



Project Summary

Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report

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Multimedia emissions from 39 source categories of conventional stationary combustion systems are characterized in this study. In the assessment process, existing emissions data were first examined to determine the adequacy of the data base. This was followed by the conduct of a measurement program to fill identified data gaps. Emissions data obtained from the sampling and analysis program were combined with existing emissions data to provide estimates of emission levels, and to define the need for additional data.

The results of this study indicate that conventional stationary combustion systems contribute significantly to the nationwide emissions burden. Flue gas emissions of NO_x , SO_2 , and particulate matter from the 39 source categories studied account for approximately 86, 66, and 36 percent, respectively, of the emissions of these pollutants from all stationary sources. Additionally, flue gas emissions of sulfates and several trace elements from coal- and oil-fired combustion sources also require further attention. POM compounds in flue gas emissions are mostly naphthalene, phenanthrene, and pyrene. However, dibenz(a,h)anthracene and possibly benzo(a)pyrene, both active carcinogens, were detected at a limited number of coal-fired sites.

Also, dibenz(a,h)anthracene, and possibly benzo(a)pyrene and benzo(g,h,i)perylene, another active carcinogen, were detected at one coal- and one wood-fired underfeed stoker tested. The possible presence of benzo(a)pyrene in significant amounts was indicated in the emissions of two other wood-fired boilers.

A second major source of air emissions in steam electric plants is vapors and drifts from cooling towers. Air emissions of chlorine, magnesium, phosphorus, and sulfates from mechanical draft cooling towers were found to be comparable to flue gas emissions of these pollutants from oil-fired utility boilers.

Wastewater streams are generated from several operations in steam electric plants, and in industrial and commercial/institutional facilities but to a much lesser extent. Overall, concentrations of iron, magnesium, manganese, nickel, and phosphorus are at levels that may be of environmental concern. Average organic levels ranged from 0.01 mg/l for ash pond effluents to 6.0 mg/l for boiler blowdown. Also, no POM was detected in wastewater streams.

Data on coal fly ash and bottom ash show that from 11 to 16 trace elements are present at potentially harmful levels. The only POMs de-

tected, however, were naphthalene, alkyl naphthalenes, and other relatively nontoxic compounds.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

In response to the need for a comprehensive characterization of pollutants from stationary conventional combustion processes, EPA's Industrial Environmental Research Laboratory at Research Triangle Park (IERL-RTP) in North Carolina established the Conventional Combustion Environmental Assessment (CCEA) Program as the primary vehicle for filling identified data gaps. The component project under which this study was performed is known as the Emissions Assessment of Conventional Combustion Systems (EACCS) project, whose objectives are the:

- Compilation and evaluation of all available emissions data on pollutants from selected stationary conventional combustion processes.
- Acquisition of needed new emissions data from field tests.
- Characterization of air emissions, wastewater effluents, and solid wastes generated by selected stationary conventional combustion processes, utilizing combined data from existing sources and field tests.
- Determination of additional data needs, including specific areas of data uncertainty.

The combustion source types assessed were selected because of their relevance to emissions and because they are among the largest, potentially largest, and most numerous (in use) of existing combustion source types. As shown in Table 1, 39 source types were selected for study. Selected source types were classified into five principal categories. The results of emissions assessment for these five combustion source categories are detailed in the following group/category reports:

Volume I, Gas- and Oil-Fired Residential Heating Sources (EPA-600/7-79-029b; NTIS PB 298494).

Volume II, Internal Combustion Sources (EPA-600/7-79-029c; NTIS PB 296390).

Volume III, External Combustion Sources for Electricity Generation (EPA-600/7-81-003a; NTIS PB 81-145195).

Volume IV, Commercial/Institutional Combustion Sources (EPA-600/7-81-003b; NTIS PB 81-145187).

Volume V, Industrial Combustion Sources (EPA-600/7-81-003c; NTIS PB 81-225559).

The highlights of these group/category reports are documented in this report summary.

Assessment Methodology

The assessment method employed in the project involved a critical examination of existing emissions data, followed by a measurement program to fill data gaps based on a phased sampling and

analysis strategy. Data acquired as result of the measurement program, combination with the existing data were further evaluated. Data inadequacies identified at the completion of the project are discussed with respect to the need for additional study.

Specifically, the phased approach environmental assessment provides comprehensive emissions information on all process waste streams in a cost-effective manner. To achieve this goal, two distinct samplings and analyses are employed. Level I utilizes semiquantitative (\pm a factor of 3) techniques (sample collection and laboratory air field analysis: 1) to provide preliminary emissions data for waste streams and pollutants not adequately characterized; 2) to identify potential problem areas; and 3) to prioritize waste streams and pollutants in those streams for further

Table 1. Combustion Systems Considered in the Study

Combustion Source Type	User Sector			
	Electricity Generation	Industrial	Commercial/Institutional	Residential
<u>External Combustion</u>				
<u>Coal</u>				
<u>Bituminous</u>				
Pulverized dry	X	X	X	
Pulverized wet	X	X		
Cyclone	X			
All stokers	X	X	X	
<u>Anthracite</u>				
Pulverized dry	X			
All stokers	X		X	
<u>Lignite</u>				
Pulverized dry	X			
Cyclone	X			
All stokers	X			
<u>Petroleum</u>				
<u>Residual oil</u>				
Tangential firing	X			
All other	X	X	X	
<u>Distillate oil</u>				
Tangential firing				
All other		X	X	X
<u>Gas</u>				
Tangential firing	X			
All other	X	X	X	X
<u>Wood</u>				
Stoker		X	X	
<u>Internal Combustion</u>				
<u>Distillate Oil</u>				
Gas turbine	X	X		
Reciprocating engine	X	X	X	
<u>Gas</u>				
Gas turbine	X	X		
Reciprocating engine	X	X	X	

more quantitative testing. Using the information from Level I, available resources can be directed toward Level II testing which involves specific quantitative analysis of components of those streams that contain significant pollutant levels. The data developed at Level II are used to identify control technology needs and to further define environmental hazards associated with emissions.

Existing Emissions Data Base

A major task in the project was the identification of gaps and inadequacies in the data base. Decisions as to the adequacy of the data base were made using criteria developed by considering both the reliability and variability of the data. Estimated environmental risks associated with the emission of each pollutant were also considered in determining the need for, and extent of, the sampling and analysis program.

Gas- and Oil-Fired Residential Heating Sources

The sources of emissions data for residential gas- and oil-fired systems are limited to early data used to generate EPA emission factors and more recent data developed by EPA contractors for criteria pollutants. For gas-fired systems, the data base for SO₂, NO_x, total hydrocarbons, and CO emissions is adequate. However, the data base for particulate and organic emissions is inadequate. For oil-fired systems, the emissions data base for particulate, SO₂, NO_x, HC, and CO is adequate, but inadequate for SO₃, particulate sulfate, trace element, and organic emissions.

Internal Combustion Sources

The evaluation of emissions data for electricity generation and industrial internal combustion sources indicates that the emissions data base is adequate for gas-fueled turbines and reciprocating engines. For distillate-oil-fueled gas turbines, the existing data base for NO_x, total hydrocarbons, CO, particulate, SO₂, and SO₃ emissions is adequate. However, the data base for trace elements and specific organic emissions is inadequate. For distillate-oil-fueled reciprocating engines, the data base for NO_x, total hydrocarbons, CO, and SO₂ emissions is adequate. The data base for particulates, SO₃, trace elements, and specific organic emissions was found to be inadequate.

External Combustion Sources for Electricity Generation

For flue gas emissions, the status of the data base can be summarized as follows:

- The data base for criteria pollutants is generally adequate.
- For SO₃ emissions, the data base is adequate for bituminous-coal-fired boilers, residual-oil-fired boilers, and gas-fired boilers, and inadequate for lignite-fired boilers. For emissions of primary sulfates, the data base is adequate for pulverized bituminous dry- and wet-bottom boilers, residual-oil-fired boilers, and gas-fired boilers, and inadequate for other combustion source categories.
- For emissions of particulates by size fraction and trace elements, the data base is adequate for gas-fired boilers and inadequate for all other combustion source categories.
- For emissions of specific organics and polycyclic organic matter (POM), the data base is inadequate for all combustion source categories.

Two other sources of air emissions of environmental concern are cooling tower emissions and emissions from coal storage piles. The data bases characterizing air emissions from these two sources are inadequate.

For wastewater effluents from external combustion sources for electricity generation, the data base is adequate for wastewater from water treatment processes, and inadequate for all other streams.

The evaluation of emissions data for solid wastes indicated the inadequacy of the organic data base for coal fly ash and bottom ash, and the inadequacy of the inorganic and organic data bases for FGD sludges. On the other hand, the inorganic data base for coal ash is considered to be adequate because of the adequate characterization of the inorganic content of coal. Similarly, the data base for water treatment wastes is considered to be adequate, because the waste constituents are inorganic and can be estimated from the raw water constituents and the treatment method used.

Commercial/Institutional Combustion Sources

Evaluation of emissions data indicates that the data base for gas- and oil-fired

external combustion sources, although limited, is adequate for NO_x, total hydrocarbons, CO, particulates, and SO₂. However, the data base for specific organic emissions for these sources is inadequate, and, for the oil-fired sources, the data base for SO₃ and trace elements is inadequate. Emissions data from solid-fuel-fired sources are generally inadequate for all pollutants.

In the case of oil-fired internal combustion sources, data are inadequate for SO₃, trace element, and specific organic emissions. Data for gas-fired reciprocating engines are adequate; however, one unit was tested in this program to confirm data adequacy.

Industrial Combustion Sources

The status of the data base can be summarized as follows:

- The data base for criteria pollutants is adequate, except for emissions from wood-fired combustion sources.
- The data base for particulate sulfate and sulfuric acid emissions is adequate only for gas-fired sources.
- The data base for specific organics is inadequate for all industrial source categories.

The Source Measurement Program

Because of the deficiencies in the emissions data base, source tests were conducted at a selected number of sites for each of the five principal combustion source categories.

Gas- and Oil-Fired Residential Heating Sources

Five gas- and five oil-fired residential sources were initially selected for testing. Upon review of the results obtained from the testing of the 10 sites, 1 gas-fired and 2 oil-fired systems were subsequently tested to study the effect of cycle mode on organic emissions. Level II analyses for SO₂, SO₃, and particulate sulfate were also conducted at the two oil-fired sites.

Internal Combustion Sources

Eleven internal combustion sites were selected for testing to better characterize the emissions associated with these sources. The sites tested included one gas-fueled gas turbine, five distillate-oil-fueled gas turbines, and five distillate-oil-fueled reciprocating engines (diesel engines). A gas-

fueled gas turbine site was included to ensure that previously unidentified pollutants are not being emitted in environmentally unacceptable quantities.

Test results from the first phase were evaluated to determine the need for and type of additional sampling and analysis. These evaluations led to the recommendation of additional tests to determine SO_3 and organic emissions from electricity-generation distillate-oil reciprocating engines. Level II tests were subsequently conducted at three of the diesel engine sites previously tested.

External Combustion Sources for Electricity Generation

Forty-six sites were selected for sampling and analysis of flue gas emissions. These 46 sites include: 3 pulverized dry bottom, 7 pulverized wet bottom, 6 cyclone, and 3 stoker bituminous-coal-fired boilers; 3 pulverized dry bottom, 2 cyclone, and 2 spreader-stoker lignite-fired boilers; 4 tangentially fired and 8 wall-fired boilers fueled with residual oil; and 3 tangentially fired and 5 wall-fired boilers fueled with natural gas.

At a selected number of these sites, wastewater streams and solid wastes were also sampled and analyzed. Wastewater streams sampled and analyzed included cooling tower blowdown, once-through cooling water, boiler blowdown, fly ash pond overflow, bottom ash pond overflow, and combined ash pond overflow. Intermittent wastewater streams such as chemical cleaning wastes and coal pile runoff were not sampled. Solid waste streams sampled and analyzed included fly ash, bottom ash, and FGD scrubber sludge.

In addition to the modified Level I tests, comprehensive Level II tests were also conducted for a bituminous-coal-fired cyclone boiler, two bituminous-coal-fired pulverized dry bottom boilers, and an oil-fired boiler. All these coal-fired boilers were equipped with flue gas desulfurization (FGD) systems. The oil-fired boiler tested used off-stoichiometric firing and flue gas recirculation for NO_x control.

Because direct measurements of chemical constituents present in cooling tower exhausts have not been made (except for a limited number of trace elements), six cooling towers were selected for testing. Cooling tower streams sampled and analyzed included air emissions (as evaporation and drift) and blowdown.

Commercial/Institutional Combustion Sources

Twenty-two external combustion systems were tested. These included: five gas-fired, three distillate-oil-fired, five residual-oil-fired, three anthracite stokers, three bituminous stokers, two bituminous pulverized dry units, and one wood-fired stoker. Four oil-fired, one gas-fired, and one dual-fired internal combustion reciprocating engines were also tested.

Industrial Combustion Sources

Twenty-two external combustion systems were tested. These include: 10 gas-fired, 3 distillate oil-fired, and 5 residual-oil-fired boilers; 3 bituminous pulverized wet bottom and 2 bituminous pulverized dry bottom units; 3 bituminous stokers; and 5 wood-fired stokers.

Sampling and Analysis Methodology

Level I Field Testing

The Source Assessment Sampling System (SASS) train, developed by EPA, was used to collect both vapor and particulate emissions in quantities sufficient for the wide range of analyses needed to adequately characterize emissions from external combustion sources. Briefly, the SASS train consists of a conventional heated probe, three cyclones, and a filter in a heated oven which collect four particulate size fractions ($>10 \mu m$, $3-10 \mu m$, $1-3 \mu m$, $<1 \mu m$); a gas conditioning system; an XAD-2 polymer adsorbent trap to collect gaseous organics and some inorganics; and impingers to collect the remaining gaseous inorganics and trace elements. The train is run until at least $30 m^3$ of gas has been collected.

In addition to using the SASS train for stack gas sampling, other equipment was used to collect components that could not be analyzed from the train samples. A gas chromatograph (GC) with flame ionization detection was used in the field to analyze hydrocarbons in the boiling point range of -160° to $90^\circ C$ (reported as $C_1 - C_6$) collected in gas sampling bags. Additionally, these samples were analyzed for CO , CO_2 , O_2 , and SO_2 by GC using a thermal conductivity detector.

Water samples were generally taken by either tap or dipper sampling. Tap samples, obtained on contained liquids in motion or static liquids in tanks or

drums, was generally applicable to cooling tower or boiler blowdown. The method involved fitting the valve or stopcock used for sample removal with a length of precleaned Teflon tubing long enough to reach the bottom of the container. Dipper sampling, applicable to sampling ponds or open discharge streams, was used to acquire ash pond discharge samples. The method involved a dipper with a flared bowl and attached handle, long enough to reach discharge areas. After sample recovery, water analyses using the Hach Kit were performed in the field to determine pH, conductivity, total suspended solid (TSS), hardness, alkalinity or acidity, ammonia nitrogen, cyanide, nitrate nitrogen, phosphate, sulfite, and sulfate.

For solids sampling, the fractional shovel grab samples procedure was used unless the plant had an automatic sampling system. The concept of fractional shoveling involves the acquisition of a time-integrated grab sample representative of overall process input or output during a given run time period. A standard, square-edged, 12-in. (30.5 cm) wide shovel was used. For streams entering or exiting a process operation a full cross-stream cut sample was taken from the belt hourly. Each hourly shovel sample was added to a pile to eventually form a run time period composite. At the conclusion of the run this pile was coned and quartered to form a final representative sample weighing from 2.3 to 4.5 kg. When plants were equipped with automatic samplers to remove representative cross sections of a stream while automatically forming a homogeneous composite, these were used in preference to the shovel technique.

In addition to the above sampling methods, air emissions from cooling towers were sampled, using a modified EPA Method 5 train without the filter assembly.

Modified Level I Laboratory Analysis

The basic Level I schematic, outlining flow of samples and analysis plans for particulate and gaseous emissions, is depicted in Figure 1. The corresponding schematic for solid, slurry, and liquid samples is presented in Figure 2. These schematics provide a general idea of the apportionment of samples for analysis. For example, Figure 1 shows that the probe-and-cyclone-rinses combination will only be subjected to inorganic

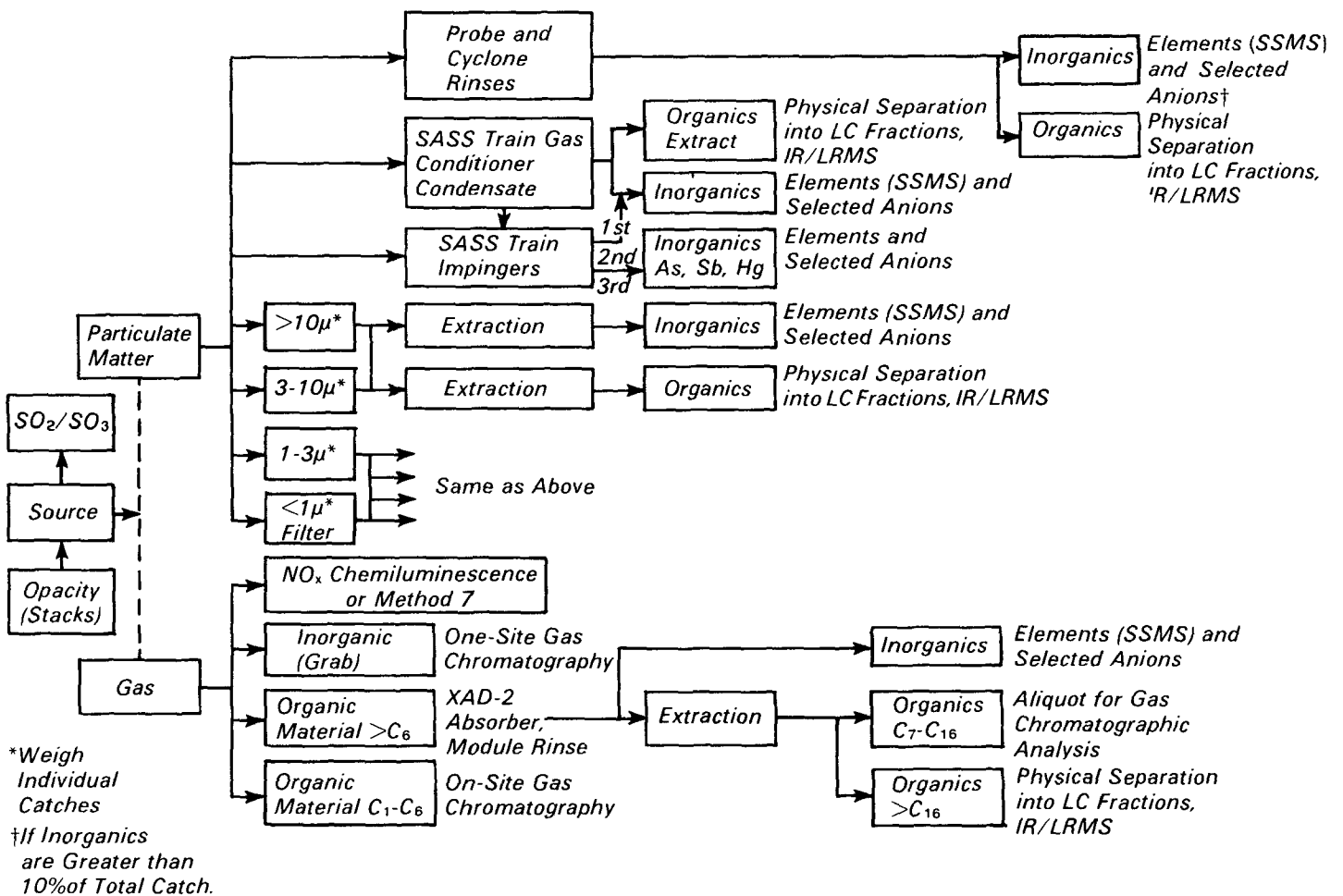


Figure 1. Basic level 1 sampling flow and analytical plan for particulates and gases.

analysis if the dried sample exceeds 10 percent of the total cyclone-and-filter-sample weight. Details of the sample handling, transfer, and analysis procedures are in the *IERL-RTP Procedures Manual: Level I Environmental Assessment, EPA-600/2-76-160a** (NTIS PB 257850). A brief description of inorganic and organic analyses performed and deviations from the basic Level I procedure follows.

*Although superseded by EPA-600/7-78-201 (NTIS PB 293795), the earlier procedures were used in this study

Inorganic Analyses

Level I analysis was used for all inorganic analyses. It was designed to identify all elemental species in the SASS train fractions and to provide semiquantitative data on the elemental distributions and total emission factors. The primary tool for Level I inorganic analysis is Spark Source Mass Spec-

trometry (SSMS). SSMS data were supplemented with Atomic Absorption Spectrometry (AAS) data for mercury, arsenic, and antimony, and with specific ion electrode determinations for chlorides.

The following SASS train fractions were analyzed for elemental composition: 1) the particulate filter, 2) the XAD-2 sorbent, and 3) a composite sample containing portions of the XAD-2 module condensate and HNO₃ rinse, and the first impinger solution. Analyses of the carbon, hydrogen, nitrogen, oxygen, and trace element contents and heating values of the fuel were also performed for the coal- and oil-fired sources.

Organic Analyses

Level I organic analyses provide data on volatile (boiling point range of 90 to 300°C, corresponding to the boiling points of C₇ - C₁₆ n-alkanes and reported

as C₇ - C₁₆) and non-volatile organic compounds (boiling point >300°C, corresponding to the boiling points of >C₁₆ n-alkanes and reported as >C₁₆) to supplement data for gaseous organics (boiling point range of -160 to 90°C, corresponding to the boiling points of C₁ - C₆ n-alkanes and reported as C₁ - C₆) measured in the field. Organics in the XAD-2 module condensate trap and XAD-2 resin were recovered by methylene chloride extraction. SASS train components including the tubing were carefully cleaned with methylene chloride or methylene chloride/methanol solvent to recover all organics collected in the SASS train.

Because all samples are too dilute to detect organic compounds by the majority of instrumental techniques employed, the first step in the analysis was to concentrate the sample fractions from 1000 to 10 ml in a Kuderna-Danish apparatus in which rinse solvent is

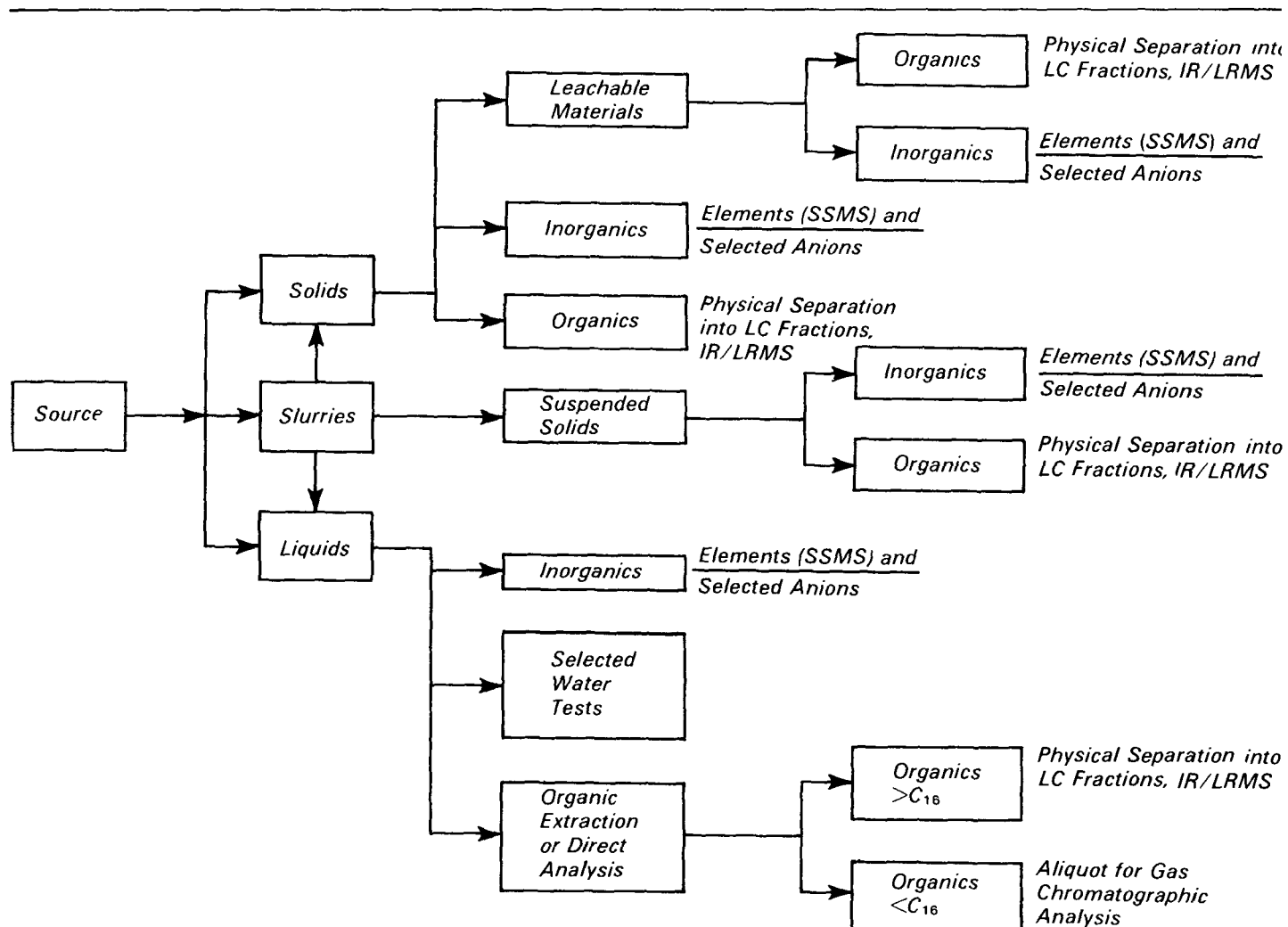


Figure 2. Basic level 1 sampling flow and analytical scheme for solids, slurries, and liquids.

evaporated while the organics of interest are retained.* Kuderna-Danish concentrates were then evaluated by gas chromatography (GC), infrared spectrometry (IR), liquid chromatography (LC) and gravimetric analysis, low resolution mass spectrometry (LRMS), and sequential gas chromatography/mass spectrometry (GC/MS)†. The extent of the organic analysis is determined by the stack gas concentrations found for total organics (volatile and non-volatile). If the total organics indicate a stack gas concentration below $500 \mu\text{g}/\text{m}^3$, a liquid concentration below $0.1 \text{ mg}/\text{l}$, or a solid concentration below $1 \text{ mg}/\text{kg}$, further analysis

*Kuderna-Danish is a glass apparatus for evaporating bulk amounts of solvents.

†The major modification in the Level I sampling and analysis procedure was the addition of GC/MS analysis for POM.

is not conducted. If the concentrations are above these levels, a class fractionation by liquid chromatography is conducted followed by GC and IR analyses. Additionally, if the concentrations in a LC fraction are above these levels, LRMS is conducted for that particular LC fraction.

Level II Sampling and Analysis

In addition to the modified Level I tests, Level II tests were also conducted at a number of sites. Level II sampling and analysis techniques used for these sites included:

- Continuous monitoring of NO_x emissions by chemiluminescent instrumentation.
- Continuous monitoring of SO_2 emissions by pulsed fluorescent analyzer.

- Determination of sulfate emissions by the Goksoyr-Ross Controlled Condensation System.
- Determination of particle size distribution by Polarized Light Microscopy (PLM) and MRI cascade impactor.
- Determination of trace element concentrations by Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma Optical Emission Spectroscopy (ICP).
- Identification of inorganic compounds from specific infrared band correlations by Fourier Transform IR (FTIR).
- Identification of crystalline material in solid samples by X-ray Diffraction (XRD).
- Determination of the surface and subsurface sulfur concentrations

and oxidation state of bulk samples by Electron Spectroscopy for Chemical Analysis (ESCA).

- Determination of the surface and subsurface composition of bulk samples by Secondary Ion Mass Spectrometry (SIMS).
- Determination of elemental composition of single particles by Scanning Electron Microscope with Energy Dispersive X-ray Fluorescence (SEM-EDX).
- Identification and quantification of non-POM organic compounds by GC/MS.

Conclusions

The results of the field measurement program, along with supplementary values from the data base, were evaluated in terms of data adequacy and by using the concept of severity factors. Two types of severity factors, ambient and discharge, were used in data evaluation. For air emissions, the ambient severity factor, defined as the ratio of the calculated maximum ground level concentration of a pollutant species to an ambient air quality level or hazard factor, was used. The hazard factor for noncriteria pollutants is a reduced threshold limit value (TLV); while for criteria pollutants, it is the ambient air quality standard. The TLV is reduced by a factor of 300 (24/8 x 100) to account for length of exposure and an added safety factor due to the higher susceptibility of the general population to exposure effects. An ambient severity factor of greater than 0.05 indicates a potential problem requiring further attention. The "greater than 0.05" criterion reflects an uncertainty factor of 20 in the calculation of ambient severity, because of potential errors introduced in the application of the dispersion model, and in Level I sampling and analysis. For residential sources, a modified ambient severity factor based on multiple sources was used. Maximum ground level concentrations for multiple sources were determined using a dispersion model for an array of 1000 sources and a grid of houses 80 x 80 m.

For wastewater effluents and solid wastes, discharge severities were used in data evaluation. Discharge severity is the ratio of discharge concentration to the health-based water or solid Discharge Multimedia Environmental Goal (DMEG). A discharge severity greater than 1.0 indicates a potential hazard

requiring further attention. The "greater than 1.0" criterion, instead of the "greater than 0.05" criterion for ambient severity, was used because calculation of discharge severities was based on conservative DMEG values. Also, the uncertainty in the calculated values only involved potential sampling and analysis errors. The error due to the application of dispersion models was no longer a component.

Flue Gas Emissions

The conventional stationary combustion source categories investigated in this study contribute significantly to the nationwide emissions burden. As shown in Table 2, flue gas emissions of NO_x, SO₂, particulate matter, CO, and total hydrocarbons from the 39 source categories studied account for approximately 86, 66, 36, 10, and 5 percent, respectively, of the emissions of these pollutants from all stationary sources.

From an environmental standpoint, emissions of NO_x, SO₂, and particulate matter are of particular concern. Ambient severity factors for NO_x emissions far exceed 0.05 for internal combustion sources, utility boilers, industrial boilers, and coal-fired commercial/institutional boilers. Additionally, ambient severity factors for emissions of SO₂ and particulate matter far exceed 0.05 for all bituminous-coal- and lignite-fired boilers. Emissions of SO₂ are also considered to be environmentally significant for all residual-oil-fired boilers.

Emissions of total hydrocarbons are considered to be a lesser problem. Ambient severity factors for emissions of total hydrocarbons exceed 0.05 only for large bituminous-coal-, lignite-, and residual-oil-fired utility boilers, industrial and commercial/institutional coal-fired and wood-fired stokers, and distillate-oil and gas reciprocating engines.

Emissions of CO are not an environmental concern: their ambient severity factors are all well below 0.05.

Aside from the criteria pollutants, flue gas emissions of SO₃ (in the form of sulfuric acid vapor and aerosol) from several combustion source categories require further attention. These combustion source categories include: oil-fired residential sources, electricity generation and industrial oil-fueled internal combustion sources, bituminous-coal- and residual-oil-fired utility boilers, bituminous-coal-fired commercial/institutional boilers, and bituminous-coal- and residual-oil-fired industrial boilers. Ambient severity factors for SO₃ emissions from these sources range from 0.05 to 7.4. For bituminous-coal- and lignite-fired boilers, emissions of particulate sulfate are also associated with ambient severity factors in excess of 0.05 and merit special concern.

Of the trace elements present in bituminous coal, flue gas emissions of aluminum, beryllium, calcium, chlorine, cobalt, chromium, fluorine, iron, lead, lithium, nickel, phosphorus, and silicon

Table 2. Contribution of Conventional Stationary Combustion Systems to Nationwide Emissions Burden

Combustion Category	Emission Contribution as Percentage of All Stationary Sources				
	NO _x	SO ₂	Particulates	Hydrocarbons	CO
Gas- and Oil-fired Residential Heating Sources	2.5	0.9	0.2	0.2	0.5
Internal Combustion Sources	18	0.07	0.1	3.7	2.7
External Combustion Sources for Electricity Generation	50	57	25	0.6	4.3
Commercial/Institutional Combustion Sources	5.0	3.0	1.7	0.3	0.5
Industrial External Combustion Sources	10	5.7	9.0	0.4	1.7
TOTAL	86	66	36	5	10

from most coal-fired boilers are of environmental significance. For residual-oil-fired boilers, flue gas emissions of beryllium, chlorine, chromium, copper, lead, magnesium, nickel, phosphorus, and vanadium are of principal concern. Elements with ambient severity factors in excess of 0.05 also include chromium, nickel, phosphorus, and vanadium from distillate-oil-fired industrial boilers, nickel from distillate-oil-fired commercial/institutional boilers, barium, calcium, potassium, and phosphorus from wood-fired boilers, and copper, nickel, and phosphorus from oil-fueled internal combustion sources.

Analysis of organic emissions indicated that the principal constituents of flue gas are: saturated straight-chain and branched hydrocarbons and substituted benzenes from oil-fueled internal combustion sources; glycols, ethers, ketones, and saturated and aliphatic hydrocarbons from utility boilers; aliphatic and aromatic hydrocarbons, esters, ketones, and carboxylic acids from commercial/institutional sources; and esters, ethers, glycols, and aliphatic and aromatic hydrocarbons from industrial boilers. The most prevalent constituents are generally associated with DMEG values in the 10 to 1000 mg/m³ range. Ambient severity factors for these organic compounds (excluding POM) are all well below 0.05 and probably not of concern with respect to human health. POMs emitted at the highest concentrations in flue gas streams include naphthalene, phenanthrene, pyrene, fluoranthene, and chrysene from bituminous-coal-fired sources. Dibenz(a,h)anthracene and possibly benzo(a)pyrene and benzo(g,h,i)perylene, all active carcinogens, were detected at a limited number of sites. POM emissions from wood-fired boilers were found to be significantly higher than those from coal-fired boilers. Dibenz(a,h)anthracene and also possibly benzo(a)pyrene and benzo(g,h,i)perylene were detected at some of the sites tested. The only POMs identified in flue gas emissions from lignite-fired sources were biphenyl and trimethylpropenyl naphthalene. Carcinogenic POMs were not detected. For residual-oil-fired sources, POMs emitted at the highest concentrations in flue gas streams are naphthalene and biphenyl. Again, carcinogenic POMs were not detected. No POM was detected in flue gas streams from gas-fired utility boiler sites.

Air Emissions from Cooling Towers

Two potential environmental problems associated with the air emissions from cooling towers have been identified. First, air emissions of chlorine, magnesium, and phosphorus from mechanical draft cooling towers with high drift rates are comparable to flue gas emissions of these elements from residual-oil-fired utility boilers and are of environmental significance. Second, sulfate emissions from mechanical draft cooling towers employing sulfuric acid as an additive, and with design drift losses in the 0.1 to 0.2 percent range, are of the same magnitude as sulfate emissions from coal- and oil-fired utility boilers.

Wastewater Discharges

The major sources of wastewater discharges from external combustion sources for electricity generation are: once-through cooling water, blowdown from recirculating cooling systems, wastes from water treatment processes, chemical cleaning wastes, and coal pile runoff. Discharges from once-through cooling system amount to 7,780,000 l/sec and account for approximately 99.8 percent of the total wastewater from conventional utility power plants. Of the remaining sources, blowdown from recirculating cooling systems is the largest contributor to wastewater discharge.

From an environmental standpoint, the pollutants of most concern in wastewater effluents from conventional utility power plants are iron, magnesium, manganese, nickel, and phosphorus. The average organic levels in the ash pond effluents sampled were less than 0.1 mg/l. Average organic levels in the cooling tower blowdown and boiler blowdown sampled were 1.5 and 6.0 mg/l, respectively. POMs were not found above the detection limit of 2 µg/l.

Based on discharge severities, the once-through cooling tower and ash pond overflow streams appear to be of less environmental significance than the other wastewater streams from conventional fossil-fueled steam electric plants. Total pollutant loading from wastewater streams will, however, depend on individual discharge flow rates.

Industrial and commercial/institutional boilers are smaller contributors to wastewater discharges when compared with electricity generation sources.

Further, characteristics of wastewater discharges from these sources would be similar to those from electricity generation sources.

Solid Wastes

Solid waste streams generated at conventional utility power plants consist primarily of coal ash and sludge from FGD systems. In 1978, total ash production was 63.6 Tg and total FGD sludge production was 2.1 Tg (ash-free). Ash production from industrial and commercial/institutional sources is proportionally less and FGD sludge production from these sources is negligible.

Leaching of trace elements from coal ash may result in environmental contamination. Concentrations of 11 trace elements in bituminous coal and lignite ash exceed their health-based solid DMEG values. The pollutants of most concern are aluminum, arsenic, calcium, chromium, iron, manganese, nickel, potassium, and silicon.

Recommendations

Because of inadequacies in the database that characterizes emissions from conventional stationary combustion systems, it is recommended that additional studies be conducted to provide the following key data needs.

Flue Gas Emissions

- There is a lack of emissions data for pulverized dry-bottom boilers firing Texas lignite. This is a serious data deficiency because approximately 16,000 MW of added generating capacity is planned for this source category in the 1978-1985 period.
- Size distribution data for flue gas emissions of particulates are inadequate for bituminous-coal-, lignite-, and residual-oil-fired boilers.
- The data bases for particulate and sulfate emissions from bituminous coal- and lignite-fired sources are inadequate. Also, SO₃ emissions data for lignite-fired sources are presently unavailable.
- For bituminous-coal-fired boilers equipped with wet scrubbers or mechanical precipitators, the data bases characterizing flue gas emissions of trace elements are inadequate. Data for flue gas emissions of trace elements from lignite-fired boilers are generally

not available. Analysis of the data acquired in this program indicated the need for additional characterization studies.

- Although current data indicated that flue gas emissions of specific organics (excluding POM) are probably not of concern with respect to human health, more detailed Level II organic analysis would be required to conclusively determine the significance of organic emissions.
- Emissions of POM from bituminous coal- and wood-fired sources will require further characterization, with special emphasis on the positive identification and quantification of carcinogenic compounds such as dibenz(a,h)anthracene, benzo(a)pyrene, and benzo(g,h,i)perylene.

Wastewater Discharges

- The data bases characterizing cooling tower blowdown, ash pond overflow, chemical cleaning wastes, wet scrubber wastewater, and coal pile runoff are inadequate. The present study has been instrumental in applying Level I techni-

ques to identification of wastewater constituents which pose potential environmental problems. Since potential problems were detected by Level I techniques, further studies using Level II techniques will be required to adequately characterize wastewater effluents from utility boilers.

Solid Wastes

- The data base characterizing flue gas emissions of POM from bituminous-coal-fired sources is adequate except for dibenz(a,h)anthracene and benzo(a)pyrene. Emissions of these specific POMs will require further characterization.

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The complete report, entitled "Emissions Assessment of Conventional Stationary Combustion Systems: Summary Report," (Order No. PB 82-109 414; Cost: \$9.50, subject to change) will be available only from.

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