved in acid and analyzed by atomic absorption spectroscopy. It is also possible to determine the concentration of many trace metals directly from the collected sample using neutron activation or x-ray emission techniques. These latter two methods are well suited for determining total concentrations of a wide range of elements on different particle-size fractions and should provide a good overall picture of trace element toxics in ambient air. Specialized techniques are required to determine the exact chemical form of each element. This may be important where different forms vary widely in toxicity or where both volatile and particulate forms occur.

## SURVEY OF AIRBORNE METALS IN ILLINOIS

The Illinois Environmental Protection Agency (IEPA) maintains a statewide network of air sampling stations collecting TSP (total suspended particles). The filters from 48 of these sites are extracted and subjected to atomic absorption analysis on a monthly basis. Multiple sampling sites are concentrated in the Chicago and Granite City-East St. Louis areas, and other individual sites are located in smaller urban areas throughout the state (see p. 45). Total concentrations of eight elements were determined in atmospheric particles between 1978 and 1983. The detection limit using this method is about  $.001 \text{ ug/m}^3$  for most of the elements with the exception of Pb ( $.01 \text{ ug/m}^3$ ).

Levels of beryllium (Be) and copper (Cu) were similar in most of the samples. Ambient Be levels are probably below the detection limits of the methods used, and Cu concentrations may be artificially high because of sampling artifacts.

The metal concentrations for the other six elements are generally similar to typical urban levels in the U.S. except at two locations. Average concentrations of iron (Fe), manganese (Mn), arsenic (As), and zinc (Zn) were elevated in Chicago (Lake Calumet area) and Granite City compared to other urban areas in Illinois. Granite City also has relatively high levels of Pb and cadmium (Cd).

Between 1978 and 1983, the concentrations of Pb, Fe and Mn decreased at most locations while the other elements remained at about the same levels. Some seasonal variation can be seen in the data. Pb and As tend to reach

maximum concentrations during the winter at most locations, and Fe and Mn tend to peak during the spring and fall.

We conclude that the best monitoring approach for toxic trace elements will be to analyze samples for as many toxic elements as possible in the two areas with known high metal concentrations. Information is also needed on the particle size distribution of each element.

#### CONCLUSIONS

Knowledge gained during the current year should allow us to begin work on the second year's objectives in a manner very close to that planned a year ago. We have a basis for siting aerosol samplers for collection and analysis of metals in two size ranges, in both background and industrial locations. We now have the necessary literature background to begin instrumentation and laboratory work on sampling and analysis methods for some major classes of organics, as well as volatile metals. Later in the year some preliminary atmospheric samples will be collected and analyzed for these materials.

## INTRODUCTION

Emissions of toxic materials to the atmosphere can occur in a variety of ways in the generation, transport, storage, treatment, and disposal of hazardous wastes. These emissions can take place via smokestacks, e.g., those of hazardous waste incinerators, or in a fugitive mode via evaporation of spilled, exposed, or landfilled volatile substances.

Atmospheric concentrations of toxic organic materials and trace elements are not well documented in Illinois. Measurements of airborne organics are particularly lacking, but a few metals have been measured since 1978 on high-volume filters collected by the Illinois Environmental Protection Agency (IEPA). Little information is available on size distributions of the trace elements and metals on solid particles, or on the gas-solid partitioning of organics and the volatile elements.

This information is important to know, since health effects of airborne hazardous waste materials depend on the phase (gas or solid) of the airborne wastes as well as particle size distributions, which determine the degrees of penetration and retention of particles in the lung. The environmental fate, pathways, and effects of these materials are also determined by both gas-solid partitioning and particle size distribution, because both wet and dry atmospheric deposition processes are heavily dependent on these parameters. Thus, our multi-year research plan includes measurements of gas-solid partitioning and particle size distributions of both organic compounds and trace elements.

The first-year objectives of this project included

- 1) A review of hazardous waste incineration in Illinois, identifying major wastes incinerated, locations and types of incinerators, and likely emissions and residues,
- 2) A review of state-of-the-art sampling and analytical methods for both organics and trace elements in the atmosphere and at sources, and
- 3) A survey of current toxic airborne metals concentrations in Illinois.

These objectives have in large part been accomplished, and the results are presented in the remainder of this report. However, our survey of airborne metals concentrations was based on available IEPA measurements, since our own measurements were delayed. The available measurements do not include information on particle size.

The term "hazardous waste" has been defined in the Resource Conservation and Recovery Act (RCRA) of 1976. The term signifies any solid, semisolid, liquid or contained gaseous material that is to be discarded and may pose a present or potential hazard to human health or the environment because of its quantity, concentration or physical, chemical or infectious characteristics. Obviously, this definition could include a very broad range of chemical compounds depending on physical properties, toxicity, and the manner of disposal. The U.S. Environmental Protection Agency (USEPA) has designated four categories of hazardous waste:

- (1) ignitable materials, (2) corrosive materials, (3) highly reactive materials (e.g., explosives) and (4) toxic materials. Toxic materials are

further divided into "acutely toxic wastes" for very poisonous compounds and "toxic wastes" for compounds with a moderate hazard level. A large number of industrial process streams and pure compounds have been designated as hazardous wastes by virtue of one or more of these properties. These materials are listed in Appendix A with their USEPA hazardous waste numbers. Some of these and many other compounds are so toxic that their presence, even in low concentrations, can pose a hazard if a material containing them is disposed of improperly. Appendix B lists these compounds as recognized by the USEPA. The presence of one or more of these compounds may cause waste material to be considered hazardous depending on concentration, toxicity and physical properties. The lists of chemicals designated hazardous by the USEPA should not be considered complete. Very little is known about the toxicity of many compounds, especially at low concentration over long exposure periods. As more scientific information is obtained, the lists of potentially hazardous materials can be expected to change.

#### REVIEW OF HAZARDOUS WASTE INCINERATION IN ILLINOIS

Federal regulations have prohibited the placing of liquid hazardous wastes in landfills since 1 July 1984, and will eventually prohibit landfill disposal of all liquid hazardous wastes for which there is a technically and economically feasible alternative. With the landfill alternative greatly reduced incineration, is likely to become more and more



the method of choice for disposal for many hazardous wastes. Incineration, or course, implies the emission of combustion products to the atmosphere, and raises the issue of possible emissions of hazardous materials to the atmosphere from incinerators. Thus, a logical early step in a research program to measure airborne hazardous substances in Illinois is a review of the current status of hazardous waste incineration in the state.

The Illinois Environmental Protection Agency (IEPA) (1983) recently reviewed and evaluated hazardous waste incinerators in Illinois. Through a search of the files of the agency's Divisions of Air Pollution Control (DAPC) and Land Pollution Control (DLPC), 76 potential hazardous waste incinerators in the state were identified. A separate listing of facilities for which RCRA Part A Applications have been filed with the U.S. EPA included 35 of these 76 and one additional facility. Further investigation narrowed the list to nine incinerators subject to RCRA regulations. These nine facilities had a combined capacity to burn 69,852 lb/hr (about 13 million gal/yr), but three of them, with a combined capacity of 7000 lb/hr were not in operation as of spring, 1983.

The IEPA 1983 report examined the status of these nine RCRA-regulated incinerators and an additional nine non-RCRA-regulated incinerators (with a combined capacity of about 4 million gal/yr) with respect to operating conditions, the existence of operating logs, air pollution control equipment, contingency plans, emission data, RCRA compliance, and the types of wastes burned. A major finding of the IEPA report was that some components of wastes burned in non-RCRA-regulated

incinerators may produce emissions that have similar impacts on human health and welfare as do hazardous substances as defined by RCRA. This led to the conclusion by IEPA that state regulations are needed to control the operation of non-RCRA-regulated facilities.

In the two years since the IEPA report, a limited amount of new information on hazardous waste incinerators in Illinois has become available as decisions have been reached by individual companies regarding the filing of the RCRA Part B Applications. Some facilities have filed Part B, some have decided to close the facility in question, some may have discovered that they are not required to file, and others are apparently in the process of compiling their applications. The following summary of the current status of hazardous waste incineration in Illinois is based on a list of facilities in Illinois having RCRA Part B process codes, furnished to this project by U.S. EPA, Region V (personal communication from John Shirey, U.S. EPA, Region V.), and by inspection of Part B applications received by Region V as of 6 May 1985.

Current information is summarized in Tables I and II. Table I lists 19 hazardous waste facilities that have filed, or are considered (by EPA) likely to file, Part B Applications. For five of these facilities, the Part B Application does not mention an incinerator, or indicates that the incinerator will be closed. The others are believed to be currently operating under Interim Status. Table II lists 10 facilities that are considered unlikely to receive operating permits for various reasons. One additional facility on the original Region V list, Genstar Corp., asked for its documents to be returned, and has apparently gone out of business.

Table I. Hazardous waste incineration facilities in Illinois having RCRA Part B process codes indicating the potential for permitting. (Personal communication, John Shirey, USEPA Region V, April, 1985.)

<u>Facility name, address and ID No.</u>	<u>Type of facility</u>	<u>Part B status<sup>a</sup></u>	<u>Incinerator type</u>	<u>Capacity by waste category<sup>b</sup></u>	<u>Waste streams incinerated</u>
Abbott Laboratories 1400 N. Sheridan North Chicago, IL 60064 ILD055409940	Generator Transporter TSD <sup>c</sup>	R	N/A <sup>d</sup>	Total: 708 gal/hr <sup>d</sup>	N/A <sup>d</sup>
Akzo Chemie America Arnak Chemicals Div. Rte. 6 & Tabler Rd. Morris, IL 60450 ILD065237851	Generator TSD	S	Liquid injection (single chamber)	Total: 6.0 tons/hr Liquid: 16,000 lb/hr	1. Liquid pitch and fat residues (max. 600 lb/hr) 2. Wastewater contaminated with fatty materials and their nitrogen derivations (10,000 lb/hr) <sup>e</sup> 3. Gas from various processes
Cargill, Inc. Chemical Products Div. Lake Marion Rd. & Cottage Ave. Carpentersville, IL 60110 ILD005083316	Generator TSD	R	N/A	Total: 151 tons/hr	N/A
A. B. Dick, Co. 5700 W. Touhy Ave. Chicago, IL 60648 ILD005093109	Generator TSD	S <sup>f</sup>	N/A <sup>f</sup>	Total: 50 gal/hr <sup>f</sup>	N/A <sup>f</sup>
Kelly-Springfield Tire Co. Route 20 East Freeport, IL 61032 ILD003096286	Generator TSD	R	N/A	Total: 0.713 tons/hr	N/A
Koppers Co., Inc. 3900 S. Laramie Chicago, IL 60650 ILD005164611	Generator Transporter TSD	S <sup>g</sup>	Liquid injection (single chamber)	Total: 2400 gal/hr <sup>g</sup>	D001 (corrosive) (scrubber liquor, containing phthalic anhydride, maleic anhydride, or naphthoquinone) (30,000 tons/yr)
Marathon Oil Co. Marathon Ave. Robinson, IL 62454 ILD005476882	Generator TSD	S	N/A <sup>h</sup>	Total: 262 gal/hr <sup>h</sup>	N/A <sup>h</sup>

Table I. (cont.)

<u>Facility name, address and ID No.</u>	<u>Type of facility</u>	<u>Part B status<sup>a</sup></u>	<u>Incinerator type<sup>b</sup></u>	<u>Capacity by waste category</u>	<u>Waste streams incinerated</u>
Meyer Steel Drum, Inc. 3201 S. Millard St. Chicago, IL 60623 ILD081037772	Generator TSD	R	N/A	Total: 150 gal/hr	N/A
Monsanto Co. Route 3 Sauget, IL 62201 ILD000802702	N/A	N/A	N/A	Total: 2.45 tons/hr	N/A
Northern Petrochemical Co., Inc. Route 6 & Tabler Road Morris, IL 60450 ILD048296180	Generator TSD	S	Liquid injection	Liquid: 11 gal/hr	D001 (ignitable) (90% odorless mineral spirits, containing 10% by weight of di-ter-butyl peroxide, ter-butyl peroxoate, and/or t-butyl perbenzoate)
Olin Corp. Main Plant 427 Shamrock St. East Alton, IL 62024 ILD006271696	Generator Transporter TSD	R	N/A <sup>1</sup>	Total: 0.300 tons/hr	N/A <sup>1</sup>
Rexnord, Inc. Rockford Products Corp., Plant 3 707 Harrison Ave. Rockford, IL 61101 ILD005212097	Generator Transporter TSD	R	N/A	Total: 135.39 gal/hr	N/A
SCA Chemical Services, Inc. Illinois Division 11700 Stony Island Ave. Chicago, IL 60617 ILD000672121	Generator TSD	S	Rotary kiln with liquid injection in secondary chamber	Total: 2100 gal/hr Maximum: 120M BTU/hr Solid: <50M BTU/hr (kiln) Liquid: <80M BTU/hr (secondary chamber)	All, or nearly all EPA hazardous waste code numbers, at capacities (where specified) ranging from 100-7500 tons/yr.
The Sherwin-Williams Co. 11541 S. Champlain Ave. Chicago, IL 60628 ILD005456439	Generator TSD	R	N/A	Total: 290 gal/hr	N/A
Spaulding Fibre Co., Inc. Special Plastics Division 1300 S. Seventh St. DeKalb, IL 60115 ILD064000011	Generator TSD	R <sup>j</sup>	N/A <sup>j</sup>	Total: 240 gal/hr	N/A
Texaco Inc. Texaco USA Division 2nd & State St. Lockport, IL 60441 ILD041518861	Generator Transporter TSD	R	N/A <sup>k</sup>	Total: 1200 gal/hr <sup>k</sup>	N/A <sup>k</sup>

Table I. (cont.)

<u>Facility name, address and ID No.</u>	<u>Type of facility</u>	<u>Part B status<sup>a</sup></u>	<u>Incinerator type<sup>b</sup></u>	<u>Capacity by waste category</u>	<u>Waste streams incinerated</u>
Trade Waste Incineration, Inc. 1 Mobile St. Sauget, IL 62201 ILD098642424	TSD	S	Hearth with liquid injection capability	Total: 0.5 tons/hr (14M BTU/hr)	All, or nearly all, EPA hazardous waste code numbers.
U.S. Army Joliet Army Ammunition Plant (Uniroyal) 6 miles S. of Elwood off Route 53 Joliet, IL 60434 IL7213820460	Generator TSD	R	N/A	Total: 15.153 tons/hr	N/A
3M Cordova Chem-Mag A-V Highway 84 Cordova, IL 61242 ILD054236443	Generator TSD	S	N/A	Total: 1.25 tons/hr	D001 (ignitable) (mixed scrap) F003 (ignitable) (waste acetone) <sup>m</sup> F003 (ignitable) (waste xylene) <sup>m</sup>

<sup>a</sup>R = requested; S = submitted

<sup>b</sup>"Total" values from data listing provided by John Shirey, USEPA Region V. Additional information based on inspection of Part B application.

<sup>c</sup>TSD = Treatment, storage, disposal

Notes and comments based on inspection of part B application:

<sup>d</sup>"Abbott does not manage a(n)...incinerator..." (from Introduction to Section D, Process Information, Revision 0, 5-30-84).

<sup>e</sup>The waste stream is also characterized as "Aqueous waste composed of a maximum 10% formaldehyde and 90% water containing organic materials (fatty materials and nitrogen derivatives)." This material is not generated routinely, but could result from handling or storage problems.

<sup>f</sup>Inspection of the Part B application revealed no references to plans for incineration of hazardous waste.

<sup>g</sup>Information in the Region V files indicates that Koppers was not submitting Part B for the incinerator with other Part B applications (dated 4-19-85), but wanted to meet with USEPA and IEPA representatives to discuss incineration requirements (in summer, 1985).

Koppers Part A application lists incinerator capacity as 1200 gal/hr. but the Region V Part B data base shows 2400 gal/hr.

Koppers Co. believes that the waste feed to the incinerator will not contain enough phthalic anhydride, maleic anhydride, or naphthoquinone to be considered hazardous, but they are somewhat unsure because they have not previously used naphthalene as a feed stock at this facility. Possible emissions to the atmosphere include the three compounds just mentioned, but Koppers believes that their maximum 8 hr ambient concentrations will not exceed 0.005 ppm.

<sup>h</sup>A letter from David R. Saad to Thomas Golz (EPA) regarding the RCRA Part B Permit Application for the Marathon Robinson refinery indicates that their "incineration will be closed during interim status..."

<sup>i</sup>Information on incinerators in revised Part B application claimed "confidential."

<sup>j</sup>The Part B Application on file at Region V does not mention an incinerator at the facility.

<sup>k</sup>A letter to Mr. William H. Miner (USEPA) from C. W. Dougherty, dated 11-13-84, indicates that the incinerator facility is to be closed.

<sup>m</sup>The waste acetone consists of 90-100% acetone, 0-10% solids. The waste xylene consists of 90-100% xylene, 0-10% solids.

Table II. Facilities on EPA Region V list that are unlikely to be permitted (permit denied, or applications withdrawn or likely to be withdrawn).

<u>Name, Address, ID</u>	<u>Part B Status</u>
Alburn, Inc. 2200 E. 119th St. Chicago, IL 60617 ILD 000716852	Denied.
Borden, Inc. Route 36, 2 mi W of Illiopolis Illiopolis, IL 62539 ILD 005158548	Part A withdrawal candidate.
Claire Manufacturing Co., Inc. 500 Vista Ave. Addison, IL 60101 ILD 005155973	Part A withdrawn, Part B with- drawn, never met Interim Status criteria.
FMC Corp., Ag. Chem. Group Highway 17 East Wyoming, IL 61491 ILD 005472881	Part A withdrawal candidate.
Ludlow Corp. Specialty Paper Division 11235 S. Cottage Grove Ave. Chicago, IL 60628 ILD 051937340	Part A withdrawal, Part B with- drawn, never met Interim Status criteria.
Paxton Landfill Corp. 12201 S. Oglesby Chicago, IL 60633 ILD 069498186	Part A withdrawal candidate.
Pierce Chemical Co. 3747 N. Meridian St. Rockford, IL 61103 ILD 041539230	Part A withdrawal candidate.
PMR Corp/Simmons Refining Co. 4105 W. Chicago Ave. Chicago, IL 60651 ILD 005060223	Part A withdrawal candidate.
Powell Metals and Chemicals, Inc. 1122 Milford Ave. Rockford, IL 61088 ILD 064013295	Part A withdrawn, Part B with- drawn, never met Interim Status criteria.
Siebert and Sons, Inc. Route 24 & 7th St. Chenoa, IL 61726 ILD 005237524	Part A withdrawal candidate.

Table I lists the name, address, and ID number of each facility in the first column. The second column of Table I indicates the nature of the facility's involvement with hazardous wastes; i.e., as a generator of the wastes, a transporter of the wastes, or as a treatment, storage, and disposal (TSD) facility. The third column indicates whether the Part B Application has been requested by EPA (R), or has already been submitted (S) by the company. Column four lists the type of incinerator at each facility, if such information was available. Column five lists the facility's capacity, by major category (solid, liquid), and column six gives available information on the waste streams incinerated.

#### INCINERATOR LOCATIONS

A map, showing the 13 Illinois cities in which these facilities are located, is given in Figure 1. If a city has more than one facility, the number is given in parentheses. It is apparent that the facilities are concentrated in northern Illinois, and especially in Chicago, the location of five incinerators. Three others are located in the industrial zone along the Mississippi River near East St. Louis.

#### INCINERATOR TYPES

Information about the type of incinerators used at the various facilities is available for only 5 of the 19 facilities listed in Table I. In a report to the U.S. EPA, Keitz et al. (1984) listed 9 types of incinerators, described as follows:

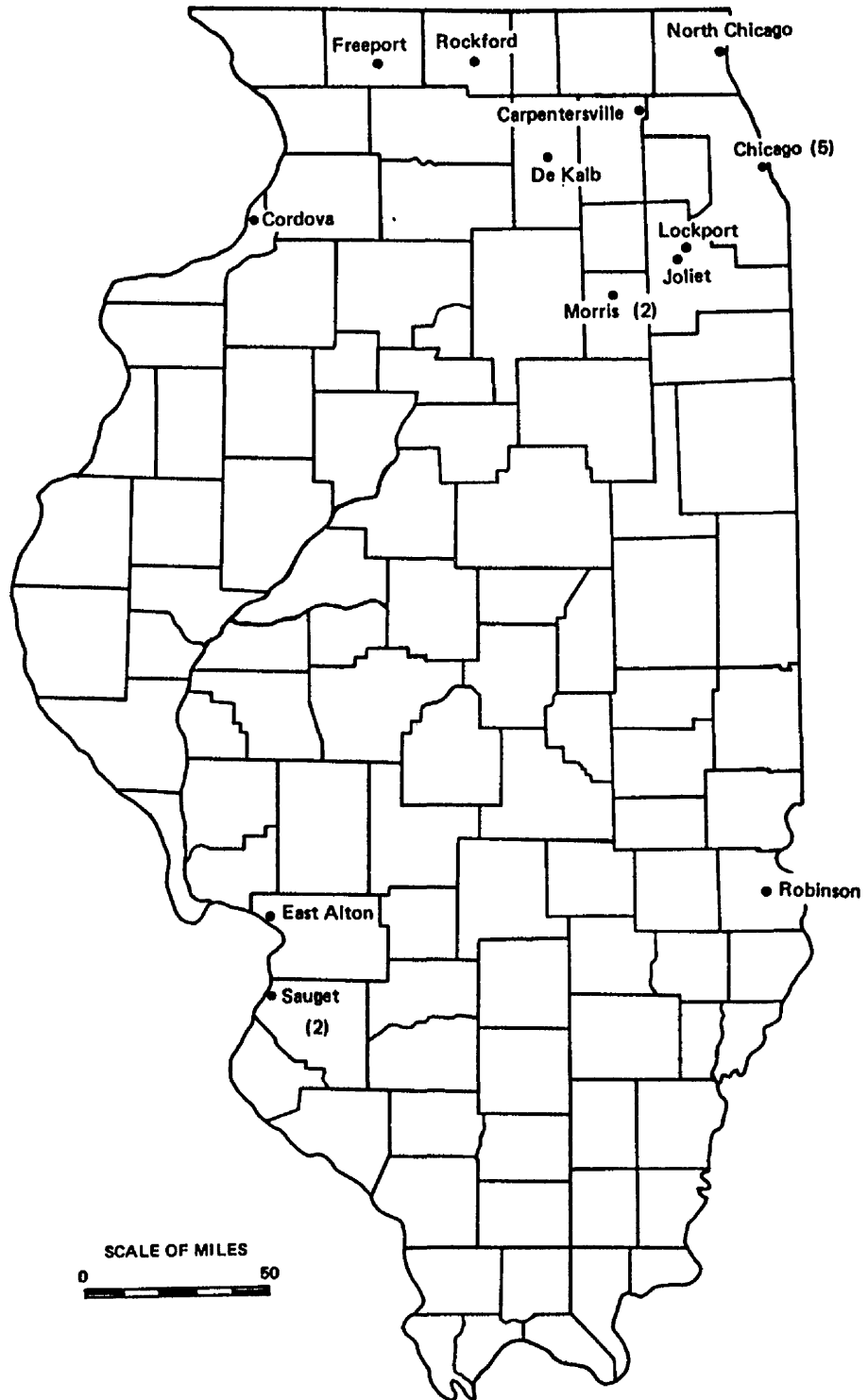


Figure 1. Map of Illinois showing actual and potential locations of hazardous waste incinerators. Numbers in parentheses indicate multiple facilities in the same city.



Liquid Injection -- an incinerator that uses an atomization device or nozzle to feed only liquid wastes.

Fume with Liquid Capability -- an incinerator principally used for burning vapors, which has an atomization device or nozzle for burning liquid waste.

Hearth with Liquid Capability -- any fixed hearth or chamber designed for the introduction of bulk waste, but equipped with an atomization device or nozzle for burning liquid waste.

Hearth (solids only) -- any fixed hearth or chamber dedicated for incineration of solids and not equipped for the injection of liquid waste.

Rotary Kiln with Liquid Capability -- a rotating cylindrical incinerator equipped with an atomization device or nozzle for burning liquid wastes in the rotating chamber.

Combination System -- any combination of connected incinerator types intended to operate as a single system.

Ammunition and Explosives -- any incinerator primarily used for the destruction of ammunition, explosives, or related wastes which are not otherwise classified as hazardous.

Drum Burner -- any incinerator specifically used for the reclamation or reconditioning of steel drums.

Other -- all hazardous waste incinerators not included in any of the above categories, including such types as fluidized bed, metal recovery, liquid flare, research prototype, pyrolyzer, and car bottom annealing furnace.

For the entire U.S., Keitz et al. reported that the liquid injection incinerator was the most prevalent, accounting for 52% of the 264 incinerators they identified by type, and that the four types of incinerators with liquid capability accounted for 79% of the total.

The five Illinois incinerators identified by type are all capable of liquid injection, and three of them are of the liquid injection (only) type. Of the two commercial incinerators, one (Trade Waste Incineration,

Inc.) is a fixed hearth with liquid injection capability, and the other (SCA Chemical Services, Inc.) is a rotary kiln with liquid injection capability in a secondary chamber.

#### WASTE STREAMS

The information available on the nature of the wastes burned is limited to those sites for which Part B Applications have been filed. However, from the information available, it is apparent that hazardous waste incinerators in Illinois fall into two groups: 1) commercial incinerators, which burn a wide variety of waste streams that come in varying quantities from a wide range of industrial and other customers, and 2) generator-owned incinerators, which burn only a few different kinds of wastes, mostly generated on-site.

Specific waste streams mentioned in Part B Applications are listed in Table I for those incinerators that handle company-generated wastes. The lists of wastes for which the commercial incinerators are seeking permits include all, or nearly all, of the general categories and specific compounds for which EPA has assigned code numbers (see Appendix A); these are not detailed in Table I.

The national profile of characteristics of hazardous waste incinerators, compiled by Keitz et al. (1980) for the U.S. EPA, gives extensive information on waste streams incinerated throughout the country, as a function of incinerator type and capacity. Due to the limited number of Illinois facilities for which complete data are available, such an analysis has not been done for Illinois, but the national profile can provide useful general information.

## EMISSIONS AND RESIDUES

Very little information is available on the composition of emissions and residues from hazardous waste incinerators, although information presented at Hazardous Waste Workshops in St. Louis and Chicago, arranged by the Air Pollution Control Association, indicates that research is in progress in this area. Two general classes of materials are of concern as atmospheric emissions. The first category is Principal Organic Hazardous Constituents (POHCs). The POHCs likely to be present in the emissions from a given incinerator depend largely on the nature of the waste streams incinerated. The second general category of concern is Products of Incomplete Combustion (PICs). The specific PICs present in a given incinerator plume are again influenced by the waste stream being burned, but are known to potentially include benzene, chloroform, bromodichloromethane, dibromochloromethane, naphthalene, bromoform, chlorobenzene, tetrachlorobenzene, 1,1,1-trichloroethane, toluene, o-nitrophenol, and methylene chloride.

A few of the incinerators listed in Table I mentioned specific emissions in their Part B Applications. Results of test burns can also yield such information, but test burns frequently are made using only a few of the possible waste streams considered the most difficult to burn, so that they cannot be interpreted directly in terms of the composition of routine emissions. It should be pointed out that the routine emissions monitoring required of hazardous waste incinerators is generally designed to warn operators of problems, or to automatically shut off the feed of wastes to the incinerator. Such routine monitoring is not designed for the purpose of measuring hazardous constituents in the emissions. If the

incinerator achieves the standard of 99.99% Destruction and Removal Efficiency (DRE) for the POHCs during the test burn, and if the incinerator is operating to specification, it is assumed that the DRE is being achieved during routine operation.

Current evidence is that modern incinerators, having sufficiently high internal temperatures and sufficiently long residence times for the injected wastes, can achieve 99.99% DRE for a wide variety of hazardous wastes. However, it appears that relatively little attention is being given to possible fugitive emissions of hazardous substances, via spills or evaporative losses during handling, from incinerator facilities. In a recent report, the U.S. EPA (1985) suggested that fugitive emissions and accidental spills may release as much or more toxic material to the environment than the direct emissions from incomplete waste incineration. Also, there are limitations to our ability to monitor many of the PIC's at trace levels in the emission streams of incinerators. Thus, a program of ambient sampling in the vicinity of such facilities would be appropriate.

#### REVIEW OF MEASUREMENT METHODS

The purpose of this section is to discuss some of the factors which must be considered in designing an air monitoring project and to review available methodology for sampling and analysis of airborne organic compounds and trace elements. The intent is to review a broad range of chemicals as candidates for monitoring and the major analytical and sampling options available. This will provide the necessary technical information for selection of the most appropriate compounds and methods after our research objectives have been fully developed.

## ORGANIC MATERIALS

### Compounds of Interest

The wide variety of organic compounds that can be found in ambient air samples has been reviewed (Simoneit and Mazurek, 1981; Brodzinsky and Singh, 1983; Lamb et al., 1980). While these compounds can be categorized in a variety of ways, separation into volatile and nonvolatile categories is perhaps the most useful because of differences in sampling methodology. Volatile organic compounds are those which are predominantly in the gaseous state at ambient temperatures (vapor pressure  $>10^{-4}$  mm Hg). Table III identifies 151 volatile organic compounds commonly found in urban atmospheres. Brodzinsky and Singh (1983) have divided them into four categories: A) hazardous materials likely to be found in urban atmospheres; B) materials likely to be found in the ambient atmosphere but whose hazard is in doubt; C) hazardous materials usually found only near specific sources; and D) organic chemicals likely to be found in urban atmospheres but not considered hazardous at this time. In addition to this list several hundred other volatile organic compounds from both natural and human activities have been identified in various atmospheric samples.

Nonvolatile organic compounds (v.p.  $<10^{-8}$  mm Hg) are present in the solid state under ambient conditions and are commonly associated with atmospheric aerosols. Daisy (1980) has identified 23 classes of organic compounds found in urban aerosols, and over 100 individual compounds have been found in some samples. Nonvolatile compounds are generally present at much lower concentrations than volatile compounds; however

Table III. Volatile organic chemicals found in atmospheric samples.\*

Category A		Category B		Category C		Category D	
Name	Number	Name	Number	Name	Number	Name	Number
Benzene (SC)	001	Toluene	101	Dibromomethane	201	Methane	301
Methyl chloride (BM)	002	o-Xylene	102	Bromodichloromethane	202	Ethane	302
Methyl bromide (BM)	003	m/p-Xylene	103	Chlorodibromomethane	203	Ethylene	303
Methyl iodide (SC, BM)	004	Styrene (BM)	104	Dichlorodibromomethane	204	Acetylene	304
Methylene chloride (BM)	005	1,3 Butadiene (BM)	105	Bromoforn	205	Propene	305
Chloroform (SC, BM)	006	n-Dodecane (SC)	106	1-Chloro-2-bromoethane	206	Propene	306
Carbon tetrachloride (SC)	007	n-Decane (SC)	107	Pentachloroethane	207	1-Butane	307
1,2 Dichloroethane (SC, BM)	008	n-Undecane (SC)	108	Bromopropene (isomers)	208	n-Butane	308
1,2 Dibromoethane (SC, BM)	009	n-Octadecane (SC)	109	Chlorobromopropene (isomers)	209	Butenes (isomers)	309
1,1,1 Trichloroethane (BM)	010	$\alpha$ -Pinene (BM)	110	1-Chloro-3-bromopropene	210	1-Pentane	310
1,1,2 Trichloroethane (SC)	011	Dodecylbenzene (BM)	111	Dibromochloropropene	211	n-Pentane	311
1,1,2,2 Tetrachloroethane (SC, BM)	012	Fluorocarbon-22 (BM)	112	1-Chloro-2,3-dibromopropene	212	1-Pentane	312
Hexachloroethane (SC)	013	Ethyl chloride	113	1,1 Dibromo-2-chloropropene	213	2-Methylpentane	313
1,2 Dichloropropane (BM)	014	1,1 Dichloroethane	114	Dichloropropene (isomers)	214	3-Methylpentane	314
Vinyl chloride (SC, BM)	015	1,1,1,2 Tetrachloroethane	115	1-Chloro-3 bromopropene	215	n-Hexane	315
Vinylidene chloride (SC, BM)	016	1,4 Dichlorobutane	116	Bromobenzene	216	2,4-Dimethyl pentane	316
(cis) 1,2 Dichloroethylene (BM)	017	1,2 Dibromopropane	117	Bromotoluene	217	Ethylbenzene	317
Trichloroethylene (SC, BM)	018	(trans) 1,2 Dichloroethylene	118	Dichlorotoluene	218	1,3,5 Trimethylbenza	318
Tetrachloroethylene (SC)	019	Benzaldehyde	119	Trichlorotoluene	219	1,2,4 Trimethylbenzene	319
Allyl chloride	020	Toluialdehyde (isomers)	120	Tetrachlorobenzene	220	1,2,3 Trimethylbenzene	320
Chloroprene (BM)	021	Phthalaldehyde (isomers)	121	Tetrachlorotoluene	221	Naphthalene	321
Hexachloro 1,3 butadiene (BM)	022	Phenol	122	Pentachlorobenzene	222	$\alpha$ -Methylnaphthalene	322
Monochlorobenzene (BM)	023	Peroxyacetyl nitrate	123	Chloronitrobenzene	223	Carbon tetrafluoride	323
o-Dichlorobenzene (BM)	024	Peroxypropionyl nitrate	124	Dichloronitrobenzene	224	Fluorocarbon-12	324
m-Dichlorobenzene (BM)	025	Peroxybenzoyl nitrate	125	Chloroaniline	225	Fluorocarbon-11	325
p-Dichlorobenzene (BM)	026	Diethyl sulphate (SC, BM)	126	Chlorobenzaldehyde	226	Fluorocarbon-113	326
Trichlorobenzene (BM)	027	Dimethyl sulphate (BM)	127	Epichlorohydrin	227	Fluorocarbon-114	327
Tetrachlorobenzene (BM)	028	Carbonyl sulfide	128	Maleic anhydride	228	Acetone	328
$\alpha$ -Chlorotoluene (SC, BM)	029	Carbon disulfide	129	1,4 Dioxane	229	Methylethyl ketone	329
Hexachlorocyclopentadiene (BM)	030	Tetramethyl lead	130	Aniline	230	Methyl isobutyl ketone	330
Ethylene oxide (BM)	031	Tetraethyl lead	131	Benzonitrile	231	Acetophenone	331
Propylene oxide (SC, BM)	032	Trimethyl ethyl lead	132	$\beta$ -Chloro ethers	232	Propiophenone	332
Formaldehyde (SC, BM)	033	Dimethyl diethyl lead	133	Polychloronaphthalenes	233	n-Heptane	333
Acetaldehyde	034	Methyl triethyl lead	134	Allyl bromide	234	n-Octane	334
Phosgene	035					n-Nonane	335
o-Cresol (SC)	036					4-Ethyl toluene	336
p-Cresol (SC)	037					Dimethyl sulfide	337
m-Cresol (SC)	038						
Acrolein (SC)	039						
bis-Chloromethyl ether (SC, BM)	040						
bis-(2-Chloroethyl) ether (SC)	041						
Acrylonitrile (SC, BM)	042						
Nitrobenzene	043						
Dimethyl nitrosamine (SC)	044						
Diethyl nitrosamine (SC)	045						
2-Nitropropane (SC)	046						

## Key:

Category A: Ubiquitous toxic chemicals in urban ambient environment; Category B: ubiquitous suspect toxic chemicals in urban ambient environment; Category C: Toxic chemicals that are likely to be site specific and Category D: Chemicals considered to be nontoxic

BM: Bacterial mutagens; SC: Suspected carcinogens

\* Brodzinsky and Singh (1983)

several are important pollutants. These include some polycyclic aromatic hydrocarbons (PAH's), polychlorinated biphenyls (PCB's), and polychlorinated dioxins and furans, all of which are of concern because of their high toxicities.

Many high-molecular-weight organic compounds have vapor pressures between  $10^{-4}$  and  $10^{-8}$  mm Hg and therefore are present in both vapor and particulate fractions (Eisenreich et al., 1980; Murphy, 1984). In polluted atmospheres, organics that are normally volatile can also become partially bound to particles, especially those with a high carbon content. Separation of particle-bound and vapor phase forms of a compound presents a difficult analytical problem because a dynamic equilibrium exists between the two fractions. Changes in temperature, humidity, or particle characteristics can all affect the distribution between the vapor and solid phases. In addition, the proportion of material in the vapor phase can be strongly influenced by the sampling method. Some organic components collected as particles in high volume air samplers can be lost from filters by vaporization (Van Veck et al., 1984; Riggin, 1983).

Finally, it is important to consider chemical reactions that can occur in the atmosphere and during sampling and analysis of organic compounds. These may result in the formation of secondary pollutants, the loss of primary pollutants, low analytical results, or the production of analytical artifacts (Grosjean, 1983).

Obviously, an important preliminary step in formulating our atmospheric organic sampling plan is to develop a limited list of target chemicals to be monitored from the hundreds of possible compounds. Some of the

important considerations in making up this list are source characteristics, toxic hazard, reactivity, specificity to the source and available methods for sampling and analysis. The specific set of target compounds will represent a compromise between technical feasibility and environmental significance.

Most identification and monitoring research has been done on the hydrocarbons (compounds containing only H and C) and halogenated hydrocarbons. This is because of the high levels of these compounds found in the atmosphere, their importance in the formation of secondary pollutants, their toxicity and the potential effects of halogenated hydrocarbons on the stratospheric ozone layer. Other classes of atmospheric organics which have been studied include aldehydes and ketones, ethers, phenols, nitrogen compounds and sulfur compounds.

#### Ambient Sampling Methods

Volatile Organics. Table IV lists available sampling methods for vapor phase and particulate organics. For organic volatiles, sampling procedures are usually based on preconcentration during sampling. In some cases, however, direct analysis (i.e., no sampling) is possible when analyte concentrations are high. These techniques include diffusional samplers in which organic vapors diffuse into absorption tubes where they interact with an absorbent producing a color reaction. Ambient concentration is related to the intensity of the color. This sampler can also be coupled with a pump to obtain an instantaneous (5-10 min) sample. Gas detection tubes are presently available for about 40 organic compounds (Riggin, 1983). They



are most useful in industrial hygiene applications where pollutant concentrations are relatively high and the mixture of target compounds is simple and well characterized.

Table IV. Sampling methods for organics in air.

<u>Vapor Phase</u>	<u>Particles</u>
Direct analysis	Filtration
Whole air collection	- Cellulose, Glass or
Impinger collection	Quartz Mat
Derivitization	- Polymeric membrane fiber
Cryogenic collection	
Solid absorbents	Centrifugal collection
- Organic polymers	Impaction
- Inorganic absorbents	Electrostatic precipitation
- Carbon absorbents	

Whole air collection involves the isolation of a relatively small volume of air (1-10 L) in a Teflon, glass or stainless steel container. Typically, the sample is then transported to a lab where components of the sample can be concentrated and analyzed. This approach is best suited for instantaneous sampling, but it can result in a loss of certain reactive sample components through interaction with container walls (Katz, 1977a).

The most commonly used sampling procedures for ambient concentrations of vapor phase organics involve passing an airstream through some sort of trap capable of capturing organics. Typically, polymeric (Tenax or XAD resins) or charcoal-based absorbents are used for nonpolar compounds, and silica gel or florosil for polar compounds. Air is pumped continuously through the absorbent which allows the sampling of a large volume of air integrated over a time period of several hours or more. Before analysis,

the preconcentrated organics are desorbed onto an analytical instrument in the laboratory using heat or solvent extraction. One problem that can arise with some of the polymeric absorbents is that reactions can occur with ozone or other reactive gases in the atmosphere to produce artifacts (Schlitt et al., 1980). If no particle filter is placed upstream from the vapor trap, both gaseous materials and some particles will be collected. On the other hand, the addition of a filter will allow separate determination of gaseous and particle-bound forms of a compound.

Organic vapors can also be trapped using cryogenic collection methods where the airstream is passed over a trap cooled with liquid argon or other suitable cryogen and recovered in the lab by flash evaporation. A major disadvantage with this technique is that water and some reactive inorganic gases are also collected causing trap plugging or decomposition of the collected organics.

Finally, impinger methods can be used to trap organic vapors. In this case, air is bubbled through a solvent or reagent solution to collect the vapor-phase organics. This technique is especially useful for capturing and derivitizing pollutants that are very reactive and would normally be lost during collection, transport and storage. Since only small volumes of air can be handled, this method is generally used to monitor high concentrations of pollutant.

Particulate Organics. Nonvolatile organic compounds (v.p.  $<10^{-8}$  mm Hg) are always found associated with atmospheric particulates. Additionally, at least a portion of many volatile (v.p.  $>10^{-8}$  mm Hg) organics may be

bound to particles depending on factors discussed earlier. The ratio of particle-bound to vapor phase material can also be strongly dependent on the sampling method. Basically, methods in which a large volume of air is passed over collected particles can result in increased volatilization of particle-bound compounds. The methods for collecting atmospheric particles are listed in Table IV and have been reviewed (Giever, 1976).

The most widely used method for particle collection is filtration. The various filter materials are listed in Table IV. Mat filters consist of a matrix of fibers with a range of pore sizes. They have rough surfaces and are relatively thick. Among mat fibers, cellulose filters are the least expensive and are suitable for high volume sampling; however, they do not collect very small particles ( $<0.3 \mu\text{m}$ ) very efficiently at low face velocities (Katz, 1977b). They are also hygroscopic which makes accurate weight determination more difficult.

Glass and quartz fiber filters have better collection efficiencies for small particles and are more inert chemically than cellulose filters. However, they are more expensive and have less mechanical strength. They also have a higher trace element background level and may react with some atmospheric organics (Grosjean, 1983). These filters are used as the standard collection medium for high-volume samplers in the U.S. EPA's National Air Sampling Network.

Membrane filters are made from a thin film of Teflon, cellulose acetate or other polymer with small, very uniform cylindrical pores. They have good collection efficiencies and very smooth surfaces allowing easy examination of particles by electron microscopy. The major disadvantage of

membrane filters is their high resistance to flow and consequent low sampling capacity.

Skogerboe (1973) has argued that none of the filter materials in current use act as absolute filters for very small particles (<0.3  $\mu\text{m}$ ) so that the material passed by the filter is always a mixture of gaseous compounds and very small particles. An additional problem sometimes encountered during filtration of polluted atmospheres is the reaction of some collected organics with reactive atmospheric gases such as ozone and  $\text{NO}_x$  which may alter the sample characteristics from those originally present in the atmosphere.

Most particle sampling approaches other than filtration are employed for the purpose of size classification to distinguish respirable particles (<10  $\mu\text{m}$ ) from larger ones. Methods using centrifugal collectors (cyclones) or impactors rely on differences in momentum to fractionate particles. The air stream is accelerated to progressively higher velocities, which results in the deposition of increasingly finer particles on the collecting surfaces. Typically, these devices are backed up by a filter and absorbent to collect submicron particles and vapors that pass through impaction and cyclone samplers.

Fractionation of the particles into size classes can make analysis of bound organics more difficult. The typical atmospheric concentrations of particle-bound organics are less than 10% of those of volatile organics. This means that very large volumes of air (>1000  $\text{m}^3$ ) must be filtered to accumulate enough particulate matter for extraction and analysis. This usually means sampling durations of 24 hr or more. If the particulate

matter is subdivided into size fractions and an analysis of each fraction is desired, sampling durations of a week or more may be required.

Electrostatic precipitation has also been used for collection of particulate matter. With this method, it is possible to capture particles with diameters greater than 0.1  $\mu\text{m}$  in large volumes of air. Particles entering the device become charged and are attracted to charged plates. The effect of the corona discharge and the presence of reactive gases (e.g., ozone) on the collected organic chemicals has not been thoroughly investigated. Mitchell et al. (1977) have described a device which collects large amounts of particulates (ca. 1 g/day) in three size classes. It consists of an impaction collector backed up by an electrostatic precipitator to collect the fraction below 0.3  $\mu\text{m}$ .

#### Analysis Methods for Ambient Samples

The field of analysis of organic chemicals is a very broad one due to the large number of organic compounds and the wide variety of possible analytical strategies. This discussion is limited to the techniques that are commonly applied to ambient air sampling. Table V lists these methods along with some of their applications and limitations. Reviews are available on specific techniques and on organic analysis in general (Lanster and Young, 1977; Bursey et al., 1977).

Since most environmental samples are very complex mixtures, the first task of the analyst is usually separation into pure compounds. For compounds which are volatile and stable at temperatures below 350°C, gas chromatography (GC) is the best method for carrying out this task. The

Table V. Analytical methods for organic compounds in ambient air samples.

<u>Method</u>	<u>Applications</u>	<u>Scope/Limitations</u>
<u>Chromatography</u>		
GC	C <sub>1</sub> - C <sub>40</sub> *	Widely used for organics that volatilize up to around 250°C
HPLC	PAH, aldehydes	Only certain classes of compounds detectable
TLC	PAH, Lipids	Limited to compounds with low volatility
<u>Mass Spectrometry</u>		
	C <sub>1</sub> - C <sub>50</sub> *	Any compound that can be volatilized
<u>Spectroscopy</u>		
IR	C <sub>1</sub> - C <sub>4</sub> *	High detection limit
UV	Detector for HPLC	High detection limit
Visible	Aldehydes, specific compounds with color reactions	High detection limit

\*This refers to the number of carbon atoms in hydrocarbon molecules, i.e., C<sub>1</sub> - C<sub>40</sub> means that molecules containing between 1 and 40 carbons can be analyzed.

compounds are passed through a long thin tube or column containing a nonvolatile liquid absorbent and are separated on the basis of their volatility and polarity. Under ideal conditions, each component of the mixture emerges from the column as a pure compound or "peak" and passes through a detector. GC instruments are capable of both qualitative and quantitative analysis. Qualitative information is determined by comparison of the retention time (time required to pass through the column,  $t_D$ ) of an unknown peak with the  $t_D$  of a known standard. Quantification is accomplished from the response of the detector compared with the response from a known amount of standard.

Several types of detector are available for use with GC instruments. Thermal conductivity (TCD) and flame ionization detectors (FID) both respond to most organic compounds, but have relatively high detection limits. Other detectors respond selectively to certain classes of organic chemicals. For example, photoionization detectors (PID) are used for unsaturated compounds and electron capture detectors (ECD) are used for halogenated compounds. The sensitivity of these devices to trace level concentrations (parts per billion) tends to be much greater than the general purpose detectors for these classes of organic compounds.

Although GC is an extremely powerful analytical method for volatile organic compounds, problems arise when it is used with the complex mixtures present in ambient air samples. If a sample component happens to have the same retention time as a nonidentical standard or if two sample components have the same retention time, errors in identification or quantification can arise. These problems can sometimes be overcome by sample clean-up procedures or by chromatography with a variety of columns and detectors (Cox and Earp, 1982). This is time consuming and costly.

During the past ten years, analysis of organic compounds has been greatly improved by the availability of mass spectrometers used in tandem with the gas chromatograph (Barlingame et al., 1978). This combination (GC-MS) has the ability to rapidly separate, identify, and quantify most of the components in a mixture containing dozens of individual compounds. Sample vapors eluting from the GC pass into the MS where they are ionized and fragmented. The resulting population of fragment ions is then separated according to mass to produce a mass spectrum which serves

as a unique "fingerprint" for the identification of a specific compound. The usual procedure is to compare the observed mass spectrum with spectra of known compounds to find the closest fit. Computerized databases containing up to 100,000 spectra are available for search and retrieval. In many cases, an unambiguous identification can be obtained in a matter of minutes. There are a few groups of compounds which have large numbers of structurally similar isomers that cannot always be unambiguously identified with MS. The PAH's and PCB's are two important environmental examples of such groups.

GC-MS can be used for ambient air monitoring in two generalized operating modes. The first mode involves surveying collected samples by MS to determine that compounds are present and the approximate concentrations. Exact quantification is obtained by use of the GC with a specific, high-sensitivity detector such as the ECD. In the second mode, the MS is used as the detector and quantification is based on the intensity of one or more of the fragment ions from the compound of interest.

Another application of MS is the use of two or more MS units in tandem (MS-MS). The first unit ionizes sample components and separates all the compounds on the basis of mass. One ion is then selected for fragmentation in the second MS. Using this technique, mixtures can be analyzed without prior GC separation. Wider application of MS techniques is limited by the high cost and complexity of the instrumentation and the high level of expertise required to generate and analyze the data.

High pressure liquid chromatography (HPLC) is a useful technique for compounds which are unstable at temperatures required for vaporization in



the GC and MS. The principles of operation are similar to the GC except that compounds pass through the column dissolved in a carrier solvent. Separation is based on differences in polarity and adsorption to a stationary adsorbent which may be polar or nonpolar. Detection is generally by UV absorbance or fluorescence so the technique is limited to compounds which have UV-absorbing or fluorescent functional groups. In some cases, such groups can be attached by chemical reaction to form a detectable derivative of the compound of interest. HPLC is most useful for nonvolatile compounds with aromatic groups and many chemicals of biological origin fall into this category. In environmental work, aldehydes are often analyzed by HPLC.

Except in a few specialized cases, older chromatographic techniques such as thin-layer chromatography (TLC) and liquid chromatography have been largely replaced by GC and HPLC. The latter techniques are generally faster and more sensitive.

Spectroscopic techniques involving absorption in the ultraviolet and visible region are generally not specific enough to identify individual compounds without prior separation by chromatography. However, UV spectra are useful for identification of separated PAH isomers. A variety of colorimetric methods for specific classes of compounds that are useful in applications where high concentrations of organic vapors are encountered or where a generalized screening procedure is desired (Riggin, 1983).

The infrared (IR) spectra of most organic compounds can also serve as a "fingerprint" for identification and quantification. This technique has been limited by high detection limits and the fact that few compounds have

unique absorbance bands. However, with the development of Fourier transform IR (FTIR) and laser induced IR fluorescence, this method has been applied to ambient air analysis. Gelbwachs and Jones (1980) have used laser IR in remote sensing of atmospheric pollutants.

#### Source Sampling and Analysis

The sampling and analysis of pollution sources for organic compounds is mainly a specific application of the techniques described for ambient sampling. For area sources such as complexes of industrial plants or hazardous waste landfills, ambient sampling must be used to estimate the contribution of the source to ambient atmospheric organic concentrations (Durchin, 1983). This generally requires a network of sampling sites and collection of both upwind and downwind data. It is often difficult to find control sites that are completely free of organic pollutants. Sexton (1984) found that in Illinois, even rural sites are frequently downwind of one major source or another.

The stack gases of incinerators and other point sources can be sampled directly. For this type of sampling, procedures must be modified because of the high temperatures, heavy particulate load and high concentrations of water, CO<sub>2</sub>, and corrosive materials which occur in stack gases. A number of sampling systems have been reviewed recently (Polcy and Hesketh, 1985). These usually consist of a train of filters, condensers and absorption tubes. Collected organics are then desorbed and analyzed by the GC or GC-MS methods described earlier.

### Quality Assurance in Sampling and Analysis

Quality assurance is an important part of any field sampling and laboratory analysis research project. It is especially important in the analysis of trace metals and organics for a number of reasons. Few of the methods in the literature have been fully validated so in most cases methods must be evaluated for accuracy, detection limit and interferences. Standards are not available for some compounds; and even when pure standards are available, it is often difficult to prepare accurate samples at the dilutions characteristic of ambient air. Environmental sampling involves a large number of variables such as temperature, humidity and the presence of other atmospheric components which may affect a particular method. Finally, compounds of interest are often present in very low concentrations and/or are highly toxic, so that they present handling difficulties.

Method validation involves measurement of known concentrations in the laboratory under conditions identical to those found in the field. This is often difficult because of the variability of field conditions and the instability of some organics under normal field conditions. Both static and dynamic systems (e.g., permeation tubes) are used to generate known atmospheric concentrations. Inert atmospheres are required for some reactive compounds. Field validation of accuracy and precision is accomplished by comparison with a reference method, parallel sampling (precision only) or spiking the sample with a known quantity of analyte. Two or more samplers placed in series will allow estimation of capture efficiency (analyte breakthrough).

Calibration of the analytical instruments requires the preparation of a known sample with the same characteristics as the unknown. This is relatively simple when the sample is recovered in a solvent, but more complicated if the sample is desorbed directly into the GC as a vapor. In the latter case, standards are usually added to a blank absorption tube and desorbed like unknown samples.

Routine quality control procedures should include field and laboratory blanks, spiked samples, internal standards, duplicate samples, calibration standards, reference standards and series samples.

## TRACE ELEMENTS

### Elements of Interest

Sampling and analysis methods for airborne trace elements are discussed where different from those described in the section on organic chemicals. Many toxic elements that have not been listed in the previous tables as occurring in the atmosphere could potentially reach the atmosphere through combustion or other processes; however, they have not been discussed in any of the literature reviewed for this report.

The term "trace element" is used rather than "heavy metal" because some of the metals considered are very light (Be) and some of the elements are not metals (Se, As). The term trace element is also used to distinguish small amounts of potentially toxic elements which may occur in a variety of chemical forms from other elements in the atmosphere. Not included are the major atmospheric elements, elements occurring in small amounts which are

not considered toxic in their elemental forms (e.g., Ca, S), elements which reach the atmosphere only by natural processes, and radioactive elements.

Some of the trace elements in aerosols arise primarily from man's activities while others are derived in part from natural processes such as blowing soil, sea spray, and volcanic action. Table VI lists the trace elements which have been found in ambient air and are potentially toxic to humans (Pierson et al., 1973; Evans et al., 1984). The concentrations listed are typical values; however, actual values can vary considerably from these averages depending on the type of industry, fuel use, and other factors for a particular region. A few other elements have been studied in ambient air; however levels are in the picograms per cubic meter range and they are not included in this review.

Generally, only the total mass of an element is measured, and only those chemical forms associated with particulate matter are sampled. Separate analyses of the chemical forms of a particular element are not usually attempted because of the small quantities present in most samples. Although most of the trace elements are only found in the solid phase, a significant proportion of some elements can be in a volatile chemical form.

Mercury (Hg) is the only element in Table VI which has a significant vapor pressure under ambient conditions and is found primarily in the vapor phase. In addition to gaseous atomic Hg, volatile  $\text{HgCl}_2$  and organomercury compounds such as methylmercury have been found in air samples (Natusch and Hopke, 1983). These latter forms are important because they are easily absorbed and highly toxic.

Table VI. Trace elements in ambient air (1978-79).

<u>Element</u>	<u>Common Sources</u>	<u>Typical concentration<sup>a</sup></u> (urban/rural)
Arsenic (As)**	Pb smelters, pesticides	5/2
Zinc (Zn)	Incinerators, oil & rubber additive	160/40
Cadmium (Cd)	Associated with Zn	2/1
Lead (Pb)	Gasoline additive, smelters	500/100
Copper (Cu)	Smelters, industry	200/200
Nickel (Ni)**	Smelters, industry, fuel oil	10/5
Chromium (Cr)**	Industry	40/5
Selenium (Se)**	Associated with S	5/1
Vandium (V)**	Fuel oil additive	20/8
Manganese (Mn)**	Associated with Fe	50/20
Cobalt (Co)**	Industry	10/.1
Mercury (Hg)**	Industry	20/.2
Silver (Ag)	Industry	1/.3
Beryllium (Be)	Industry	0.05/0.04
Molybdenum (Mo)	Industry	2/1
Barium (Ba)	Industry	30/7
Antimony (Sb)	Industry	30/3
Tin (Sn)**	Industry	20/2
Thallium (Tl)	Industry	.1/.01

\* Concentrations in nanograms per cubic meter (Evans et al., 1984; Saltzman et al., 1985).

\*\* Significant natural emission sources.

Much of the arsenic (As) emitted to the atmosphere from high-temperature industrial processes is in the form of  $As_2O_3$  which volatilizes as  $As_4O_6$ . Volatile methyl arsines have also been found in some air samples (Natusch and Hopke, 1983).

Airborne lead (Pb) is found in both gaseous and particulate forms. Additionally, much of the particulate lead is on very small particles (<0.3  $\mu m$ ) that are not efficiently trapped on high-volume filters (Skogerboe, 1973). Gaseous Pb compounds are mostly lead alkyls including tetraethyl lead and related materials.

Selenium (Se) has a volatile form,  $H_2Se$ ; however, it is probably oxidized rapidly in air to the nonvolatile element or oxide.

Finally, a number of metallic carbonyls and organometallics can be present as gases under ambient conditions (Riggin et al., 1984).

#### Sampling and Analysis of Trace Elements

Since most trace elements are entirely associated with atmospheric particles, sampling methods are very similar to those for particle-bound organics. Air samples are typically filtered in high volume samplers using one of the filters listed in Table IV. The resulting samples are ashed, and then dissolved in strong acid to solubilize the element for analysis.

Many elements are non-uniformly distributed on the various particle-size fractions of atmospheric solids. Elements that are predominantly released as vapors (Pb, V) tend to condense on very small (<1  $\mu m$ ) particles. Some elements (e.g., Fe) are mostly associated with larger particles, while others are associated with both large and small particles (Lee et al., 1972).

Volatile trace elements are generally concentrated by passing air through an absorbent and then desorbing the sample for analysis. The polymeric or carbon absorbents used to trap organic vapors also collect many of the organometallics. Other specialized absorbents have been developed to collect most of the inorganic forms of the volatile trace elements such as Hg and As compounds (Natusch and Hopke, 1983; Schroeder and Jackson, 1983).

After a sample is dissolved in an appropriate solution, there are a number of methods available for analysis. These are listed in Table VII.

Table VII. Analysis methods for trace elements.

<u>Method</u>
Atomic Absorption/Emission
Inductively Coupled Plasma Emission
Atomic Fluorescence
Colorimetric Methods
- Spectrophotometric
- Ring Oven Method
Voltammetry
- Polarography
- Anodic Stripping
X-Ray Fluorescence
Neutron Activation Analysis

Atomic absorption (AA) is probably the most widely employed method for trace elements. Dissolved samples are aspirated into a flame or electrothermal device to convert constituent ions and molecules to atoms. Absorption of visible or UV light at specific wavelengths allows identification and quantification of an element. Since the wavelengths that characterize most elements are well separated from one another, no prior separation is required. Another advantage is that several elements can be run with successive measurements on the same solution. The method, however, is subject to a number of interferences due to interactions between sample components. Careful calibration using internal standards is required for accurate results.



Two closely related methods which are more sensitive than AA for some elements. With inductively coupled plasma emission spectroscopy, the elements are excited in an argon plasma. Each element emits a characteristic wavelength and signal response proportional to concentration. Most of the elements, with the exception of Hg and Tl, can be determined with this method. In the second method, atomic fluorescence, the flame is exposed to UV light and fluorescent emission is measured at right angles to the incident light path. Higher sensitivities for Cd, Cu, Ni, Ag and Zn can be achieved in this way.

Colorimetric methods are available for most elements, and they are sometimes the methods of choice when the AA analysis is subject to strong interferences (e.g., Se). However, some chemical work-up is usually required in order to remove interfering ions, and a completely separate analysis is involved for each element. This means that more sample is needed and that more time is required for a multi-element analysis. The ring-oven method (West, 1976) is an adaptation of older chemical spot-test methods to give semi-quantitative results rapidly and inexpensively. As with other colorimetric methods, a separate sample and test is required for each element.

Many trace elements can be analyzed by voltammetry, a method in which ions in solution are electrolytically reduced. By measuring the potential required for reduction and the current produced, both the identity and concentration of many elements can be determined. After solubilization, several elements can be measured simultaneously in a single sample. With the application of anodic stripping techniques,

many of the elements listed in Table IV can be determined at sub-ppb levels (Wang, 1982). The cost of the required instrumentation is low compared to the other instrumental methods discussed in this section.

Neutron activation and x-ray fluorescence have the advantage that trace element concentrations can be determined directly from particulate matter with no requirement for solubilization or any other treatment. In neutron activation, the sample is bombarded by neutrons which produce radioactive isotopes of most elements. The gamma radiation from the decay of these isotopes is then measured and can be used to determine both the composition of a sample and concentrations of individual elements. Although the detection limit varies considerably between elements, it is possible to determine 25-50 elements in a single sample including many rare elements which are otherwise difficult to analyze (Katz, 1977c).

X-ray fluorescence is another non-destructive method which requires little or no sample preparation. Solid or liquid samples are bombarded with x-rays, which results in the emission of some fluorescent radiation in x-ray region. The wavelength and intensity of this radiation can be related to the identity and concentration of a particular element.

Another way of generating x-rays from a sample is by bombardment with high-energy protons. This method, proton induced x-ray emission (PIXE), is capable of detecting picogram quantities of many elements. It is especially useful for thin samples such as particulate matter collected filters.

X-ray techniques are applicable to all elements heavier than Mg ( $Z = 12$ ) and are capable of detecting concentrations in the ppm range in a

milligram of sample (West, 1976). A major disadvantage of both neutron activation and x-ray fluorescence is the high cost and high level of expertise required for suitable instrumentation.

Finally, it should be noted that the same considerations and quality assurance that were discussed in the organic analysis section apply to trace element analysis as well. Any time that analysis of trace quantities of materials in complex substrates is attempted, proper calibration, standardization, and testing of sampling and analytical methods are very important. In the case of the trace elements, the array of potential chemical species is much smaller than is the case with the toxic organics. This means, among other things, that there are fewer problems in obtaining calibration standards.

#### SURVEY OF AIRBORNE METALS IN ILLINOIS

Data on ambient concentrations of particle-bound trace elements in Illinois were reviewed. Most of the data discussed here were collected by the Illinois Environmental Protection Agency (IEPA) between 1978 and 1983 (IEPA, 1984). A sampling network of 48 sites is maintained in mostly urban areas throughout the state. At each site, 24-hour samples of total suspended particulate are collected on glass fiber filters with a high volume sampler. About 2000 m<sup>3</sup> of air are sampled to yield approximately 100 mg of sample. Three to five of these samples are combined, chemically solubilized and analyzed by atomic absorption. At most sites, this

composite sample was analyzed each month to yield 12 composite values per year. Eight elements were determined during this period: Fe, Mn, Pb, As, Cd, Zn, Cu and Be. The data for Be have not been used here, because almost all of the results were at or below the detection limit ( $.001 \text{ ug/m}^3$ ). The nine sites chosen for this analysis are shown in Figure 2. They include the two sites with the highest trace element levels--Chicago (Lake Calumet area) and Granite City - East St. Louis. The other areas were chosen either because several sampling sites were clustered in the same area or to give a more complete geographical coverage of the state.

#### BASIC STATISTICS AND SPATIAL VARIATIONS

Table VIII summarizes the average levels for various locations during 1978 and 1979, the only years in which extensive metals data were collected at most sites. Both Chicago and Granite City had elevated concentrations of several metals compared to the other sites. In Chicago, levels of Fe, Mn, As and Zn were about double the values obtained at other locations. At the Granite City sites, the average concentrations of these metals were 3-5 times higher and levels of Cd and Pb were similarly elevated. Cu levels were similar at all locations. Moyers et al. (1972) described the contamination of particulate samples with Cu from the motors of high-volume samplers. The Cu levels found by IEPA (1984) and Evans et al. (1984) may be too high because of this artifact. At most sites, the concentrations of all the elements except Cu and As were elevated compared to typical nonurban values in the United



Figure 2. Map showing locations of IEPA atmospheric sampling sites.

Table VIII. Ambient levels of trace elements in Illinois (1978-79).

Site	Fe	Mn	Pb	As	Cd	Zn	Cu
Chicago	2200+1700	150+120	500+200	5+ 3	4+4	320+170	170+220
Granite City	4900+4500	390+420	1100+900	11+13	8+4	420+380	150+ 80
Joliet	1000+ 500	50+ 30	400+150	3+ 1	2+1	190+200	120+ 90
Peoria	1100+ 500	75+ 35	400+180	3+ 2	2+1	160+ 70	140+160
Moline	600+ 200	50+ 20	350+150	2+ 1	3+2	100+ 30	150+120
Decatur	1200+ 750	60+ 50	450+150	2+ 1	2+1	140+ 50	130+ 90
Rockford	600+ 300	50+ 50	430+180	2+ 1	4+1	150+100	120+ 80
Carbondale	700+ 200	40+ 10	500+300	2+ 1	2+2	NA	140+ 50
Springfield	600+ 300	30+ 2	300+200	2+ 1	1+1	110+ 70	220+100
Rural Background <sup>b</sup>	300	20	100	2	1	40	200
Avg. Urban <sup>b</sup>	1100	50	500	5	2	160	200

a. ng/m<sup>3</sup>

b. refs. Evans et al., 1984; Saltzman et al., 1985)

States. Except for Chicago and Granite City, the values are generally similar to typical urban metal levels found by Evans et al. nationwide.

#### TEMPORAL TRENDS

In order to determine changes in trace element concentrations during the study period, annual averages were computed for the years 1978 to 1983. Unfortunately, for many sites and many of the trace metals the data were not complete. Average annual metals concentrations at four sites where data were collected for at least nine months during all six years are shown in Figures 3-6. The three elements for which the data were

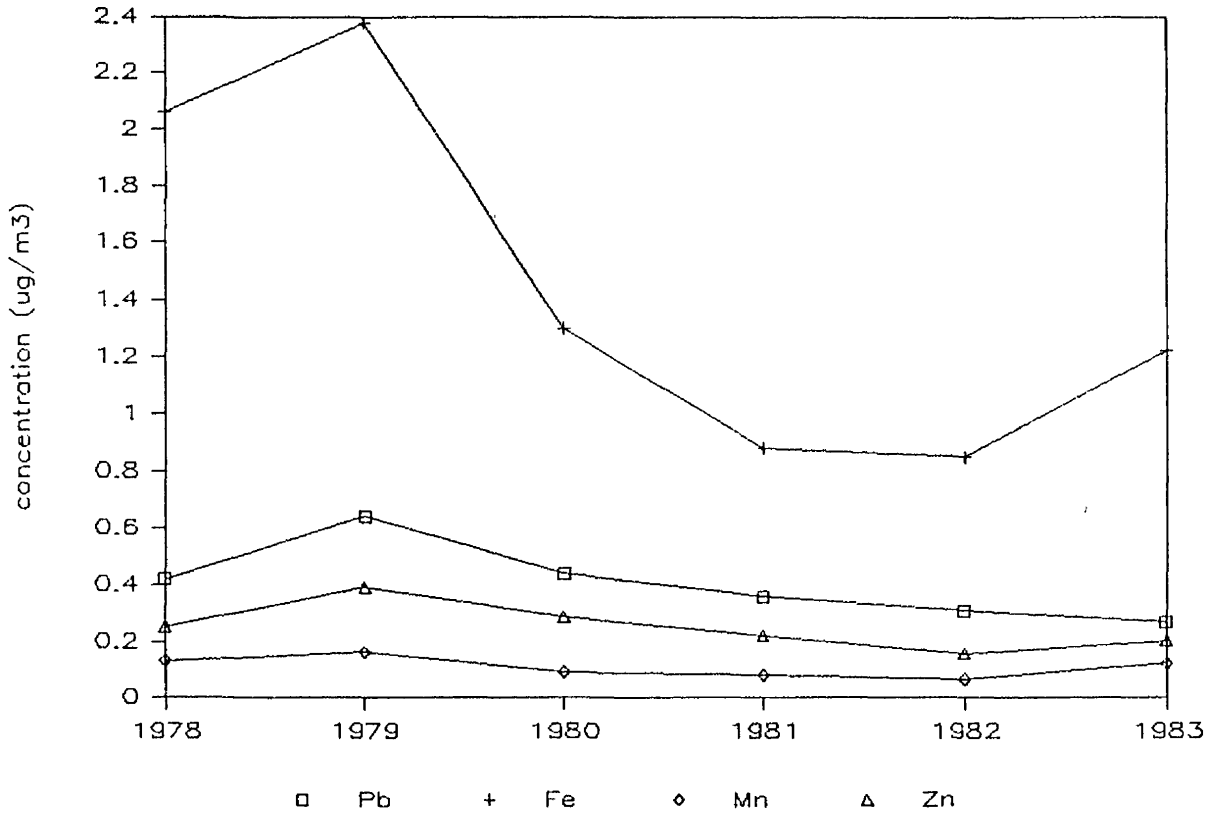


Figure 3. Atmospheric concentrations of metals in Chicago between 1978 and 1983.

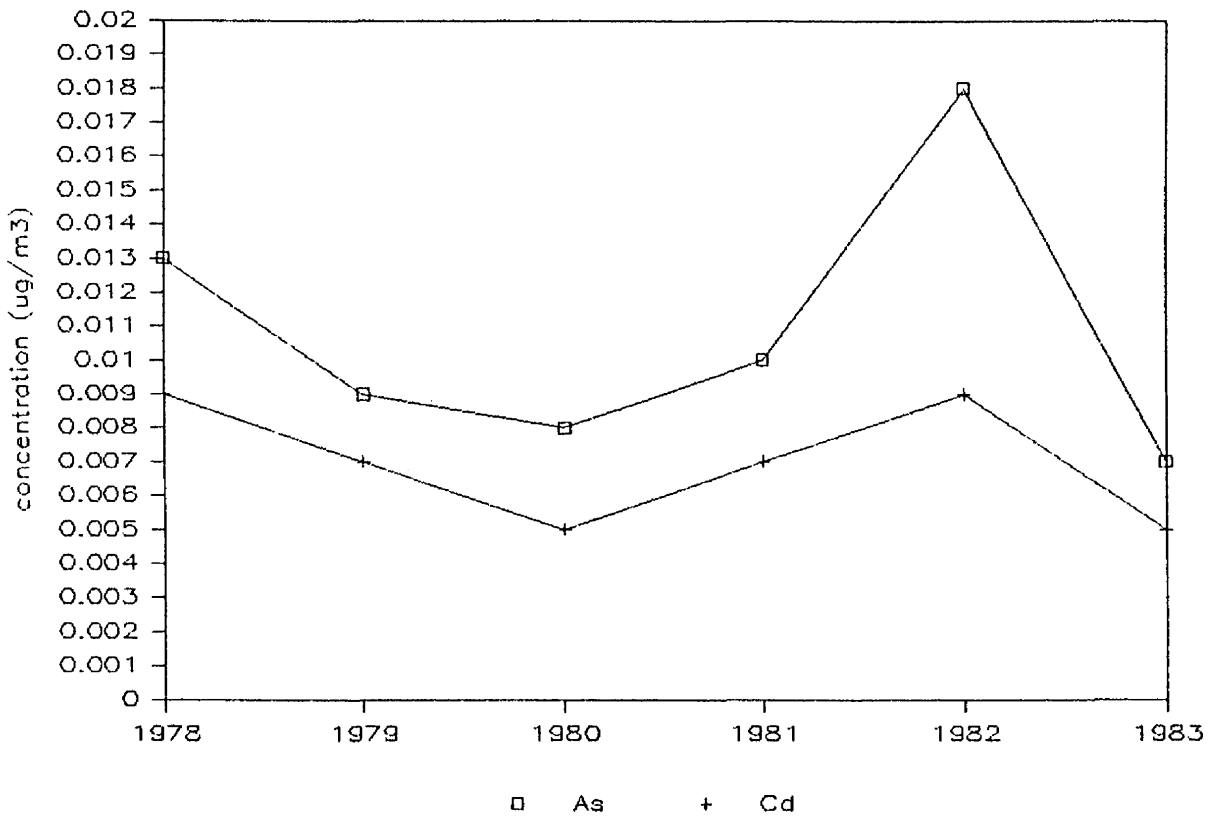
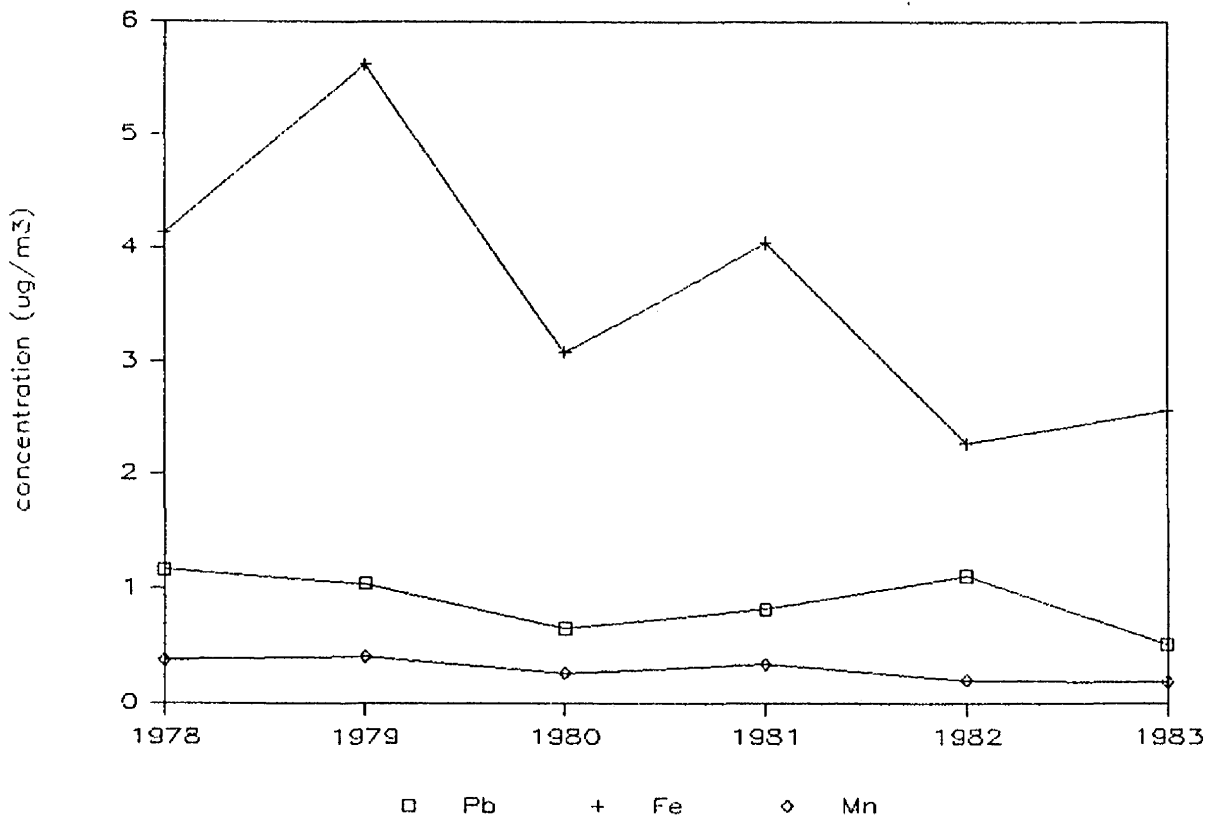


Figure 4. Atmospheric concentrations of metals in Granite City between 1978 and 1983.



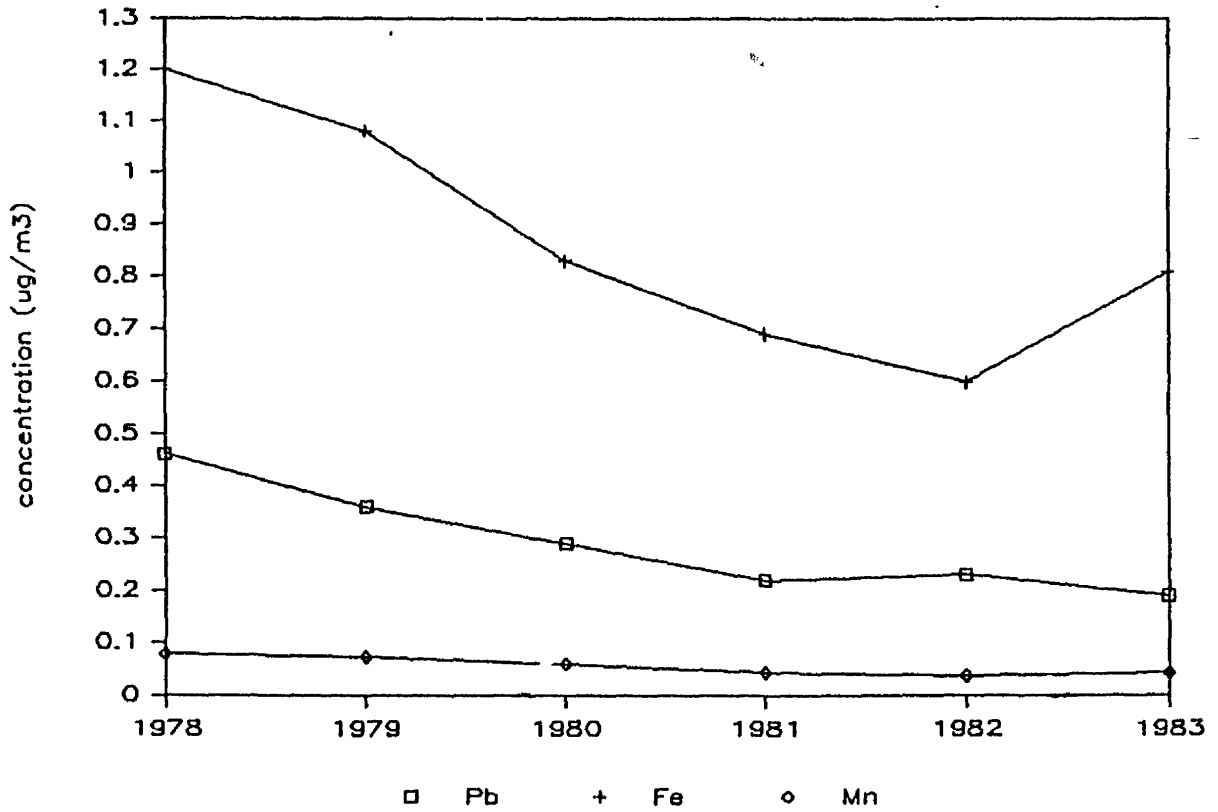


Figure 5. Atmospheric concentrations of metals in Peoria between 1978 and 1983.

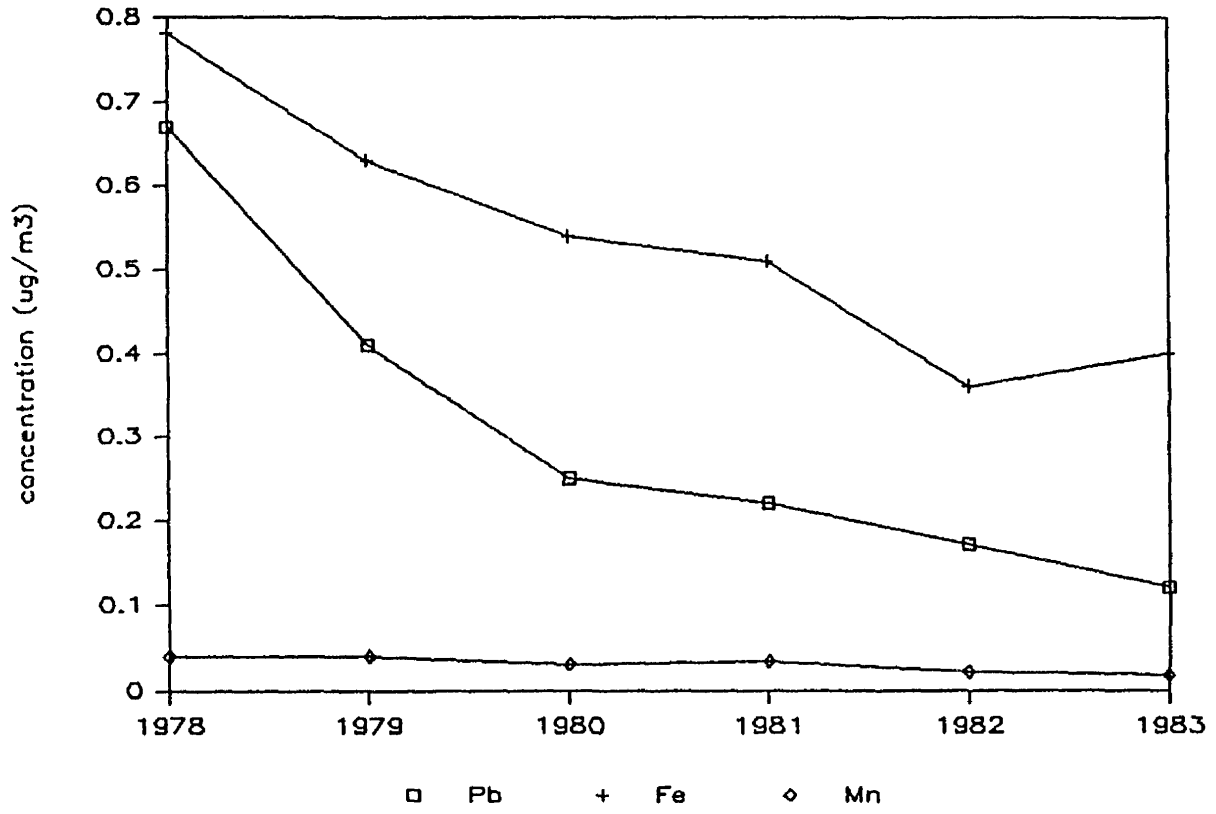


Figure 6. Atmospheric concentrations of metals in Carbondale between 1978 and 1983.

most complete--Pb, Fe and Mn--generally declined over the 6-year period. This is consistent with the decrease in industrial activity and increased use of unleaded gasoline occurring over the same period. The only Zn data for the entire 6-year period are from the Chicago area. These data show that Zn concentrations were essentially unchanged between 1978 and 1983. At the Granite City location concentrations of As and Cd in air did not show any consistent trend during the sampling period. The data for Cu were not included in the figures because the values were very similar for all locations throughout the period, and they may not be accurate for reasons discussed earlier.

Comparison of the IEPA results to 1970 Chicago data from two other sampling networks (Lee et al., 1972; Saltzman et al., 1985) indicate that the 1983 concentrations of Pb and Zn are much lower than their 1970 values. On the other hand, the concentrations of Fe and Mn in air were about the same in 1970 and 1983. The concentration of Cd in Chicago may have declined slightly between 1970 and 1979, the last year for which IEPA data are available at that location.

#### SEASONAL VARIATIONS

The data were also examined for seasonal variations. In Figures 7-10, the normalized concentration for each metal is shown for each month. Normalized concentrations were obtained by dividing an individual monthly value by the highest value obtained for that metal, at that site during a particular year. These numbers were then averaged over the six years for which data were available. Only sites and metals with at least nine months

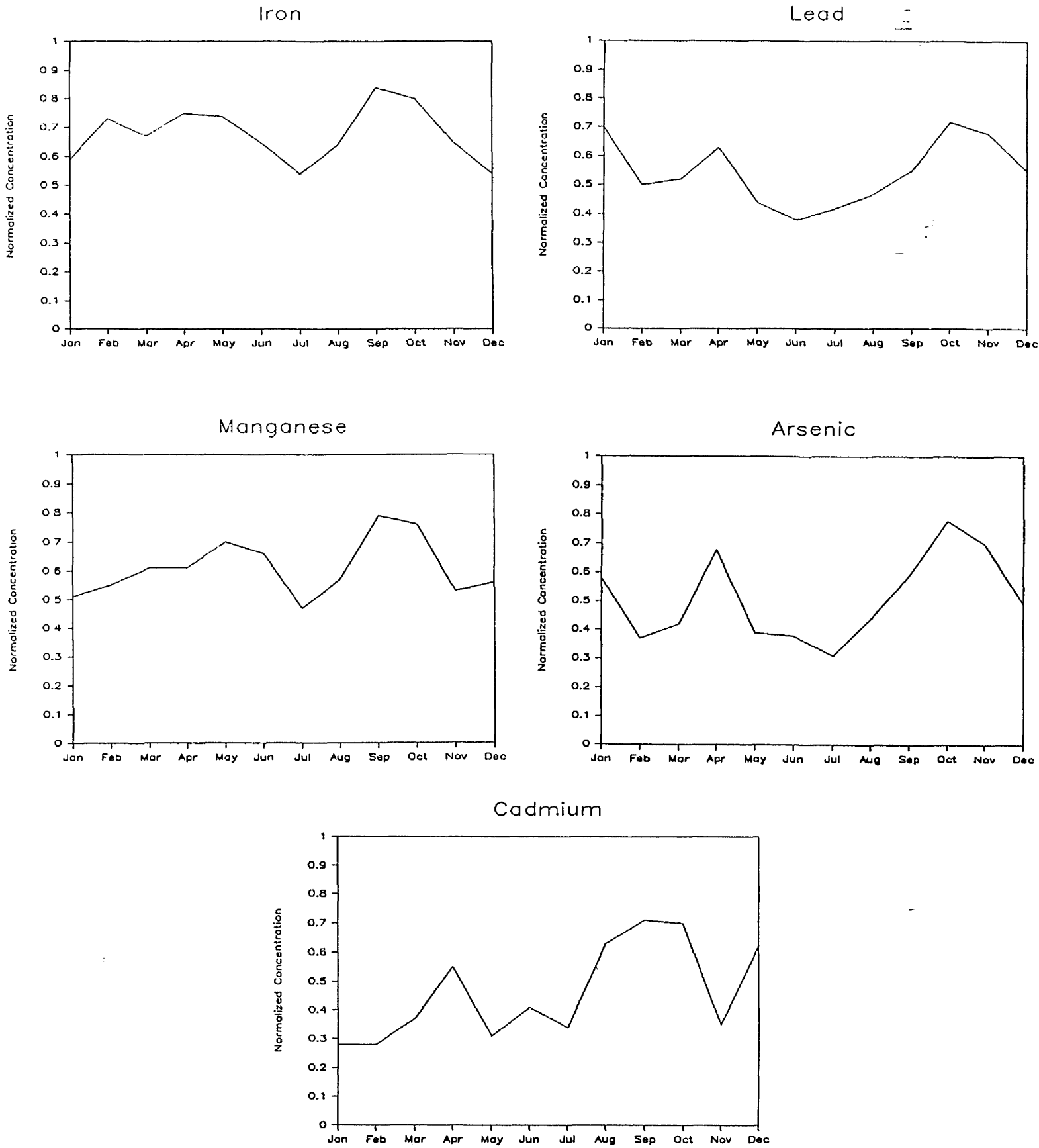
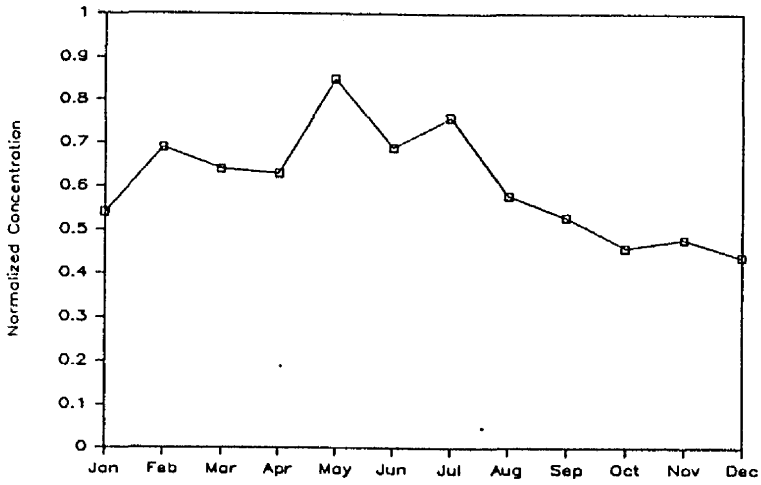
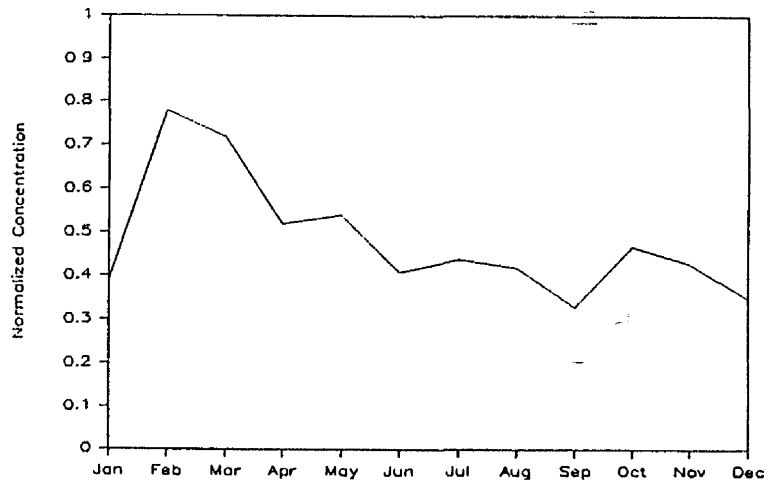


Figure 7. Seasonal variation of metals in Granite City air.

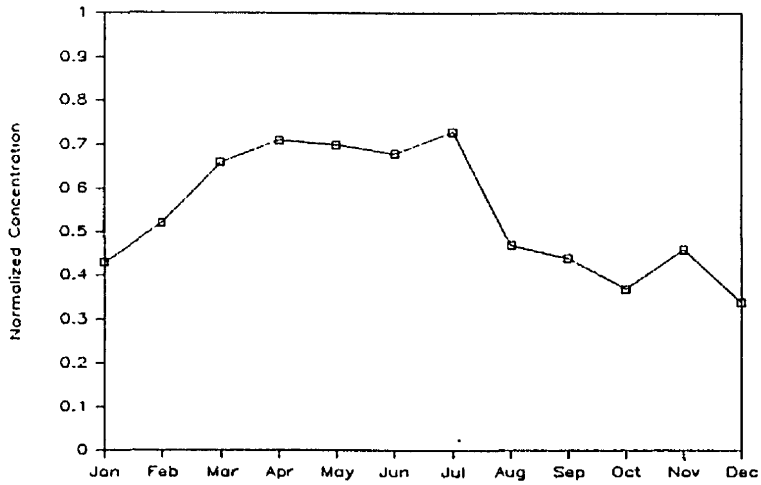
Iron



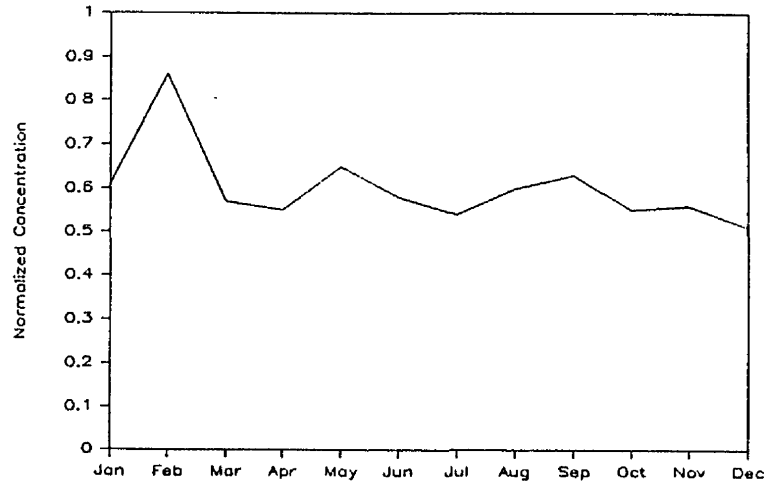
Zinc



Manganese



Lead



Copper

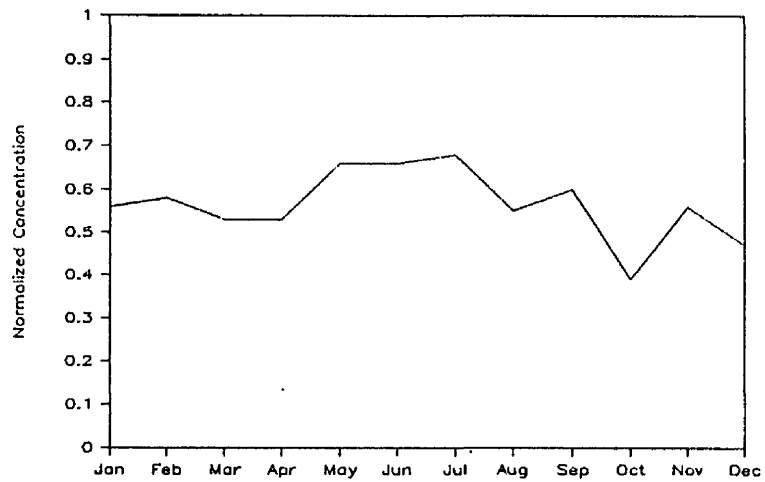


Figure 8. Seasonal variation of metals in Chicago air.

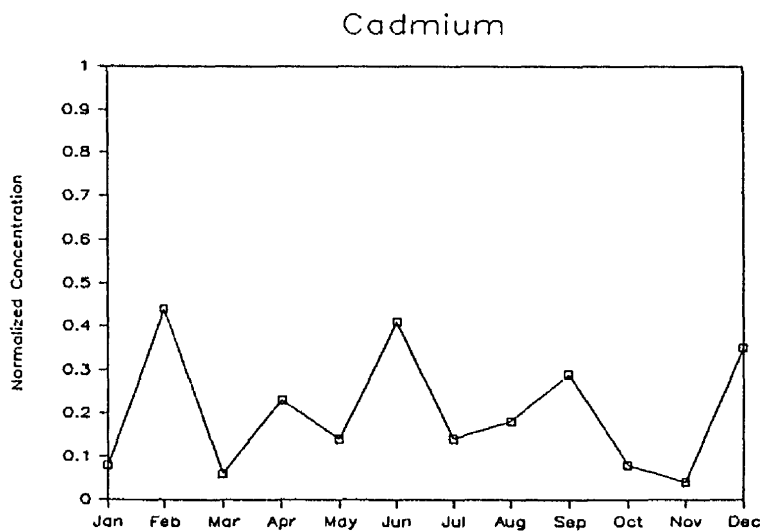
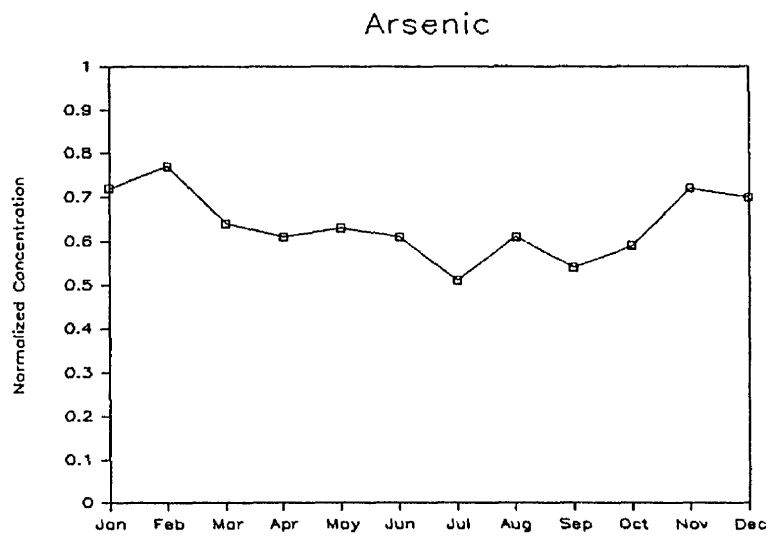
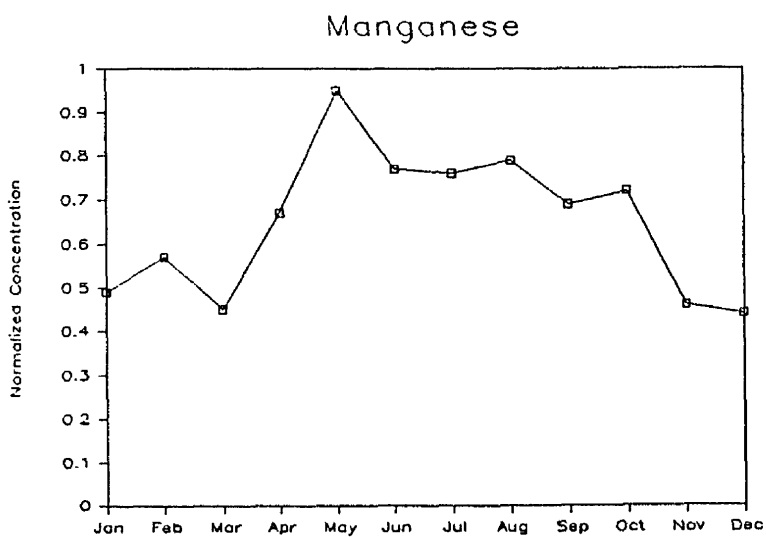
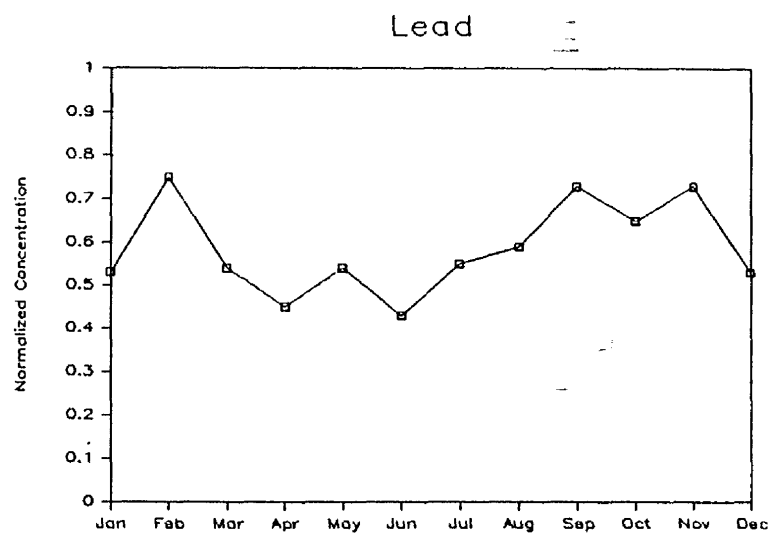
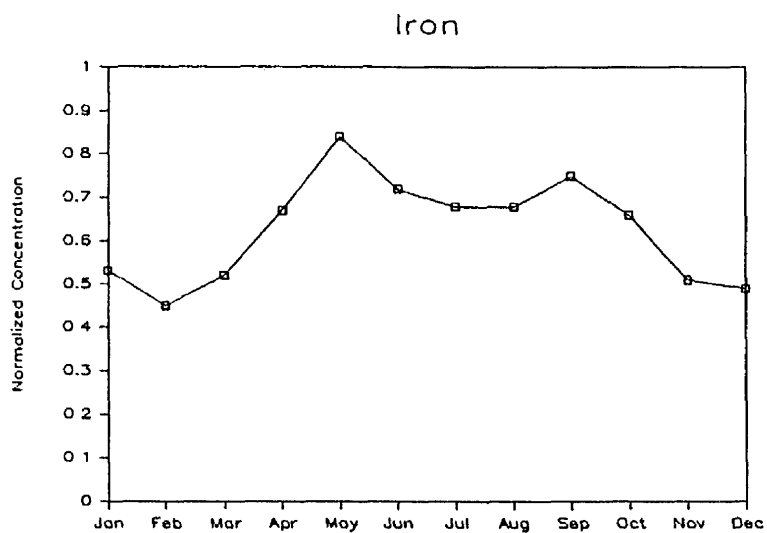


Figure 9. Seasonal variation of metals in Peoria air.

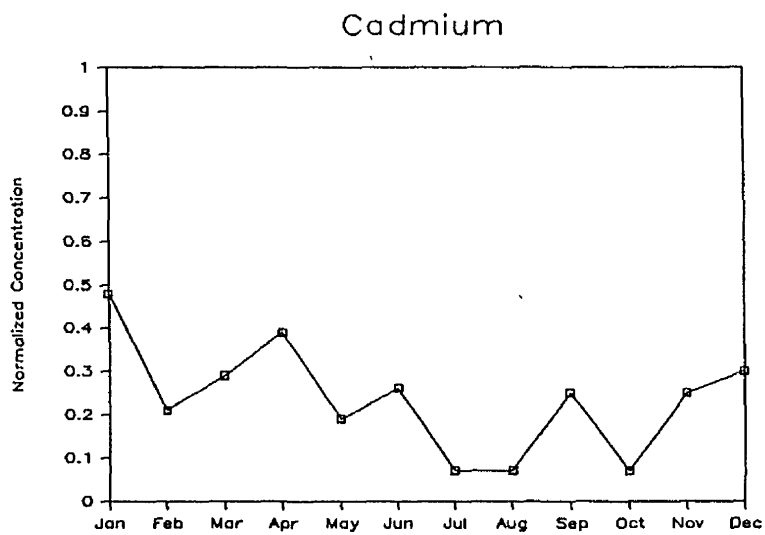
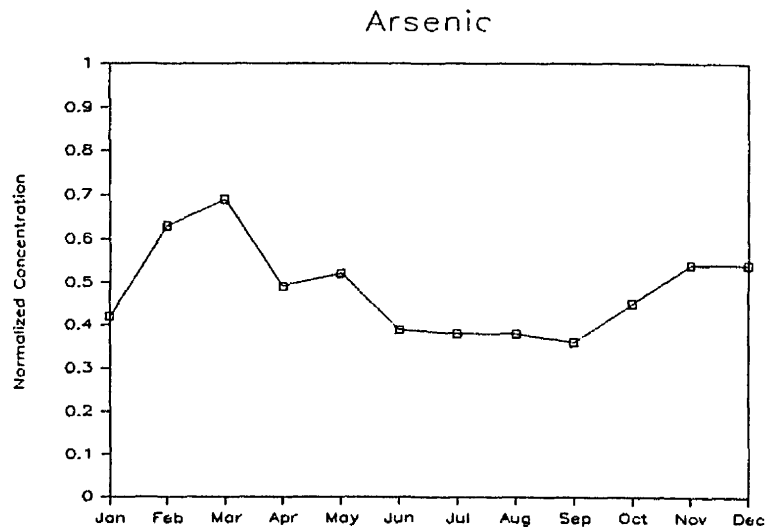
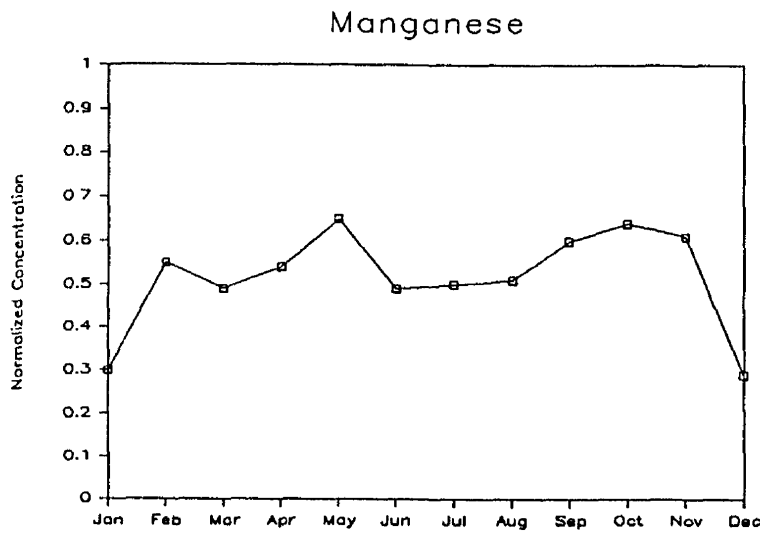
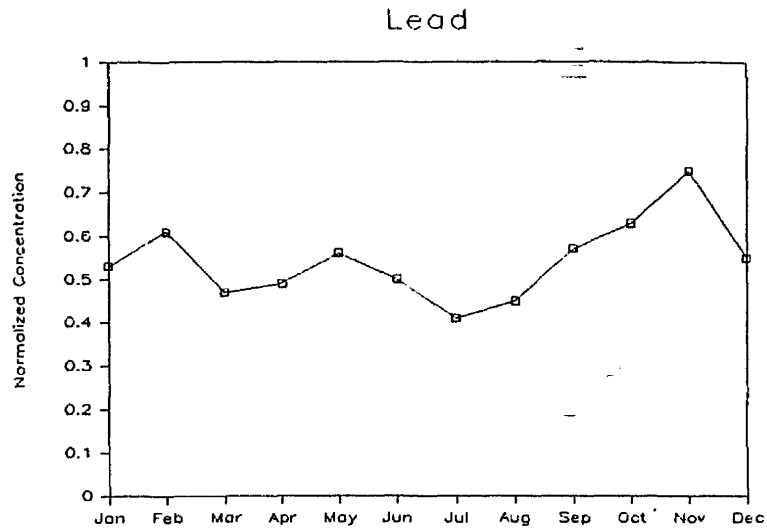
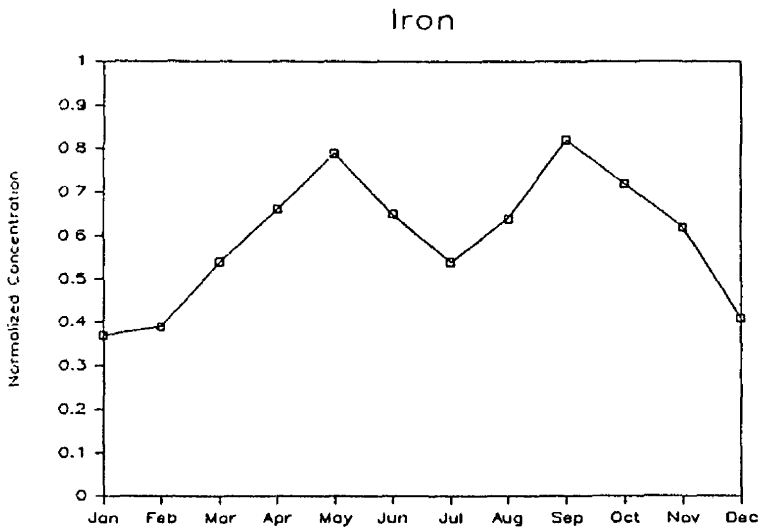


Figure 10. Seasonal variation of metals in Decatur air.

of data per year during at least 4 years were used. Years which had no data for two consecutive months or more were excluded. High normalized values indicate that maximum or near maximum values were common during that month. Conversely, low normalized values indicate that yearly minimums were more common for a particular month.

Seasonal variation for both Pb and As was slight at most sites with annual minima occurring during the summer at most of the sites. Fe and Mn also vary seasonally with maximum concentrations more likely in late spring (May) or early fall (September). The seasonal variation of these two metals was very similar at all locations. National Air Surveillance Network data for six major U.S. cities (Lee et al., 1972) showed no clear trend for any metal except vanadium (V) which reached maximum levels during the winter. The major source of V in air is the combustion of heating oil.

## CONCLUSIONS AND RECOMMENDATIONS

### HAZARDOUS WASTE INCINERATION

Fourteen hazardous waste incinerators appear to be operating in Illinois under Interim RCRA status, and either have filed their Part B Application for an operating permit, or are considered likely to file. Two of these are commercial facilities that burn a wide variety of waste streams. The others are operated by individual companies to burn the hazardous wastes they generate themselves. Most of the operational



incinerators are in northeastern Illinois or the East St. Louis area. All Illinois incinerators for which we have information on type are able to burn liquids. The commercial units include one fixed hearth and one rotary kiln, which can burn solids as well. Incineration emissions are not well characterized, but all facilities will have to show themselves capable of meeting emission standards in order to obtain RCRA permits. Nevertheless, fugitive emissions from spills and evaporative losses during handling may contribute the majority of airborne hazardous emissions, and justify future monitoring of atmospheric concentrations of organics in their vicinity.

#### SAMPLING AND ANALYSIS OF TOXIC ORGANICS

The most useful analysis technique for field monitoring ambient levels of trace organics is gas chromatography using specific detectors. There are two classes of volatile compounds that can be monitored easily using this method. Halogenated hydrocarbons can be detected at sub-ppb levels using an electron capture detector (ECD); a photoionization detector (PID) can be used to measure aromatic hydrocarbons. Most of the common compounds in these classes can be identified by retention time and detector response. Identification of certain other compounds may require GC-MS in the laboratory.

Selection of an exact list of target compounds is difficult because of limited information on incinerator waste streams and probable emissions. Halogenated hydrocarbons and aromatic hydrocarbons are likely to be of interest for a variety of reasons. Many compounds in both classes are high-volume industrial products or are present in petroleum. Consequently,

large amounts are released during production and use of these materials. Additionally, chlorinated compounds are difficult to burn efficiently and can be expected to make up part of the PICs from hazardous waste incinerators. Both aromatic hydrocarbons and chlorocarbon solvents are likely to be major components of hazardous waste streams so they will also be important POHCs and fugitive emissions from facilities handling large quantities of volatile waste materials. Thomson et al. (1985) recently identified the ambient toxics in air that are likely to cause the greatest cancer risk in the U.S. Of the 15 most important pollutants in this study, 5 were halogenated hydrocarbons (carbon tetrachloride, chloroform, perchloroethylene, trichloroethylene, and ethylene dibromide) and 2 were volatile aromatic hydrocarbons (benzene and gasoline vapors).

Halogenated and volatile aromatic hydrocarbons are present in relatively high concentrations in ambient air (0.1-10 ppb), which may allow direct sampling with no preconcentration in many cases. Rapid and accurate detection of these compounds can be made using GC-ECD or GC-PID, even under field conditions. In order to assess the impact of hazardous waste incineration on ambient levels of target compounds, data must be obtained in conjunction with meteorological observations. Sufficient data should be collected to determine normal fluctuations over time spans ranging from hours to months. Collection of both upwind and downwind samples during the course of the experiment will then allow estimation of the contribution of various sources to ambient levels of toxic organics. It will also be important to sample at several locations ranging from background to near-source sites.

## SAMPLING AND ANALYSIS OF TRACE ELEMENTS

Fairly extensive data are available on the atmospheric concentrations of a few elements in Illinois urban areas. Two locations with relatively high levels of Pb, As, Zn, Cd and Mn have been identified. In addition, information is available on the seasonal variation and long-term trends in the concentrations of some of these metals.

There are several areas where additional data are needed to assess the impact of incineration on toxic trace element levels. First, more elements need to be analyzed. Application of neutron activation and x-ray fluorescence techniques would allow the determination of a large number of trace elements including many which are known to be important air pollutants (e.g., Cr) and were not included in the IEPA study. Secondly, some information about particle size distribution should be obtained. Variation in the metal concentration for particles of different sizes is great and this is important in predicting both human exposure and atmospheric transport and deposition. It is necessary to have particle size information to accurately assess direct impacts on human health through absorption of toxins in the lung and to evaluate the rate of transfer of airborne trace elements to soil and water via wet or dry deposition. Finally, some of the trace elements have important volatile forms. High levels of As were found in particulate samples at two locations. We need to determine whether total levels of As are even higher due to the presence of volatile As compounds.

The locations that should be examined most intensively are the two sites with high trace element concentrations, Granite City and south Chicago. A rural control location should be monitored as well to determine minimum values for Illinois.

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APPENDIX A

Hazardous Waste Identification Numbers

The following numbers and identifications were taken from the Code of Federal Regulations (CFR, Title 40, Part 261, 1984) and subsequent amendments in the Federal Register. The following hazard codes are used to indicate the type of waste: Ignitable (I), Corrosive (C), Reactive (R), Extractable Toxic (E), Acutely Toxic (H), Toxic (T).

EPA Hazardous Waste Numbers

- D001 Ignitable hazardous wastes that are not listed otherwise.
- D002 Corrosive hazardous wastes that are not listed otherwise.
- D003 Reactive hazardous wastes that are not listed otherwise.

Hazardous wastes that have the following water-extractable contaminants:

EPA hazardous waste number	Contaminant	Maximum concentration (milligrams per liter)
D004	Arsenic	5.0
D005	Barium	100.0
D006	Cadmium	1.0
D007	Chromium	5.0
D008	Lead	5.0
D009	Mercury	0.2
D010	Selenium	1.0
D011	Silver	5.0
D012	Endrin (1,2,3,4,10,10-hexachloro-1,7-epoxy-1,4,4a,5,8,7,8,8a-octahydro-1,4-endo, endo-5,8-dimethano-naphthalene).	0.02
D013	Lindane (1,2,3,4,5,6-hexachlorocyclohexane, gamma isomer).	0.4
D014	Methoxychlor (1,1,1-Trichloro-2,2-bis [p-methoxyphenyl]ethane).	10.0
D015	Toxaphene (C <sub>12</sub> H <sub>10</sub> Cl <sub>6</sub> , Technical chlorinated camphene, 67-69 percent chlorine).	0.5
D016	2,4-D, (2,4-Dichlorophenoxyacetic acid).	10.0
D017	2,4,5-TP Silvex (2,4,5-Trichlorophenoxypropionic acid).	1.0

§ 261.31 Hazardous wastes from non-specific sources.

Industry and EPA hazardous waste No.	Hazardous waste	Hazard Code
Generic:		
F001.....	The following spent halogenated solvents used in degreasing: tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons; and sludges from the recovery of these solvents in degreasing operations.	(T)
F002.....	The following spent halogenated solvents: tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene, 1,1,2-trichloro-1,2,2-trifluoroethane, ortho-dichlorobenzene, and trichlorofluoromethane; and the still bottoms from the recovery of these solvents.	(T)
F003.....	The following spent non-halogenated solvents: xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methyl isobutyl ketone, n-butyl alcohol, cyclohexanone, and methanol; and the still bottoms from the recovery of these solvents.	(I)
F004.....	The following spent non-halogenated solvents: cresols and cresylic acid, and nitrobenzene; and the still bottoms from the recovery of these solvents.	(T)
F005.....	The following spent non-halogenated solvents: toluene, methyl ethyl ketone, carbon disulfide, isobutanol, and pyridine; and the still bottoms from the recovery of these solvents.	(I, T)
F006.....	Wastewater treatment sludges from electroplating operations except from the following processes: (1) sulfuric acid anodizing of aluminum; (2) tin plating on carbon steel; (3) zinc plating (segregated basis) on carbon steel; (4) aluminum or zinc-aluminum plating on carbon steel; (5) cleaning/stripping associated with tin, zinc and aluminum plating on carbon steel; and (6) chemical etching and milling of aluminum.	(T)
F019.....	Wastewater treatment sludges from the chemical conversion coating of aluminum.....	(T)
F007.....	Spent cyanide plating bath solutions from electroplating operations (except for precious metals electroplating spent cyanide plating bath solutions).	(R, T)
F008.....	Plating bath sludges from the bottom of plating baths from electroplating operations where cyanides are used in the process (except for precious metals electroplating plating bath sludges).	(R, T)
F009.....	Spent stripping and cleaning bath solutions from electroplating operations where cyanides are used in the process (except for precious metals electroplating spent stripping and cleaning bath solutions).	(R, T)
F010.....	Quenching bath sludge from oil baths from metal heat treating operations where cyanides are used in the process (except for precious metals heat-treating quenching bath sludges).	(R, T)
F011.....	Spent cyanide solutions from salt bath pot cleaning from metal heat treating operations (except for precious metals heat treating spent cyanide solutions from salt bath pot cleaning).	(R, T)
F012.....	Quenching wastewater treatment sludges from metal heat treating operations where cyanides are used in the process (except for precious metals heat treating quenching wastewater treatment sludges).	(T)
F024.....	Wastes, including but not limited to, distillation residues, heavy ends, tars, and reactor clean-out wastes from the production of chlorinated aliphatic hydrocarbons, having carbon content from one to five, utilizing free radical catalyzed processes. [This listing does not include light ends, spent filters and filter aids, spent desiccants, wastewater, wastewater treatment sludges, spent catalysts, and wastes listed in § 261.32.]	(T)

Generic .....	F020 Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tri- or tetrachlorophenol, or of intermediates used to produce their pesticide derivatives. (This listing does not include wastes from the production of Hexachlorophene from highly purified 2,4,5-trichlorophenol).	(H)
	F021 Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of pentachlorophenol, or of intermediates used to produce its derivatives	(H)
	F022 Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tetra-, penta-, or hexachlorobenzenes under alkaline conditions.	(H)
	F023 Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production of materials on equipment previously used for the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tri- and tetrachlorophenols. (This listing does not include wastes from equipment used only for the production or use of Hexachlorophene from highly purified 2,4,5-trichlorophenol).	(H)
	F026 Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production of materials on equipment previously used for the manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tetra-, penta-, or hexachlorobenzene under alkaline conditions.	(H)
	F027 Discarded unused formulations containing tri-, tetra-, or pentachlorophenol or discarded unused formulations containing compounds derived from these chlorophenols. (This listing does not include formulations containing Hexachlorophene synthesized from prepurified 2,4,5-trichlorophenol as the sole component).	(H)
	F028 Residues resulting from the incineration or thermal treatment of soil contaminated with EPA Hazardous Waste Nos. F020, F021, F022, F023, F026, and F027.	(T)

§ 261.32 Hazardous wastes from specific sources.

Industry and EPA hazardous waste No.	Hazardous waste	Hazard code
Wood preservation: K001 .....	Bottom sediment sludge from the treatment of wastewaters from wood preserving processes that use creosote and/or pentachlorophenol.	(T)
Inorganic pigments:		
K002 .....	Wastewater treatment sludge from the production of chrome yellow and orange pigments.	(T)
K003 .....	Wastewater treatment sludge from the production of molybdate orange pigments .....	(T)
K004 .....	Wastewater treatment sludge from the production of zinc yellow pigments.....	(T)
K005 .....	Wastewater treatment sludge from the production of chrome green pigments .....	(T)
K006 .....	Wastewater treatment sludge from the production of chrome oxide green pigments (anhydrous and hydrated).	(T)
K007 .....	Wastewater treatment sludge from the production of iron blue pigments .....	(T)
K008 .....	Oven residue from the production of chrome oxide green pigments.....	(T)
Organic chemicals:		
K009 .....	Distillation bottoms from the production of acetaldehyde from ethylene .....	(T)
K010 .....	Distillation side cuts from the production of acetaldehyde from ethylene.....	(T)
K011 .....	Bottom stream from the wastewater stripper in the production of acrylonitrile.....	(R, T)
K013 .....	Bottom stream from the acetonitrile column in the production of acrylonitrile .....	(R, T)
K014 .....	Bottoms from the acetonitrile purification column in the production of acrylonitrile .....	(T)
K015 .....	Still bottoms from the distillation of benzyl chloride .....	(T)
K016 .....	Heavy ends or distillation residues from the production of carbon tetrachloride .....	(T)
K017 .....	Heavy ends (still bottoms) from the purification column in the production of epichlorohydrin.	(T)
K018 .....	Heavy ends from the fractionation column in ethyl chloride production.....	(T)
K019 .....	Heavy ends from the distillation of ethylene dichloride in ethylene dichloride production.	(T)
K020 .....	Heavy ends from the distillation of vinyl chloride in vinyl chloride monomer production.	(T)
K021 .....	Aqueous spent antimony catalyst waste from fluoromethanes production .....	(T)
K022 .....	Distillation bottom tars from the production of phenol/acetone from cumene.....	(T)
K023 .....	Distillation light ends from the production of phthalic anhydride from naphthalene .....	(T)
K024 .....	Distillation bottoms from the production of phthalic anhydride from naphthalene .....	(T)
K023 .....	Distillation light ends from the production of phthalic anhydride from ortho-xylene .....	(T)
K024 .....	Distillation bottoms from the production of phthalic anhydride from ortho-xylene .....	(T)
K025 .....	Distillation bottoms from the production of nitrobenzene by the nitration of benzene.....	(T)
K026 .....	Stripping still tails from the production of methy ethyl pyridines .....	(T)
K027 .....	Centrifuge and distillation residues from toluene diisocyanate production.....	(R, T)
K028 .....	Spent catalyst from the hydrochlorinator reactor in the production of 1,1,1-trichloroethane.	(T)
K029 .....	Waste from the product steam stripper in the production of 1,1,1-trichloroethane .....	(T)
K025 .....	Distillation bottoms from the production of 1,1,1-trichloroethane .....	(T)
K026 .....	Heavy ends from the heavy ends column from the production of 1,1,1-trichloroethane.	(T)
K030 .....	Column bottoms or heavy ends from the combined production of trichloroethylene and perchloroethylene.	(T)
K023 .....	Distillation bottoms from aniline production .....	(T)
K103 .....	Process residues from aniline extraction from the production of aniline.....	(T)
K104 .....	Combined wastewater streams generated from nitrobenzene/aniline production .....	(T)
K025 .....	Distillation or fractionation column bottoms from the production of chlorobenzenes.....	(T)
K105 .....	Separated aqueous stream from the reactor product washing step in the production of chlorobenzenes.	(T)
Inorganic chemicals:		
K071 .....	Brine purification muds from the mercury cell process in chlorine production, where separately prepurified brine is not used.	(T)
K073 .....	Chlorinated hydrocarbon waste from the purification step of the diaphragm cell process using graphite anodes in chlorine production.	(T)
K106 .....	Wastewater treatment sludge from the mercury cell process in chlorine production.....	(T)
Pesticides:		
K031 .....	By-product salts generated in the production of MSMA and cacodylic acid .....	(T)
K032 .....	Wastewater treatment sludge from the production of chlordane.....	(T)
K033 .....	Wastewater and scrub water from the chlorination of cyclopentadiene in the production of chlordane.	(T)
K034 .....	Filter solids from the filtration of hexachlorocyclopentadiene in the production of chlordane.	(T)
K027 .....	Vacuum stripper discharge from the chlordane chlorinator in the production of chlordane.	(T)
K035 .....	Wastewater treatment sludges generated in the production of creosote.....	(T)
K036 .....	Still bottoms from toluene reclamation distillation in the production of disulfoton.....	(T)
K037 .....	Wastewater treatment sludges from the production of disulfoton.....	(T)
K038 .....	Wastewater from the washing and stripping of phorate production.....	(T)

Industry and EPA hazardous waste No.	Hazardous waste	Hazard code
K039	Filter cake from the filtration of diethyldiphosphorodithioic acid in the production of phosphate.	(T)
K040	Wastewater treatment sludge from the production of phosphate	(T)
K041	Wastewater treatment sludge from the production of toxaphene	(T)
K098	Untreated process wastewater from the production of toxaphene	(T)
K042	Heavy ends or distillation residues from the distillation of tetrachlorobenzene in the production of 2,4,5-T.	(T)
K043	2,6-Dichlorophenol waste from the production of 2,4-D	(T)
K099	Untreated wastewater from the production of 2,4-D	(T)
<b>Explosives:</b>		
K044	Wastewater treatment sludges from the manufacturing and processing of explosives	(R)
K045	Spent carbon from the treatment of wastewater containing explosives	(R)
K046	Wastewater treatment sludges from the manufacturing, formulation and loading of lead-based initiating compounds.	(T)
K047	Pink/red water from TNT operations	(R)
<b>Petroleum refining:</b>		
K048	Dissolved air flotation (DAF) float from the petroleum refining industry	(T)
K049	Slop oil emulsion solids from the petroleum refining industry	(T)
K050	Heat exchanger bundle cleaning sludge from the petroleum refining industry	(T)
K051	API separator sludge from the petroleum refining industry	(T)
K052	Tank bottoms (lead) from the petroleum refining industry	(T)
<b>Iron and steel:</b>		
K061	Emission control dust/sludge from the primary production of steel in electric furnaces.	(T)
K062	Spent pickle liquor from steel finishing operations	(C, T)
<b>Secondary lead:</b>		
K069	Emission control dust/sludge from secondary lead smelting	(T)
K100	Waste leaching solution from acid leaching of emission control dust/sludge from secondary lead smelting.	(T)
<b>Veterinary pharmaceuticals:</b>		
K084	Wastewater treatment sludges generated during the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.	(T)
K101	Distillation tar residues from the distillation of aniline-based compounds in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.	(T)
K102	Residue from the use of activated carbon for decolorization in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.	(T)
<b>Ink formulation: K066</b>		
	Solvent washes and sludges, caustic washes and sludges, or water washes and sludges from cleaning tubs and equipment used in the formulation of ink from pigments, driers, soaps, and stabilizers containing chromium and lead.	(T)
<b>Coking:</b>		
K060	Ammonia still lime sludge from coking operations	(T)
K067	Decanter tank tar sludge from coking operations	(T)

Acutely Hazardous Wastes

P023	Acetaldehyde, chloro-	P028	Benzene, (chloromethyl)-
P002	Acetamide, N-(aminothioxomethyl)-	P042	1,2-Benzenediol, 4-[1-hydroxy-2-(methylamino)ethyl]-
P057	Acetamide, 2-fluoro-		
P058	Acetic acid, fluoro-, sodium salt	P014	Benzenethiol
P066	Acetimidic acid, N-[(methylcarbamoyl)oxy]thio-, methyl ester	P028	Benzyl chloride
P001	3-(alpha-Acetylbenzyl)-4-hydroxycoumarin and salts, when present at concentrations greater than 0.3%	P015	Beryllium dust
P002	1-Acetyl-2-thiourea	P016	Bis(chloromethyl) ether
P003	Acrolein	P017	Bromoacetone
P070	Aldicarb	P018	Bruceine
P004	Aldrin	P021	Calcium cyanide
P005	Allyl alcohol	P123	Camphene, octachloro-
P008	Aluminum phosphide	P103	Carbamimidoseleonic acid
P007	5-(Aminomethyl)-3-isoxazolol	P022	Carbon disulfide
P008	4-aminopyridine	P022	Carbon disulfide
P009	Ammonium picrate (R)	P095	Carbonyl chloride
P119	Ammonium vanadate	P033	Chlorine cyanide
P010	Arsenic acid	P023	Chloroacetaldehyde
P012	Arsenic (III) oxide	P024	p-Chloroaniline
P011	Arsenic (V) oxide	P026	1-(o-Chlorophenyl)thiourea
P011	Arsenic pentoxide	P027	3-Chloropropionitrile
P012	Arsenic trioxide	P029	Copper cyanides
P038	Arginine, diethyl-	P030	Cyanides (soluble cyanide salts), not elsewhere specified
P054	Azirdine	P031	Cyanogen
P013	Barium cyanide	P033	Cyanogen chloride
P024	Benzenamine, 4-chloro-	P036	Dichlorophenylarsine
P077	Benzenamine, 4-nitro-	P037	Dieldrin
		P038	Diethylarsine

Hazardous waste No.	Substance	Hazardous waste No.	Substance
P039.....	O,O-Diethyl S-[2-(ethylthio)ethyl] phosphorodithioate	P074.....	Nickel(II) cyanide
P041.....	Diethyl-p-nitrophenyl phosphate	P073.....	Nickel tetracarbonyl
P040.....	O,O-Diethyl O-pyrazinyl phosphorothioate	P075.....	Nicotine and salts
P043.....	Diisopropyl fluorophosphate	P076.....	Nitric oxide
P044.....	Dimethoate	P077.....	p-Nitroaniline
P045.....	3,3-Dimethyl-1-(methylthio)-2-butanone, O-[(methylamino)carbonyl] oxime	P078.....	Nitrogen dioxide
P071.....	O,O-Dimethyl O-p-nitrophenyl phosphorothioate	P076.....	Nitrogen(II) oxide
P082.....	Dimethylnitrosamine	P078.....	Nitrogen(IV) oxide
P046.....	alpha, alpha-Dimethylphenethylamine	P081.....	Nitroglycerine (R)
P047.....	4,6-Dinitro-o-cresol and salts	P082.....	N-Nitrosodimethylamine
P034.....	4,6-Dinitro-o-cyclohexylphenol	P084.....	N-Nitrosomethylvinylamine
P048.....	2,4-Dinitrophenol	P050.....	5-Norbornene-2,3-dimethanol, 1,4,5,6,7,7-hexachloro, cyclic sulfite
P020.....	Dinoseb	P085.....	Octamethylpyrophosphoramidate
P085.....	Diphosphoramidate, octamethyl-	P087.....	Osmium oxide
P039.....	Disulfoton	P087.....	Osmium tetroxide
P049.....	2,4-Dithiobiuret	P088.....	7-Oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid
P109.....	Dithiopyrophosphoric acid, tetraethyl ester	P089.....	Parathion
P050.....	Endosulfan	P034.....	Phenol, 2-cyclohexyl-4,6-dinitro-
P088.....	Endothal	P048.....	Phenol, 2,4-dinitro-
P051.....	Endrin	P047.....	Phenol, 2,4-dinitro-6-methyl-
P042.....	Epinephrine	P020.....	Phenol, 2,4-dinitro-6-(1-methylpropyl)-
P046.....	Ethanamine, 1,1-dimethyl-2-phenyl-	P009.....	Phenol, 2,4,6-trinitro-, ammonium salt (R)
P084.....	Ethanamine, N-methyl-N-nitroso-	P036.....	Phenyl dichloroarsine
P101.....	Ethyl cyanide	P092.....	Phenylmercuric acetate
P054.....	Ethylenimine	P093.....	N-Phenythiourea
P097.....	Famphus	P094.....	Phorate
P056.....	Fluorine	P095.....	Phosgene
P057.....	Fluoroacetamide	P096.....	Phosphine
P058.....	Fluoroacetic acid, sodium salt	P041.....	Phosphoric acid, diethyl p-nitrophenyl ester
P065.....	Fulminic acid, mercury(II) salt (R,T)	P044.....	Phosphorodithioic acid, O,O-dimethyl S-[2-(methylamino)-2-oxoethyl]ester
P059.....	Heptachlor	P043.....	Phosphorofluoric acid, bis(1-methylethyl)-ester
P051.....	1,2,3,4,10,10-Hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo,endo-1,4:5,8-dimethanonaphthalene	P094.....	Phosphorothioic acid, O,O-diethyl S-(ethylthio)methyl ester
P037.....	1,2,3,4,10,10-Hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo,exo-1,4:5,8-dimethanonaphthalene	P089.....	Phosphorothioic acid, O,O-diethyl O-(p-nitrophenyl) ester
P060.....	1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-endo, endo-dimethanonaphthalene	P040.....	Phosphorothioic acid, O,O-diethyl O-pyrazinyl ester
P004.....	1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-endo,exo-dimethanonaphthalene	P097.....	Phosphorothioic acid, O,O-dimethyl O-[p-((dimethylamino)sulfonyl)phenyl]ester
P060.....	Hexachlorohexahydro-exo,exo-dimethanonaphthalene	P110.....	Plumbane, tetraethyl-
P062.....	Hexaethyl tetraphosphate	P098.....	Potassium cyanide
P116.....	Hydrazinecarbothioimide	P099.....	Potassium silver cyanide
P068.....	Hydrazine, methyl-	P070.....	Propanal, 2-methyl-2-(methylthio)-, O-[(methylamino)carbonyl]oxime
P063.....	Hydrocyanic acid	P101.....	Propanenitrile
P063.....	Hydrogen cyanide	P027.....	Propanenitrile, 3-chloro-
P098.....	Hydrogen phosphide	P069.....	Propanenitrile, 2-hydroxy-2-methyl-
P064.....	Isocyanic acid, methyl ester	P081.....	1,2,3-Propanetriol, trinitrate- (R)
P007.....	3(2H)-isoxazolone, 5-(aminomethyl)-	P017.....	2-Propanone, 1-bromo-
P092.....	Mercury, (acetato-O)phenyl-	P102.....	Propargyl alcohol
P065.....	Mercury fulminate (R,T)	P003.....	2-Propenal
P016.....	Methane, oxybis(chloro-	P005.....	2-Propen-1-ol
P112.....	Methane, tetranitro- (R)	P067.....	1,2-Propylenimine
P118.....	Methanethiol, trichloro-	P102.....	2-Propyn-1-ol
P059.....	4,7-Methano-1H-indene, 1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-	P008.....	4-Pyridinamine
P066.....	Methomyl	P075.....	Pyridine, (S)-3-(1-methyl-2-pyrroldinyl)-, and salts
P067.....	2-Methylaziridine	P111.....	Pyrophosphoric acid, tetraethyl ester
P068.....	Methyl hydrazine	P103.....	Selenourea
P064.....	Methyl isocyanate	P104.....	Silver cyanide
P069.....	2-Methylacetonitrile	P105.....	Sodium azide
P071.....	Methyl parathion	P108.....	Sodium cyanide
P072.....	alpha-Naphthylthiourea	P107.....	Strontium sulfide
P073.....	Nickel carbonyl	P108.....	Strychnidin-10-one, and salts
P074.....	Nickel cyanide	P018.....	Strychnidin-10-one, 2,3-dimethoxy-
		P108.....	Strychnine and salts
		P115.....	Sulfuric acid, thallium(I) salt
		P109.....	Tetraethyldithiopyrophosphate

Hazardous waste No.	Substance
P110.....	Tetraethyl lead
P111.....	Tetraethylpyrophosphate
P112.....	Tetranitromethane (R)
P062.....	Tetraphosphoric acid, hexaethyl ester
P113.....	Thallic oxide
P113.....	Thallium(III) oxide
P114.....	Thallium(I) selenite
P115.....	Thallium(I) sulfate
P045.....	Thiofanox
P049.....	Thioimidodicarbonic diamide
P014.....	Thiophenol
P116.....	Thiosemicarbazide

Hazardous Waste No.	Substance
P026.....	Thiourea, (2-chlorophenyl)-
P072.....	Thiourea, 1-naphthalenyl-
P093.....	Thiourea, phenyl-
P123.....	Toxaphene
P118.....	Trichloromethanethiol
P119.....	Vanadic acid, ammonium salt
P120.....	Vanadium pentoxide
P120.....	Vanadium(V) oxide
P001.....	Warfarin, when present at concentrations greater than 0.3%
P121.....	Zinc cyanide
P122.....	Zinc phosphide, when present at concentrations greater than 10%

### Hazardous Wastes

U001.....	Acetaldehyde (I)	U038.....	Benzeneacetic acid, 4-chloro-alpha-(4-chlorophenyl)-alpha-hydroxy, ethyl ester
U034.....	Acetaldehyde, trichloro-	U030.....	Benzene, 1-bromo-4-phenoxy-
U187.....	Acetamide, N-(4-ethoxyphenyl)-	U037.....	Benzene, chloro-
U005.....	Acetamide, N-9H-fluoren-2-yl-	U190.....	1,2-Benzenedicarboxylic acid anhydride
U112.....	Acetic acid, ethyl ester (I)	U028.....	1,2-Benzenedicarboxylic acid, [bis(2-ethylhexyl)] ester
U144.....	Acetic acid, lead salt	U069.....	1,2-Benzenedicarboxylic acid, dibutyl ester
U214.....	Acetic acid, thallium(I) salt	U088.....	1,2-Benzenedicarboxylic acid, diethyl ester
U002.....	Acetone (I)	U102.....	1,2-Benzenedicarboxylic acid, dimethyl ester
U003.....	Acetonitrile (I,T)	U107.....	1,2-Benzenedicarboxylic acid, di-n-octyl ester
U248.....	3-(alpha-Acetylbenzyl)-4-hydroxycoumarin and salts, when present at concentrations of 0.3% or less	U070.....	Benzene, 1,2-dichloro-
U004.....	Acetophenone	U071.....	Benzene, 1,3-dichloro-
U005.....	2-Acetylaminofluorene	U072.....	Benzene, 1,4-dichloro-
U008.....	Acetyl chloride (C,R,T)	U017.....	Benzene, (dichloromethyl)-
U007.....	Acrylamide	U223.....	Benzene, 1,3-diisocyanatomethyl- (R,T)
U008.....	Acrylic acid (I)	U239.....	Benzene, dimethyl-(I,T)
U009.....	Acrylonitrile	U201.....	1,3-Benzenediol
U150.....	Alanine, 3-[p-bis(2-chloroethyl)amino] phenyl-, L-	U127.....	Benzene, hexachloro-
U011.....	Amitrole	U058.....	Benzene, hexahydro- (I)
U012.....	Aniline (I,T)	U188.....	Benzene, hydroxy-
U014.....	Auramine	U220.....	Benzene, methyl-
U015.....	Azaserine	U105.....	Benzene, 1-methyl-1,2,4-dinitro-
U010.....	Azirino(2',3':3,4)pyrrolo(1,2-a)indole-4,7-dione, 6-amino-8-(((aminocarbonyl oxy)methyl)-1,1a,2,8,8a,8b-hexahydro-8a-methoxy-5-methyl-,	U108.....	Benzene, 1-methyl-2,6-dinitro-
U157.....	Benz[ ]aceanthrylene, 1,2-dihydro-3-methyl-	U203.....	Benzene, 1,2-methylenedioxy-4-allyl-
U016.....	Benz[ c ]acridine	U141.....	Benzene, 1,2-methylenedioxy-4-propenyl-
U016.....	3,4-Benzacridine	U090.....	Benzene, 1,2-methylenedioxy-4-propyl-
U017.....	Benzal chloride	U055.....	Benzene, (1-methylethyl)- (I)
U018.....	Benz[ a ]anthracene	U189.....	Benzene, nitro- (I,T)
U018.....	1,2-Benzanthracene	U183.....	Benzene, pentachloro-
U094.....	1,2-Benzanthracene, 7,12-dimethyl-	U185.....	Benzene, pentachloro-nitro-
U012.....	Benzenamine (I,T)	U020.....	Benzenesulfonic acid chloride (C,R)
U014.....	Benzenamine, 4,4'-carbonimidoylbis(N,N-dimethyl-	U020.....	Benzenesulfonyl chloride (C,R)
U049.....	Benzenamine, 4-chloro-2-methyl-	U207.....	Benzene, 1,2,4,5-tetrachloro-
U093.....	Benzenamine, N,N'-dimethyl-4-phenylazo-	U023.....	Benzene, (trichloromethyl)-(C,R,T)
U158.....	Benzenamine, 4,4'-methylenebis(2-chloro-	0234.....	Benzene, 1,3,5-trinitro- (R,T)
U222.....	Benzenamine, 2-methyl-, hydrochloride	U021.....	Benzidine
U181.....	Benzenamine, 2-methyl-5-nitro	U202.....	1,2-Benzisothiazolin-3-one, 1,1-dioxide
U019.....	Benzene (I,T)	U120.....	Benzo[ j, k ]fluorene
		U022.....	Benzo[ a ]pyrene
		U022.....	3,4-Benzopyrene
		U197.....	p-Benzoquinone

Hazardous Waste No.	Substance	Hazardous Waste No.	Substance
U023	Benzotrichloride (C,R,T)	U063	Dibenz[a,h]anthracene
U050	1,2-Benzphenanthrene	U063	1,2,5,6-Dibenzanthracene
U085	2,2'-Bioxirane (I,T)	U064	1,2:7,8-Dibenzopyrene
U021	(1,1'-Biphenyl)-4,4'-diamine	U064	Dibenz[a,i]pyrene
U073	(1,1'-Biphenyl)-4,4'-diamine, 3,3'-dichloro-	U066	1,2-Dibromo-3-chloropropane
U091	(1,1'-Biphenyl)-4,4'-diamine, 3,3'-dimethoxy-	U069	Dibutyl phthalate
U095	(1,1'-Biphenyl)-4,4'-diamine, 3,3'-dimethyl-	U062	S-(2,3-Dichloroallyl) diisopropylthiocarbamate
U024	Bis(2-chloroethoxy) methane	U070	o-Dichlorobenzene
U027	Bis(2-chloroisopropyl) ether	U071	m-Dichlorobenzene
U244	Bis(dimethylthiocarbamoyl) disulfide	U072	p-Dichlorobenzene
U028	Bis(2-ethylhexyl) phthalate	U073	3,3'-Dichlorobenzidine
U246	Bromine cyanide	U074	1,4-Dichloro-2-butene (I,T)
U225	Bromoform	U075	Dichlorodifluoromethane
U030	4-Bromophenyl phenyl ether	U192	3,5-Dichloro-N-(1,1-dimethyl-2-propynyl) benzamide
U128	1,3-Butadiene, 1,1,2,3,4,4-hexachloro-	U060	Dichloro diphenyl dichloroethane
U172	1-Butanamine, N-butyl-N-nitroso-	U061	Dichloro diphenyl trichloroethane
U035	Butanoic acid, 4-[Bis(2-chloroethyl)amino] benzene-	U078	1,1-Dichloroethylene
U031	1-Butanol (I)	U079	1,2-Dichloroethylene
U159	2-Butanone (I,T)	U025	Dichloroethyl ether
U160	2-Butanone peroxide (R,T)	U081	2,4-Dichlorophenol
U053	2-Butenal	U082	2,6-Dichlorophenol
U074	2-Butene, 1,4-dichloro- (I,T)	U240	2,4-Dichlorophenoxyacetic acid, salts and esters
U031	n-Butyl alcohol (I)	U083	1,2-Dichloropropane
U136	Cacodylic acid	U084	1,3-Dichloropropene
U032	Calcium chromate	U085	1,2:3,4-Diepoxybutane (I,T)
U238	Carbamic acid, ethyl ester	U108	1,4-Diethylene dioxide
U178	Carbamic acid, methylnitroso-, ethyl ester	U086	N,N-Diethylhydrazine
U176	Carbamide, N-ethyl-N-nitroso-	U087	O,O-Diethyl-S-methyl-dithiophosphate
U177	Carbamide, N-methyl-N-nitroso-	U088	Diethyl phthalate
U219	Carbamide, thio-	U089	Diethylstilbestrol
U097	Carbamoyl chloride, dimethyl-	U148	1,2-Dihydro-3,6-pyridinedione
U215	Carbonic acid, dithallium(I) salt	U090	Dihydrosoafole
U156	Carbonochloridic acid, methyl ester (I,T)	U091	3,3'-Dimethoxybenzidine
U033	Carbon oxyfluoride (R,T)	U092	Dimethylamine (I)
U211	Carbon tetrachloride	U093	Dimethylaminoazobenzene
U033	Carbonyl fluoride (R,T)	U094	7,12-Dimethylbenz[a]anthracene
U034	Chloral	U095	3,3'-Dimethylbenzidine
U035	Chlorambucil	U096	alpha, alpha-Dimethylbenzylhydroperoxide (R)
U036	Chloroform, technical	U097	Dimethylcarbamoyl chloride
U026	Chloromaphazine	U098	1,1-Dimethylhydrazine
U037	Chlorobenzene	U099	1,2-Dimethylhydrazine
U039	4-Chloro-m-cresol	U101	2,4-Dimethylphenol
U041	1-Chloro-2,3-epoxypropane	U102	Dimethyl phthalate
U042	2-Chloroethyl vinyl ether	U103	Dimethyl sulfate
U044	Chloroform	U105	2,4-Dinitrotoluene
U046	Chloromethyl methyl ether	U106	2,6-Dinitrotoluene
U047	beta-Chloronaphthalene	U107	Di-n-octyl phthalate
U048	o-Chlorophenol	U108	1,4-Dioxane
U049	4-Chloro-o-toluidine, hydrochloride	U109	1,2-Diphenylhydrazine
U032	Chromic acid, calcium salt	U110	Dipropylamine (I)
U050	Chrysene	U111	Di-N-propylnitrosamine
U051	Cresote	U001	Ethanal (I)
U052	Cresols	U174	Ethanamine, N-ethyl-N-nitroso-
U052	Cresylic acid	U067	Ethane, 1,2-dibromo-
U053	Crotonaldehyde	U076	Ethane, 1,1-dichloro-
U055	Cumene (I)	U077	Ethane, 1,2-dichloro-
U246	Cyanogen bromide	U114	1,2-Ethanediybliscarbamodithioic acid
U197	1,4-Cyclohexadienedione	U131	Ethane, 1,1,1,2,2,2-hexachloro-
U056	Cyclohexane (I)	U024	Ethane, 1,1'-[methylenebis(oxy)]bis[2-chloro-
U057	Cyclohexanone (I)	U003	Ethanenitrile (I, T)
U130	1,3-Cyclopentadiene, 1,2,3,4,5,5-hexa- chloro-	U117	Ethane, 1,1'-oxybis- (I)
U058	Cyclophosphamide	U025	Ethane, 1,1'-oxybis[2-chloro-
U240	2,4,4-D, salts and esters	U184	Ethane, pentachloro-
U059	Daunomycin	U208	Ethane, 1,1,1,2-tetrachloro-
U060	DDD	U209	Ethane, 1,1,2,2-tetrachloro-
U061	DDT	U218	Ethanethioamide
U142	Decachlorooctahydro-1,3,4-metheno-2H-cyclobuta[c,d]-pentalen-2-one	U247	Ethane, 1,1,1,-trichloro-2,2-bis(p-methoxy-phenyl).
U062	Diallate	U227	Ethane, 1,1,2-trichloro-
U133	Diamine (R,T)	U043	Ethane, chloro-
U221	Diaminotoluene		

Hazardous Waste No.	Substance	Hazardous Waste No.	Substance
U042	Ethene, 2-chloroethoxy-	U068	Methane, dibromo-
U078	Ethene, 1,1-dichloro-	U080	Methane, dichloro-
U079	Ethene, trans-1,2-dichloro-	U075	Methane, dichlorodifluoro-
U210	Ethene, 1,1,2,2-tetrachloro-	U138	Methane, iodo-
U173	Ethanol, 2,2'-(nitrosoimino)bis-	U119	Methanesulfonic acid, ethyl ester
U004	Ethanone, 1-phenyl-	U211	Methane, tetrachloro-
U006	Ethanoyl chloride (C,R,T)	U121	Methane, trichlorofluoro-
U112	Ethyl acetate (I)	U153	Methanethiol (I,T)
U113	Ethyl acrylate (I)	U225	Methane, tribromo-
U238	Ethyl carbamate (urethan)	U044	Methane, trichloro-
U038	Ethyl 4,4'-dichlorobenzilate	U121	Methane, trichlorofluoro-
U114	Ethylenebis(dithiocarbamic acid)	U123	Methanoic acid (C,T)
U067	Etylene dibromide	U036	4,7-Methanoindan, 1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-
U077	Ethylene dichloride	U154	Methanol (I)
U115	Ethlene oxide (I,T)	U155	Methapyrilene
U116	Ethylene thiourea	U247	Methoxychlor.
U117	Ethyl ether (I)	U154	Methyl alcohol (I)
U076	Ethylidene dichloride	U029	Methyl bromide
U118	Ethylmethacrylate	U186	1-Methylbutadiene (I)
U119	Ethyl methanesulfonate	U045	Methyl chloride (I,T)
U139	Feric dextran	U156	Methyl chlorocarbonate (I,T)
U120	Fluoranthene	U226	Methylchloroform
U122	Formaldehyde	U057	3-Methylcholanthrene
U123	Formic acid (C,T)	U158	4,4'-Methylenebis(2-chloroaniline)
U124	Furan (I)	U132	2,2'-Methylenebis(3,4,6-trichlorophenol)
U125	2-Furancarboxaldehyde (I)	U068	Methylene bromide
U147	2,5-Furandione	U080	Methylene chloride
U213	Furan, tetrahydro- (I)	U122	Methylene oxide
U125	Furfural (I)	U159	Methyl ethyl ketone (I,T)
U124	Furfuran (I)	U160	Methyl ethyl ketone peroxide (R,T)
U206	D-Glucopyranose, 2-deoxy-2(3-methyl-3-nitrosoureido)-	U138	Methyl iodide
U126	Glycidylaldehyde	U161	Methyl isobutyl ketone (I)
U163	Guanidine, N-nitroso-N-methyl-N'-nitro-	U162	Methyl methacrylate (I,T)
U127	Hexachlorobenzene	U163	N-Methyl-N'-nitro-N-nitrosoguanidine
U128	Hexachlorobutadiene	U161	4-Methyl-2-pentanone (I)
U129	Hexachlorocyclohexane (gamma isomer)	U164	Methylthiouracil
U130	Hexachlorocyclopentadiene	U010	Mitomycin C
U131	Hexachloroethane	U059	5,12-Naphthacenedione, (8S-cis)-8-acetyl-10-[(3-amino-2,3,6-trideoxy-alpha-L-xylohexopyranosyl)oxyl]-7,8,9,10-tetrahydro-6,8,11-trihydroxy-1-methoxy-
U132	Hexachlorophene	U165	Naphthalene
U243	Hexachloropropene	U047	Naphthalene, 2-chloro-
U133	Hydrazine (R,T)	U166	1,4-Naphthalenedione
U066	Hydrazine, 1,2-diethyl-	U236	2,7-Naphthalenedisulfonic acid, 3,3'-[3,3'-dimethyl-(1,1'-biphenyl)-4,4'-diyl]-bis(azo)bis(5-amino-4-hydroxy)-, tetrasodium salt
U096	Hydrazine, 1,1-dimethyl-	U166	1,4-Naphthaquinone
U099	Hydrazine, 1,2-dimethyl-	U167	1-Naphthylamine
U109	Hydrazine, 1,2-diphenyl-	U168	2-Naphthylamine
U134	Hydrofluoric acid (C,T)	U167	alpha-Naphthylamine
U134	Hydrogen fluoride (C,T)	U168	beta-Naphthylamine
U135	Hydrogen sulfide	U026	2-Naphthylamine, N,N'-bis(2-chloromethyl)-
U096	Hydroperoxide, 1-methyl-1-phenylethyl- (R)	U169	Nitrobenzene (I,T)
U136	Hydroxydimethylarsine oxide	U170	p-Nitrophenol
U116	2-Imidazolidinethione	U171	2-Nitropropane (I)
U137	Indeno[1,2,3-cd]pyrene	U172	N-Nitrosodi-n-butylamine
U139	Iron dextran	U173	N-Nitrosodiethanolamine
U140	Isobutyl alcohol (I,T)	U174	N-Nitrosodiethylamine
U141	Isosafrole	U111	N-Nitroso-N-propylamine
U142	Kepone	U176	N-Nitroso-N-ethylurea
U143	Lasiocarpine	U177	N-Nitroso-N-methylurea
U144	Lead acetate	U178	N-Nitroso-N-methylurethane
U145	Lead phosphate	U178	N-Nitrosopiperidine
U146	Lead subacetate	U180	N-Nitrosopyrrolidine
U129	Lindane	U181	5-Nitro-o-toluidine
U147	Maleic anhydride	U193	1,2-Oxathiolane, 2,2-dioxide
U148	Maleic hydrazide	U058	2H-1,3,2-Oxazaphosphorine, 2-[bis(2-chloroethyl)amino]tetrahydro-, oxide 2-
U149	Malononitrile	U115	Oxirane (I,T)
U150	Melphalan		
U151	Mercury		
U152	Methacrylonitrile (I,T)		
U092	Methanamine, N-methyl- (I)		
U029	Methane, bromo-		
U045	Methane, chloro- (I,T)		
U046	Methane, chloromethoxy-		



Hazardous Waste No.	Substance	Hazardous Waste No.	Substance
U041	Oxirane, 2-(chloromethyl)-	U205	Sulfur selenide (R,T)
U182	Paraldehyde	U232	2,4,5-T
U183	Pentachlorobenzene	U207	1,2,4,5-Tetrachlorobenzene
U184	Pentachloroethane	U208	1,1,1,2-Tetrachloroethane
U185	Pentachloronitrobenzene	U209	1,1,2,2-Tetrachloroethane
U242	Pentachlorophenol	U210	Tetrachloroethylene
U186	1,3-Pentadiene (I)	U212	2,3,4,6-Tetrachlorophenol
U187	Phenacetin	U213	Tetrahydrofuran (I)
U188	Phenol	U214	Thallium(I) acetate
U048	Phenol, 2-chloro-	U215	Thallium(I) carbonate
U039	Phenol, 4-chloro-3-methyl-	U216	Thallium(I) chloride
U081	Phenol, 2,4-dichloro-	U217	Thallium(I) nitrate
U082	Phenol, 2,6-dichloro-	U218	Thioacetamide
U101	Phenol, 2,4-dimethyl-	U153	Thiomethanol (I,T)
U170	Phenol, 4-nitro-	U219	Thiourea
U242	Phenol, pentachloro-	U244	Thiram
U212	Phenol, 2,3,4,6-tetrachloro-	U220	Toluene
U230	Phenol, 2,4,5-trichloro-	U221	Toluenediamine
U231	Phenol, 2,4,6-trichloro-	U223	Toluene diisocyanate (R,T)
U137	1,10-(1,2-phenylene)pyrene	U222	O-Toluidine hydrochloride
U145	Phosphoric acid, Lead salt	U011	1H-1,2,4-Triazol-3-amine
U087	Phosphorodithioic acid, 0,0-diethyl-, S-methyl-ester	U226	1,1,1-Trichloroethane
U189	Phosphorous sulfide (R)	U227	1,1,2-Trichloroethane
U190	Phthalic anhydride	U228	Trichloroethene
U191	2-Picoline	U228	Trichloroethylene
U192	Pronamide	U121	Trichloromonofluoromethane
U194	1-Propanamine (I,T)	U230	2,4,5-Trichlorophenol
U110	1-Propanamine, N-propyl- (I)	U231	2,4,6-Trichlorophenol
U066	Propane, 1,2-dibromo-3-chloro-	U232	2,4,5-Trichlorophenoxyacetic acid
U149	Propanedinitrile	U234	sym-Trinitrobenzene (R,T)
U171	Propane, 2-nitro- (I)	U182	1,3,5-Trioxane, 2,4,5-trimethyl-
U027	Propane, 2,2'-oxybis[2-chloro-	U235	Tris(2,3-dibromopropyl) phosphate
U193	1,3-Propane sulfone	U236	Trypan blue
U235	1-Propanol, 2,3-dibromo-, phosphate (3:1)	U237	Uracil, 5[bis(2-chloromethyl)amino]-
U126	1-Propanol, 2,3-epoxy-	U237	Uracil mustard
U140	1-Propanol, 2-methyl- (I,T)	U043	Vinyl chloride
U002	2-Propanone (I)	U248	Warfarin, when present at concentrations of 0.3% or less
U007	2-Propenamide	U239	Xylene (I)
U084	Propene, 1,3-dichloro-	U200	Yohimban-16-carboxylic acid, 11,17-dimethoxy-18-[(3,4,5-trimethoxy-benzoyl)oxy]-, methyl ester
U243	1-Propene, 1,1,2,3,3,3-hexachloro-	U249	Zinc phosphide, when present at concentrations of 10% or less
U009	2-Propenenitrile		
U152	2-Propenenitrile, 2-methyl- (I,T)		
U008	2-Propenoic acid (I)		
U113	2-Propenoic acid, ethyl ester (I)		
U118	2-Propenoic acid, 2-methyl-, ethyl ester		
U162	2-Propenoic acid, 2-methyl-, methyl ester (I,T)		
U233	Propionic acid, 2-(2,4,5-trichlorophenoxy)-		
U184	n-Propylamine (I,T)		
U083	Propylene dichloride		
U196	Pyridine		
U155	Pyridine, 2-[(2-(dimethylamino)-2-thenylamino)-]		
U179	Pyridine, hexahydro-N-nitroso-		
U191	Pyridine, 2-methyl-		
U164	4(1H)-Pyrimidinone, 2,3-dihydro-6-methyl-2-thioxo-		
U180	Pyrrole, tetrahydro-N-nitroso-		
U200	Reserpine		
U201	Resorcinol		
U202	Saccharin and salts		
U203	Safrole		
U204	Selenious acid		
U204	Selenium dioxide		
U205	Selenium disulfide (R,T)		
U015	L-Serine, diazoacetate (ester)		
U233	Sivex		
U089	4,4'-Stilbenediol, alpha, alpha'-diethyl-		
U206	Streptozotocin		
U135	Sulfur hydride		
U103	Sulfuric acid, dimethyl ester		
U189	Sulfur phosphide (R)		

APPENDIX B

List of Hazardous Constituents

The following list of Hazardous Constituents was taken from the Code of Federal Regulations (CFR, Title 40, Part 261, Appendix VIII, 1984).

Acetonitrile (Ethanenitrile)  
Acetophenone (Ethanone, 1-phenyl)  
3-(alpha-Acetylbenzyl)-4-hydroxycoumarin and salts (Warfarin)  
2-Acetylaminofluorene (Acetamide, N-(9H-fluoren-2-yl)-)  
Acetyl chloride (Ethanoyl chloride)  
1-Acetyl-2-thiourea (Acetamide, N-(aminothioxomethyl)-)  
Acrolein (2-Propenal)  
Acrylamide (2-Propenamido)  
Acrylonitrile (2-Propenenitrile)  
Aflatoxins  
Aldrin (1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a,8b-hexahydro-endo,exo-1,4:5,8-Dimethanonaphthalene)  
Allyl alcohol (2-Propen-1-ol)  
Aluminum phosphide  
4-Aminobiphenyl ([1,1'-Biphenyl]-4-amine)  
6-Amino-1,1a,2,8,8a,8b-hexahydro-8-(hydroxymethyl)-8a-methoxy-5-methyl-carbamate azirino[2',3':3,4]pyrrolo[1,2-a]indole-4,7-dione, (ester) (Mitomycin C)  
(Azirino[2',3':3,4]pyrrolo[1,2-a]indole-4,7-dione, 6-amino-8-[(amino-carbonyl)oxy)methyl]-1,1a,2,8,8a,8b-hexahydro-8a-methoxy-5-methyl-)  
5-(Aminomethyl)-3-isoxazolol (3(2H)-Isoxazolone, 5-(aminomethyl)-) 4-Aminopyridine (4-Pyridinamine)  
Amitrole (1H-1,2,4-Triazol-3-amine)  
Aniline (Benzenamine)  
Antimony and compounds, N.O.S.\*  
Aramite (Sulfurous acid, 2-chloroethyl-, 2-[4-(1,1-dimethylethyl)phenoxy]-1-methylethyl ester)

\* The abbreviation N.O.S. (not otherwise specified) signifies those members of the general class not specifically listed by name in this appendix.

Arsenic and compounds, N.O.S.\*  
Arsenic acid (Orthoarsenic acid)  
Arsenic pentoxide (Arsenic (V) oxide)  
Arsenic trioxide (Arsenic (III) oxide)  
Auramine (Benzenamine, 4,4'-carbonimidoylbis[N,N-Dimethyl-, mono-hydrochloride])  
Azaserine (L-Serine, diazoacetate (ester))  
Barium and compounds, N.O.S.\*  
Barium cyanide  
Benz(c)acridine (3,4-Benzacridine)  
Benz(a)anthracene (1,2-Benzanthracene)  
Benzene (Cyclohexatriene)  
Benzenearsonic acid (Arsonic acid, phenyl-)  
Benzene, dichloromethyl- (Benzal chloride)  
Benzenethiol (Thiophenol)  
Benzidine ([1,1'-Biphenyl]-4,4'diamine)  
Benzo(b)fluoranthene (2,3-Benzofluoranthene)  
Benzo(j)fluoranthene (7,8-Benzofluoranthene)  
Benzo(a)pyrene (3,4-Benzopyrene)  
p-Benzoquinone (1,4-Cyclohexadienedione)  
Benzotrifluoride (Benzene, trichloromethyl)  
Benzyl chloride (Benzene, (chloromethyl)-)  
Beryllium and compounds, N.O.S.\*  
Bis(2-chloroethoxy)methane (Ethane, 1,1'-[methylenebis(oxy)]bis[2-chloro-])  
Bis(2-chloroethyl) ether (Ethane, 1,1'-oxybis[2-chloro-])  
N,N-Bis(2-chloroethyl)-2-naphthylamine (Chlornaphazine)  
Bis(2-chloroisopropyl) ether (Propane, 2,2'-oxybis[2-chloro-])  
Bis(chloromethyl) ether (Methane, oxybis[chloro-])  
Bis(2-ethylhexyl) phthalate (1,2-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester)  
Bromoacetone (2-Propanone, 1-bromo-)  
Bromomethane (Methyl bromide)  
4-Bromophenyl phenyl ether (Benzene, 1-bromo-4-phenoxy-)

- Brucine (Strychnidin-10-one, 2,3-dimethoxy-)  
 2-Butanone peroxide (Methyl ethyl ketone, peroxide)  
 Butyl benzyl phthalate (1,2-Benzenedicarboxylic acid, butyl phenylmethyl ester)  
 2-sec-Butyl-4,6-dinitrophenol (DNBP) (Phenol, 2,4-dinitro-6-(1-methylpropyl)-)  
 Cadmium and compounds, N.O.S.\*  
 Calcium chromate (Chromic acid, calcium salt)  
 Calcium cyanide  
 Carbon disulfide (Carbon bisulfide)  
 Carbon oxyfluoride (Carbonyl fluoride)  
 Chloral (Acetaldehyde, trichloro-)  
 Chlorambucil (Butanoic acid, 4-[bis(2-chloroethyl)amino]benzene-)  
 Chlordane (alpha and gamma isomers) (4,7-Methanoindan, 1,2,4,5,6,7,8,8-octachloro-3,4,7,7a-tetrahydro-) (alpha and gamma isomers)  
 Chlorinated benzenes, N.O.S.\*  
 Chlorinated ethane, N.O.S.\*  
 Chlorinated fluorocarbons, N.O.S.\*  
 Chlorinated naphthalene, N.O.S.\*  
 Chlorinated phenol, N.O.S.\*  
 Chloroacetaldehyde (Acetaldehyde, chloro-)  
 Chloroalkyl ethers, N.O.S.\*  
 p-Chloroaniline (Benzenamine, 4-chloro-)  
 Chlorobenzene (Benzene, chloro-)  
 Chlorobenzilate (Benzenoacetic acid, 4-chloro-alpha-(4-chlorophenyl)-alpha-hydroxy-, ethyl ester)  
 2-Chloro-1,3-butadiene (chloroprene)  
 p-Chloro-m-cresol (Phenol, 4-chloro-3-methyl)  
 1-Chloro-2,3-epoxypropane (Oxirane, 2-(chloromethyl)-)  
 2-Chloroethyl vinyl ether (Ethene, (2-chloroethoxy)-)  
 Chloroform (Methane, trichloro-)  
 Chloromethane (Methyl chloride)  
 Chloromethyl methyl ether (Methane, chloromethoxy-)  
 2-Chloronaphthalene (Naphthalene, beta-chloro-)  
 2-Chlorophenol (Phenol, o-chloro-)  
 1-(o-Chlorophenyl)thiourea (Thiourea, (2-chlorophenyl)-)  
 3-Chloropropene (allyl chloride)  
 3-Chloropropionitrile (Propanenitrile, 3-chloro-)  
 Chromium and compounds, N.O.S.\*  
 Chrysene (1,2-Benzphenanthrene)  
 Citrus red No. 2 (2-Naphthol, 1-[(2,5-dimethoxyphenyl)azo]-)  
 Coal tars  
 Copper cyanide  
 Creosote (Creosote, wood)  
 Cresols (Cresylic acid) (Phenol, methyl-)  
 Crotonaldehyde (2-Butenal)  
 Cyanides (soluble salts and complexes), N.O.S.\*  
 Cyanogen (Ethanedinitrile)  
 Cyanogen bromide (Bromine cyanide)  
 Cyanogen chloride (Chlorine cyanide)  
 Cycasin (beta-D-Glucopyranoside, (methyl-ONN-azoxy)methyl-)  
 2-Cyclohexyl-4,6-dinitrophenol (Phenol, 2-cyclohexyl-4,6-dinitro-)  
 Cyclophosphamide (2H-1,3,2-Oxazaphosphorine, [bis(2-chloroethyl)amino]-tetrahydro-, 2-oxide)  
 Daunomycin (5,12-Naphthacenedione, (8S-cis)-8-acetyl-10-[(3-amino-2,3,6-trideoxy)-alpha-L-lyxo-hexopyranosyl]oxy-1,7,8,9,10-tetrahydro-6,8,11-trihydroxy-1-methoxy-)  
 DDD (Dichlorodiphenyldichloroethane) (Ethane, 1,1-dichloro-2,2-bis(p-chlorophenyl)-)  
 DDE (Ethylene, 1,1-dichloro-2,2-bis(4-chlorophenyl)-)  
 DDT (Dichlorodiphenyltrichloroethane) (Ethane, 1,1,1-trichloro-2,2-bis(p-chlorophenyl)-)  
 Diallylate (S-(2,3-dichloroallyl) diisopropylthiocarbamate)  
 Dibenz[a,h]acridine (1,2,5,6-Dibenzacridine)  
 Dibenz[a,j]acridine (1,2,7,8-Dibenzacridine)  
 Dibenz[a,h]anthracene (1,2,5,6-Dibenzanthracene)  
 7H-Dibenzof[c,g]carbazole (3,4,5,6-Dibenzcarbazole)  
 Dibenzofa,elopyrene (1,2,4,5-Dibenzopyrene)  
 Dibenzofa,hlpyrene (1,2,5,6-Dibenzopyrene)  
 Dibenzofa,ilpyrene (1,2,7,8-Dibenzopyrene)  
 1,2-Dibromo-3-chloropropane (Propane, 1,2-dibromo-3-chloro-)  
 1,2-Dibromoethane (Ethylene dibromide)  
 Dibromomethane (Methylene bromide)  
 Di-n-butyl phthalate (1,2-Benzenedicarboxylic acid, dibutyl ester)  
 o-Dichlorobenzene (Benzene, 1,2-dichloro-)  
 m-Dichlorobenzene (Benzene, 1,3-dichloro-)  
 p-Dichlorobenzene (Benzene, 1,4-dichloro-)  
 Dichlorobenzene, N.O.S.\* (Benzene, dichloro-, N.O.S.\*)  
 3,3'-Dichlorobenzidine ([1,1'-Biphenyl]-4,4'-diamine, 3,3'-dichloro-)  
 1,4-Dichloro-2-butene (2-Butene, 1,4-dichloro-)  
 Dichlorodifluoromethane (Methane, dichlorodifluoro-)  
 1,1-Dichloroethane (Ethylidene dichloride)  
 1,2-Dichloroethane (Ethylene dichloride)  
 trans-1,2-Dichloroethene (1,2-Dichloroethylene)  
 Dichloroethylene, N.O.S.\* (Ethene, dichloro-, N.O.S.\*)  
 1,1-Dichloroethylene (Ethene, 1,1-dichloro-)  
 Dichloromethane (Methylene chloride)  
 2,4-Dichlorophenol (Phenol, 2,4-dichloro-)  
 2,6-Dichlorophenol (Phenol, 2,6-dichloro-)  
 2,4-Dichlorophenoxyacetic acid (2,4-D), salts and esters (Acetic acid, 2,4-dichlorophenoxy-, salts and esters)  
 Dichlorophenylarsine (Phenyl dichloroarsine)  
 Dichloropropane, N.O.S.\* (Propane, dichloro-, N.O.S.\*)  
 1,2-Dichloropropane (Propylene dichloride)  
 Dichloropropanol, N.O.S.\* (Propanol, dichloro-, N.O.S.\*)  
 Dichloropropene, N.O.S.\* (Propene, dichloro-, N.O.S.\*)  
 1,3-Dichloropropene (1-Propene, 1,3-dichloro-)  
 Dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octa-hydro-endo,exo-1,4,5,8-Dimethanonaphthalene)  
 1,2,3,4-Diepoxbutane (2,2'-Bioxirane)  
 Diethylarsine (Arsine, diethyl-)  
 N,N-Diethylhydrazine (Hydrazine, 1,2-diethyl)  
 O,O-Diethyl S-methyl ester of phosphorodithioic acid (Phosphorodithioic acid, O,O-diethyl S-methyl ester)  
 O,O-Diethylphosphoric acid, O-p-nitrophenyl ester (Phosphoric acid, diethyl p-nitrophenyl ester)  
 Diethyl phthalate (1,2-Benzenedicarboxylic acid, diethyl ester)  
 O,O-Diethyl O-2-pyrazinyl phosphorothioate (Phosphorothioic acid, O,O-diethyl O-pyrazinyl ester)  
 Diethylstilbesterol (4,4'-Stilbenediol, alpha,alpha-diethyl, bis(dihydrogen phosphate, (E)-)  
 Dihydrosafrole (Benzene, 1,2-methylene-dioxy-4-propyl-)  
 3,4-Dihydroxy-alpha-(methylamino)methyl benzyl alcohol (1,2-Benzenediol, 4-[(1-hydroxy-2-(methylamino)ethyl]-)  
 Diisopropylfluorophosphate (DFP) (Phosphorofluoridic acid, bis(1-methylethyl) ester)  
 Dimethoate (Phosphorodithioic acid, O,O-dimethyl S-[2-(methylamino)-2-oxoethyl] ester)  
 3,3'-Dimethoxybenzidine ([1,1'-Biphenyl]-4,4'-diamine, 3,3'-dimethoxy-)  
 p-Dimethylaminoazobenzene (Benzenamine, N,N-dimethyl-4-(phenylazo)-)  
 7,12-Dimethylbenz[a]anthracene (1,2-Benzanthracene, 7,12-dimethyl-)  
 3,3'-Dimethylbenzidine ([1,1'-Biphenyl]-4,4'-diamine, 3,3'-dimethyl-)

Dimethylcarbamoyl chloride (Carbamoyl chloride, dimethyl-)  
 1,1-Dimethylhydrazine (Hydrazine, 1,1-dimethyl-)  
 1,2-Dimethylhydrazine (Hydrazine, 1,2-dimethyl-)  
 3,3-Dimethyl-1-(methylthio)-2-butanone, O-[(methylamino) carbonyl]oxime (Thiofanox)  
 alpha,alpha-Dimethylphenethylamine (Eth-  
 anamine, 1,1-dimethyl-2-phenyl-)  
 2,4-Dimethylphenol (Phenol, 2,4-dimethyl-)  
 Dimethyl phthalate (1,2-Benzenedicarboxylic acid, dimethyl ester)  
 Dimethyl sulfate (Sulfuric acid, dimethyl ester)  
 Dinitrobenzene, N.O.S.\* (Benzene, dinitro-, N.O.S.\*)  
 4,6-Dinitro-o-cresol and salts (Phenol, 2,4-dinitro-6-methyl-, and salts)  
 2,4-Dinitrophenol (Phenol, 2,4-dinitro-)  
 2,4-Dinitrotoluene (Benzene, 1-methyl-2,4-dinitro-)  
 2,6-Dinitrotoluene (Benzene, 1-methyl-2,6-dinitro-)  
 Di-n-octyl phthalate (1,2-Benzenedicarboxylic acid, dioctyl ester)  
 1,4-Dioxane (1,4-Diethylene oxide)  
 Diphenylamine (Benzenamine, N-phenyl-)  
 1,2-Diphenylhydrazine (Hydrazine, 1,2-diphenyl-)  
 Di-n-propylnitrosamine (N-Nitroso-di-n-propylamine)  
 Disulfoton (O,O-diethyl S-[2-(ethylthio)ethyl] phosphorodithioate)  
 2,4-Dithiobiuret (Thioimidodicarbonic diamide)  
 Endosulfan (5-Norbornene, 2,3-dimethanol, 1,4,5,6,7,7-hexachloro-, cyclic sulfite)  
 Endrin and metabolites (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo,endo-1,4:5,8-dimethanonaphthalene, and metabolites)  
 Ethyl carbamate (Urethan) (Carbamic acid, ethyl ester)  
 Ethyl cyanide (propanenitrile)  
 Ethylenebisdithiocarbamic acid, salts and esters (1,2-Ethanediybiscarbamodithioic acid, salts and esters)  
 Ethyleneimine (Aziridine)  
 Ethylene oxide (Oxirane)  
 Ethylenethiourea (2-Imidazolidinethione)  
 Ethyl methacrylate (2-Propenoic acid, 2-methyl-, ethyl ester)  
 Ethyl methanesulfonate (Methanesulfonic acid, ethyl ester)  
 Fluoranthene (Benzof[j,k]fluorene)  
 Fluorine  
 2-Fluoroacetamide (Acetamide, 2-fluoro-)  
 Fluoroacetic acid, sodium salt (Acetic acid, fluoro-, sodium salt)  
 Formaldehyde (Methylene oxide)  
 Formic acid (Methanoic acid)  
 Glycidylaldehyde (1-Propanol-2,3-epoxy)  
 Halomethane, N.O.S.\*  
 Heptachlor (4,7-Methano-1H-indene, 1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-)  
 Heptachlor epoxide (alpha, beta, and gamma isomers) (4,7-Methano-1H-indene, 1,4,5,6,7,8,8-heptachloro-2,3-epoxy-3a,4,7,7-tetrahydro-, alpha, beta, and gamma isomers)  
 Hexachlorobenzene (Benzene, hexachloro-)  
 Hexachlorobutadiene (1,3-Butadiene, 1,1,2,3,4,4-hexachloro-)  
 Hexachlorocyclohexane (all isomers) (Lindane and isomers)  
 Hexachlorocyclopentadiene (1,3-Cyclopentadiene, 1,2,3,4,5,5-hexachloro-)  
 Hexachloroethane (Ethane, 1,1,1,2,2,2-hexachloro-)  
 1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-endo,endo-dimethanonaphthalene (Hexachlorohexahydro-endo,endo-dimethanonaphthalene)  
 Hexachlorophene (2,2'-Methylenebis(3,4,6-trichlorophenol))  
 Hexachloropropene (1-Propene, 1,1,2,3,3,3-hexachloro-)  
 Hexaethyl tetraphosphate (Tetraphosphoric acid, hexaethyl ester)  
 Hydrazine (Diamine)  
 Hydrocyanic acid (Hydrogen cyanide)  
 Hydrofluoric acid (Hydrogen fluoride)  
 Hydrogen sulfide (Sulfur hydride)  
 Hydroxydimethylarsine oxide (Cacodylic acid)  
 Indeno(1,2,3-cd)pyrene (1,10-(1,2-phenylene)pyrene)  
 Iodomethane (Methyl iodide)  
 Iron dextran (Ferric dextran)  
 Isocyanic acid, methyl ester (Methyl isocyanate)  
 Isobutyl alcohol (1-Propanol, 2-methyl-)  
 Isosafrole (Benzene, 1,2-methylenedioxy-4-allyl-)  
 Kepone (Decachlorooctahydro-1,3,4-Methano-2H-cyclobuta[cd]pentalen-2-one)  
 Lasiocarpine (2-Butenoic acid, 2-methyl-, 7-[(2,3-dihydroxy-2-(1-methoxyethyl)-3-methyl-1-oxobutoxy)methyl]-2,3,5,7a-tetrahydro-1H-pyrrolizin-1-yl ester)  
 Lead and compounds, N.O.S.\*  
 Lead acetate (Acetic acid, lead salt)  
 Lead phosphate (Phosphoric acid, lead salt)  
 Lead subacetate (Lead, bis(acetato-O)tetrahydroxytri-)  
 Maleic anhydride (2,5-Furandione)  
 Maleic hydrazide (1,2-Dihydro-3,6-pyridazinedione)  
 Malononitrile (Propanedinitrile)  
 Melphalan (Alanine, 3-[p-bis(2-chloroethyl)amino]phenyl-, L-)  
 Mercury fulminate (Fulminic acid, mercury salt)  
 Mercury and compounds, N.O.S.\*  
 Methacrylonitrile (2-Propenenitrile, 2-methyl-)  
 Methanethiol (Thiomethanol)  
 Methapyrilene (Pyridine, 2-[(2-dimethylamino)ethyl]-2-thenylamino-)  
 Metholmyl (Acetimidic acid, N-[(methylcarbamoyl)oxy]thio-, methyl ester)  
 Methoxychlor (Ethane, 1,1,1-trichloro-2,2'-bis(p-methoxyphenyl)-)  
 2-Methylaziridine (1,2-Propylenimine)  
 3-Methylcholanthrene (Benz[fl]aceanthrylene, 1,2-dihydro-3-methyl-)  
 Methyl chlorocarbonate (Carbonochloridic acid, methyl ester)  
 4,4'-Methylenebis(2-chloroaniline) (Benzenamine, 4,4'-methylenebis-(2-chloro-))  
 Methyl ethyl ketone (MEK) (2-Butanone)  
 Methyl hydrazine (Hydrazine, methyl-)  
 2-Methylactonitrile (Propanenitrile, 2-hydroxy-2-methyl-)  
 Methyl methacrylate (2-Propenoic acid, 2-methyl-, methyl ester)  
 Methyl methanesulfonate (Methanesulfonic acid, methyl ester)  
 2-Methyl-2-(methylthio)propionaldehyde-o-(methylcarbonyl) oxime (Propanal, 2-methyl-2-(methylthio)-, O-[(methylamino)carbonyl]oxime)  
 N-Methyl-N'-nitro-N-nitrosoguanidine (Guanidine, N-nitroso-N-methyl-N'-nitro-)  
 Methyl parathion (O,O-dimethyl O-(4-nitrophenyl) phosphorothioate)  
 Methylthiouracil (4-1H-Pyrimidinone, 2,3-dihydro-6-methyl-2-thioxo-)  
 Mustard gas (Sulfide, bis(2-chloroethyl)-)  
 Naphthalene  
 1,4-Naphthoquinone (1,4-Naphthalenedione)  
 1-Naphthylamine (alpha-Naphthylamine)  
 2-Naphthylamine (beta-Naphthylamine)  
 1-Naphthyl-2-thiourea (Thiourea, 1-naphthalenyl-)  
 Nickel and compounds, N.O.S.\*  
 Nickel carbonyl (Nickel tetracarbonyl)  
 Nickel cyanide (Nickel (II) cyanide)

- Nicotine and salts (Pyridine, (S)-3-(1-methyl-2-pyrrolidinyl)-, and salts)  
 Nitric oxide (Nitrogen (II) oxide)  
 p-Nitroaniline (Benzenamine, 4-nitro-)  
 Nitrobenzine (Benzene, nitro-)  
 Nitrogen dioxide (Nitrogen (IV) oxide)  
 Nitrogen mustard and hydrochloride salt (Ethanamine, 2-chloro-, N-(2-chloroethyl)-N-methyl-, and hydrochloride salt)  
 Nitrogen mustard N-Oxide and hydrochloride salt (Ethanamine, 2-chloro-, N-(2-chloroethyl)-N-methyl-, and hydrochloride salt)  
 Nitroglycerine (1,2,3-Propanetriol, trinitrate)  
 4-Nitrophenol (Phenol, 4-nitro-)  
 4-Nitroquinoline-1-oxide (Quinoline, 4-nitro-1-oxide-)  
 Nitrosamine, N.O.S.\*  
 N-Nitrosodi-n-butylamine (1-Butanamine, N-butyl-N-nitroso-)  
 N-Nitrosodiethanolamine (Ethanol, 2,2'-nitrosoimino)bis-)  
 N-Nitrosodiethylamine (Ethanamine, N-ethyl-N-nitroso-)  
 N-Nitrosodimethylamine (Dimethylnitrosamine)  
 N-Nitroso-N-ethylurea (Carbamide, N-ethyl-N-nitroso-)  
 N-Nitrosomethylethylamine (Ethanamine, N-methyl-N-nitroso-)  
 N-Nitroso-N-methylurea (Carbamide, N-methyl-N-nitroso-)  
 N-Nitroso-N-methylurethane (Carbamic acid, methylnitroso-, ethyl ester)  
 N-Nitrosomethylvinylamine (Ethenamine, N-methyl-N-nitroso-)  
 N-Nitrosomorpholine (Morpholine, N-nitroso-)  
 N-Nitrosornicotine (Nornicotine, N-nitroso-)  
 N-Nitrosopiperidine (Pyridine, hexahydro-, N-nitroso-)  
 Nitrosopyrrolidine (Pyrrole, tetrahydro-, N-nitroso-)  
 N-Nitrososarcosine (Sarcosine, N-nitroso-)  
 5-Nitro-o-toluidine (Benzenamine, 2-methyl-5-nitro-)  
 Octamethylpyrophosphoramidate (Diphosphoramidate, octamethyl-)  
 Osmium tetroxide (Osmium (VIII) oxide)  
 7-Oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid (Endothal)  
 Paraldehyde (1,3,5-Trioxane, 2,4,6-trimethyl-)  
 Parathion (Phosphorothioic acid, O,O-diethyl O-(p-nitrophenyl) ester)  
 Pentachlorobenzene (Benzene, pentachloro-)  
 Pentachloroethane (Ethane, pentachloro-)  
 Pentachloronitrobenzene (PCNB) (Benzene, pentachloronitro-)  
 Pentachlorophenol (Phenol, pentachloro-)  
 Phenacetin (Acetamide, N-(4-ethoxyphenyl)-)  
 Phenol (Benzene, hydroxy-)  
 Phenylenediamine (Benzenediamine)  
 Phenylmercury acetate (Mercury, acetatophenyl-)  
 N-Phenylthiourea (Thiourea, phenyl-)  
 Phosgene (Carbonyl chloride)  
 Phosphine (Hydrogen phosphide)  
 Phosphorodithioic acid, O,O-diethyl S-[(ethylthio)methyl] ester (Phorate)  
 Phosphorothioic acid, O,O-dimethyl O-[p-((dimethylamino)sulfonyl)phenyl] ester (Famphur)  
 Phthalic acid esters, N.O.S.\* (Benzene, 1,2-dicarboxylic acid, esters, N.O.S.\*)  
 Phthalic anhydride (1,2-Benzenedicarboxylic acid anhydride)  
 2-Picoline (Pyridine, 2-methyl-)  
 Polychlorinated biphenyl, N.O.S.\*  
 Potassium cyanide  
 Potassium silver cyanide (Argentate(1-), dicyano-, potassium)  
 Pronamide (3,5-Dichloro-N-(1,1-dimethyl-2-propynyl)benzamide)  
 1,3-Propane sultone (1,2-Oxathiolane, 2,2-dioxide)  
 n-Propylamine (1-Propanamine)  
 Propylthiouracil (Undecamethylenediamine, N,N'-bis(2-chlorobenzyl)-, dihydrochloride)  
 2-Propyn-1-ol (Propargyl alcohol)  
 Pyridine  
 Reserpine (Yohimban-16-carboxylic acid, 11,17-dimethoxy-18-[(3,4,5-trimethoxybenzoyl)oxyl-, methyl ester)  
 Resorcinol (1,3-Benzenediol)  
 Saccharin and salts (1,2-Benzisothiazolin-3-one, 1,1-dioxide, and salts)  
 Safrole (Benzene, 1,2-methylenedioxy-4-allyl-)  
 Selenious acid (Selenium dioxide)  
 Selenium and compounds, N.O.S.\*  
 Selenium sulfide (Sulfur selenide)  
 Selenourea (Carbamimidoseleonic acid)  
 Silver and compounds, N.O.S.\*  
 Silver cyanide  
 Sodium cyanide  
 Streptozotocin (D-Glucopyranose, 2-deoxy-2-(3-methyl-3-nitrosoureido)-)  
 Strontium sulfide  
 Strychnine and salts (Strychnidin-10-one, and salts)  
 1,2,4,5-Tetrachlorobenzene (Benzene, 1,2,4,5-tetrachloro-)  
 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) (Dibenzo-p-dioxin, 2,3,7,8-tetrachloro-)  
 Tetrachloroethane, N.O.S.\* (Ethane, tetrachloro-, N.O.S.\*)  
 1,1,1,2-Tetrachloroethane (Ethane, 1,1,1,2-tetrachloro-)  
 1,1,2,2-Tetrachloroethane (Ethane, 1,1,2,2-tetrachloro-)  
 Tetrachloroethane (Ethene, 1,1,2,2-tetrachloro-)  
 Tetrachloromethane (Carbon tetrachloride)  
 2,3,4,6-Tetrachlorophenol (Phenol, 2,3,4,6-tetrachloro-)  
 Tetraethylthiopyrophosphate (Dithiopyrophosphoric acid, tetraethyl-ester)  
 Tetraethyl lead (Plumbane, tetraethyl-)  
 Tetraethylpyrophosphate (Pyrophosphoric acid, tetraethyl ester)  
 Tetranitromethane (Methane, tetranitro-)  
 Thallium and compounds, N.O.S.\*  
 Thallous oxide (Thallium (III) oxide)  
 Thallium (I) acetate (Acetic acid, thallium (I) salt)  
 Thallium (I) carbonate (Carbonic acid, thallium (I) salt)  
 Thallium (I) chloride  
 Thallium (I) nitrate (Nitric acid, thallium (I) salt)  
 Thallium selenite  
 Thallium (I) sulfate (Sulfuric acid, thallium (I) salt)  
 Thioacetamide (Ethanethioamide)  
 Thiosemicarbazide (Hydrazinecarbothioamide)  
 Thiourea (Carbamide thio-)  
 Thiuram (Bis(dimethylthiocarbamoyl) disulfide)  
 Toluene (Benzene, methyl-)  
 Toluenediamine (Diaminotoluene)  
 o-Toluidine hydrochloride (Benzenamine, 2-methyl-, hydrochloride)  
 Toluene diisocyanate (Benzene, 1,3-diisocyanatomethyl-)  
 Toxaphene (Camphene, octachloro-)  
 Tribromomethane (Bromoform)  
 1,2,4-Trichlorobenzene (Benzene, 1,2,4-trichloro-)  
 1,1,1-Trichloroethane (Methyl chloroform)  
 1,1,2-Trichloroethane (Ethane, 1,1,2-trichloro-)  
 Trichloroethene (Trichloroethylene)  
 Trichloromethanethiol (Methanethiol, trichloro-)  
 Trichloromonofluoromethane (Methane, trichlorofluoro-)  
 2,4,5-Trichlorophenol (Phenol, 2,4,5-trichloro-)  
 2,4,6-Trichlorophenol (Phenol, 2,4,6-trichloro-)  
 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) (Acetic acid, 2,4,5-trichlorophenoxy-)

2,4,5-Trichlorophenoxypropionic acid (2,4,5-TP) (Silvex) (Propionic acid, 2-(2,4,5-trichlorophenoxy)-)  
Trichloropropane, N.O.S.\* (Propane, trichloro-, N.O.S.\*)  
1,2,3-Trichloropropane (Propane, 1,2,3-trichloro-)  
O,O,O-Triethyl phosphorothioate (Phosphorothioic acid, O,O,O-triethyl ester)  
sym-Trinitrobenzene (Benzene, 1,3,5-trinitro-)  
Tris(1-aziridiny) phosphine sulfide (Phosphine sulfide, tris(1-aziridiny)-)  
Tris(2,3-dibromopropyl) phosphate (1-Propanol, 2,3-dibromo-, phosphate)  
Trypan blue (2,7-Naphthalenedisulfonic acid, 3,3'-[(3,3'-dimethyl(1,1'-biphenyl)-4,4'-diyl)bis(azo)]bis(5-amino-4-hydroxy-, tetrasodium salt)  
Uracil mustard (Uracil 5-[bis(2-chloroethyl)amino]-)  
Vanadic acid, ammonium salt (ammonium vanadate)  
Vanadium pentoxide (Vanadium (V) oxide)  
Vinyl chloride (Ethene, chloro-)  
Zinc cyanide  
Zinc phosphide

hexachlorodibenzo-*p*-dioxins  
hexachlorodibenzofurans  
pentachlorodibenzo-*p*-dioxins  
pentachlorodibenzofurans  
tetrachlorodibenzo-*p*-dioxins  
tetrachlorodibenzofurans

