California Environmental Protection Agency

Air Resources Board

Technical Support Document

Proposed Identification of Inorganic Lead as a Toxic Air Contaminant

Pb

Part A

Exposure Assessment

Stationary Source Division
Release Date: March 1997

TECHNICAL SUPPORT DOCUMENT

PUBLIC EXPOSURE TO SOURCES AND EMISSIONS OF INORGANIC LEAD IN CALIFORNIA

PART A

EXPOSURE ASSESSMENT

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In accordance with California Health and Safety Code sections 39660-39662, the Air Resources Board staff is considering the identification of inorganic lead as a toxic air contaminant. The draft report, Proposed Identification of Inorganic Lead as a Toxic Air Contaminant, was written for the purpose of a public comment period, and workshops which were conducted on April 21, 1993, May 20, 1994, and March 7, 1996. After the workshops, the report was revised, and this current version will be made available to the public for a ~~fourth~~ *seventh* comment period and for review by the Scientific Review Panel. No control measures are being proposed in this report. The Scientific Review Panel has approved the report and prepared Findings which are included in the Executive Summary. The report will be presented to the Air Resources Board at a public hearing on April 24, 1997. If the Air Resources Board approves the report and identifies inorganic lead as a toxic air contaminant, the information in the report may be used in the development of control measures. Any consideration of potential control measures will be conducted through a full public participatory process, including public comment periods and workshops. In preparing this report, we reviewed pertinent literature through May 1996.

TECHNICAL SUPPORT DOCUMENT

Part A - Public Exposure to Sources and Emissions of Inorganic lead in California

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I.

INTRODUCTION

The air toxics identification and control program is required by a California law which took effect in 1984 (AB 1807, Tanner, Chapter 1047, statutes of 1983, Health and Safety Code sections 39650-39674). This statute created a comprehensive program administered by the Air Resources Board (ARB or Board) to address the adverse public health impacts caused by emissions of toxic substances to the ambient air.

The program consists of a two-phase process which separates risk assessment (identification) from risk management (control). During the identification phase, a report is developed which determines whether there are potential adverse health effects from substances in consideration of the quantities of their emissions and human exposure in California. Some of the information in the report is derived from focused ARB research projects and reports. If the Board formally identifies a substance as a toxic air contaminant (TAC), it enters the risk management phase. In the risk management phase, the ARB staff determines the need for and appropriate degree of controls in consideration of cost and potential health benefits. Both the identification phase and control phase are open public processes in which the ARB staff actively seeks industry and public participation.

According to section 39655 of the California Health and Safety Code, a TAC is "an air pollutant which may cause or contribute to an increase in mortality or an increase in serious illness, or which may pose a present or potential hazard to human health." This report, Part A of the Technical Support Document, Proposed Identification of Inorganic Lead as a Toxic Air Contaminant, was prepared by the staff of the ARB and is an evaluation of atmospheric exposure to inorganic lead in the state of California. The Part B report, prepared by the staff of the Office of Environmental Health Hazard Assessment (OEHHA), assesses the health effects of inorganic lead. The Staff Report/Executive Summary, prepared by the staff of the ARB and the OEHHA, is a summary of Parts A and B. Part C consists of copies of the public comments received on the previous draft versions of the report, and the ARB/OEHHA staff responses.

With the adoption of the AB 2728 legislation (signed by the Governor in September 1992 and effective in January 1993), the procedure for identifying substances already classified as federal hazardous air pollutants (HAPs) as TACs was changed. Pursuant to section 39657 (b) of the California Health and Safety Code, the state Board identified as a TAC, substances listed as federal HAPs through a simplified process. Lead compounds (includes inorganic and organic lead) are listed as HAPs and therefore, were identified on April 8, 1993 (Title 17, California Code of Regulations, section 93001). The federal HAPs list does not include elemental lead under their definition of lead compounds. However, inorganic lead, which is the subject of this

report, includes elemental lead and will be considered for identification under the AB 1807 process.

In November of 1970, California adopted an ambient air quality standard for lead based on a 30-day running average of 1.5 micrograms per cubic meter ($\mu g/m^3$). In the early 1970's, this standard was exceeded in many areas of the state by a significant amount. As a result of the regulatory efforts to reduce the amount of lead in gasoline and the decreased market for leaded gasoline caused by the introduction of catalyst equipped vehicles, the state is now in attainment of the ambient lead standard at all of our ambient monitoring locations.

Based on information in this report and the Part B report, even though California is in attainment for the ambient air quality standard for lead, ambient and near source exposure still present a potential public health concern.

Also, the ARB and the OEHHA staff have participated in the Environmental and Consumer Sources Workgroup in the development of the report, Strategies for Collaborative Action: Eliminating Lead Poisoning in California. The report is being prepared by the California Department of Health Services. The purpose of the workgroup was to develop goals, problem statements, and strategies for the elimination of lead poisoning in waste disposal, air, water, and consumer products. The plan has gone through public comment and is expected to be implemented in the future

A. SUMMARY OF CALIFORNIA HEALTH AND SAFETY CODE SECTIONS 39660-39662 (IDENTIFICATION OF TOXIC AIR CONTAMINANTS)

Section 39660 of the California Health and Safety Code requires using the following criteria for prioritizing compounds for evaluation as possible toxic air contaminants: 1) risk of harm to public health, 2) amount or potential amount of emissions, 3) manner of usage, 4) persistence in the atmosphere, and 5) ambient concentrations.

In consultation with the OEHHA staff, the ARB staff prepares a report that serves as the basis for regulatory action. Health and Safety Code section 39660 requires that, upon the request of the ARB, the OEHHA evaluates the health effects of a potential TAC while the ARB evaluates the exposure data associated with it.

The ARB's exposure assessment is based, to the extent available, upon research and monitoring data, emissions inventory data, toxic chemical release data, information on estimated actual exposures as data on ambient and indoor air environments [Health and Safety Code section 39660(f)].

The OEHHA's health evaluation includes an assessment of the availability and quality of

data on health effects, including potency and mode of action. Where it can be established that a threshold of adverse health effects exists, the estimate must include a safe exposure level and an explanation of the uncertainties of the data. If there is no threshold of significant adverse health effects, a range of risk for exposure is determined.

The report, together with the scientific data on which the report is based, is made available to the public and is formally reviewed by the Scientific Review Panel (SRP or Panel) pursuant to Health and Safety Code section 39661. The SRP reviews scientific procedures and methods used to support the data, the data itself, and the conclusions and assessments on which the report is based. The SRP submits its findings on the report, and may reject the report if the SRP finds it to be seriously deficient. If so, the report is revised by the staff and again reviewed by the Panel. Subsequent to the SRP review, the Board conducts a public hearing to determine, based on the staff's report and the SRP findings, if a substance should be listed as a TAC. If the Board decides to list the substance as a TAC, it is added to section 93000 of the California Code of Regulations.

B. INORGANIC LEAD

Lead (Pb), the eighty-second element in the periodic table, is a bluish-gray metal that occurs naturally in the earth's crust. People have used the metal in a wide-variety of products for hundreds of years because it is readily shaped, molded, and resistant to chemical corrosion. Ordinarily, lead exists in combination with organic and inorganic compounds. "Organic lead" refers to lead compounds which contain carbon while "inorganic lead" refers to lead compounds, including elemental lead, which do not contain carbon. For this report, lead salts (e.g., lead acetate, lead subacetate) are considered to be forms of inorganic lead

This exposure assessment focuses on inorganic rather than organic lead compounds because the most significant non-workplace, outdoor air exposure to lead in California is expected to be to inorganic lead particulate matter. In this document, "lead" refers to inorganic lead unless specified otherwise. Although different lead species (e. g., lead oxide, lead sulfide, etc) are absorbed to varying degrees following inhalation, all are capable of causing adverse health effects once they reach sensitive tissues. Therefore, all inorganic lead species are considered potentially toxic for the purpose of this exposure assessment.

II.

CHEMICAL AND PHYSICAL PROPERTIES OF INORGANIC LEAD

Lead (Pb) is a metallic element with atomic number 82 and atomic weight 207.2. The four stable isotopes of this substance are: 204 (one percent), 206 (25 percent), 207 (22 percent), and 208 (52 percent). Lead exists in two oxidation states: divalent (+2) and tetravalent (+4). The divalent oxidation state predominates (Hawley, 1987; U.S. EPA, 1986).

Lead is the heaviest of the Group IV elements of the periodic table. Other elements in Group IV are carbon, silicon, germanium, and tin. Individual atoms of this substance show little tendency to catenate (form Pb-Pb bonds with each other); however, the metal readily forms stable compounds with other elements. In the earth's crust, lead is most commonly complexed with sulfur in galena ore (lead sulfide or PbS) (U.S. EPA, 1986; Merck, 1983).

As shown in Table II-1, elemental lead and most inorganic lead compounds have high melting points and low water-solubilities. Lead is malleable, ductile, a poor electrical conductor, and very resistant to corrosion. These characteristics make it a useful metal in industry and manufacturing (U.S. EPA, 1986). Please see Chapters III and V for sources, particle-sizes, and other characteristics of lead emissions.

TABLE II-1
PHYSICAL PROPERTIES OF INORGANIC LEAD AND SELECTED LEAD COMPOUNDS[1]

Compound	Formula	Molecular Weight	Specific Gravity	Melting Point (°C)	Cold Water (0-25 °C) Solubility (g/100 ml)[2]
Elemental Lead	Pb	207.2	11.35	327.5	I[3]
Lead Acetate	$Pb(C_2H_3O_2)_2$	325.3	3.25	280	44.3
Lead arsenate (diorthoarsenate)	$PbHAsO_4$	347.1	5.79	720 d[4]	I
Lead arsenate (orthoarsenate)	$Pb_3(AsO_4)_2$	899.4	7.80	1042	I
Lead bromide	$PbBr_2$	367.0	6.66	373	0.8441
Lead chloride	$PbCl_2$	278.1	5.85	501	0.99
Lead chromate	$PbCrO_4$	323.2	6.12	844	6×10^{-6}
Lead dioxide	PbO_2	239.2	9.37	290 d	I
Lead nitrate	$Pb(NO_3)_2$	331.2	4.53	470 d	37.65
Lead oxide (litharge)	PbO	223.0	9.53	888	0.0017
Lead phosphate	$Pb_3(PO_4)_2$	811.5	7.0	1014	1.4×10^{-5}
Lead subacetate	$2Pb(OH)_2$ $Pb(C_2H_3O_2)_2$	807.7	NA	NA	NA
Lead sulfate	$PbSO_4$	303.3	6.2	1170	0.0042
Lead sulfide	PbS	239.2	7.5	1114	I

(U.S. EPA, 1986; CRC, 1988)

[1]Most of the compounds listed are potentially emitted by sources of inorganic lead in California. Lead acetate, lead phosphate, and lead subacetate were included because the International Agency for Research on Cancer (IARC) has specified that these chemicals show sufficient evidence of carcinogenicity in exposed animals.

[2]grams/100 milliliters

[3]I = insoluble

[4]d = decomposes

References for Chapter II

CRC Handbook of Chemistry and Physics 69th Edition. 1988. Boca Raton, Florida. Chemical Rubber Publishing Company.

Hawley, N.I. Sax and R.J. Lewis, Sr. 1987. Condensed Chemical Dictionary Eleventh Edition. New York, New York. Van Nostrand Reinhold Company.

The Merck Index Tenth Edition. 1983. Rahway, New Jersey. Merck and Company, Inc.

U.S. Environmental Protection Agency (U.S. EPA). June 1986. Air Quality Criteria for Lead Volume II. EPA-600/8-83/0286F. Research Triangle Park, North Carolina.

III.

PRODUCTION, USES, SOURCES, AND EMISSIONS OF INORGANIC LEAD

Although lead ore is not expected to be mined or refined in California, various processes conducted in the state involve intentional or incidental use of the metal. Lead is intentionally used in processes such as the manufacture of storage batteries, soldering, and electroplating. Lead is often present as a trace contaminant in fuel and in the raw material for processes such as cement manufacturing and waste incineration.

Based on information from the ARB Technical Support Division Air Toxics Emission Data System (ATEDS), local air districts, and surveys conducted by the ARB staff, approximately 175 to 182 tons of lead are directly emitted to California's atmosphere annually. Most of the lead emitted is expected to be associated with small [less than 10 micrometers (μm)] particles. The species of lead emitted may be determined by the content of the raw material processed or the fuel burned. The major identified sources of outdoor air emissions in California include: aircraft fuel combustion, autobody refinishing, battery manufacturing, cement manufacturing, cogeneration plants, sawmills, and paperboard mills, foundries and steel mills, incineration, paint and coatings, sand and gravel, secondary lead recycling facilities, and stationary point and area source fuel combustion. Table III-1 shows the estimated lead emissions for these sources.

In contrast to the direct lead emissions estimated by the ARB staff, the U.S. Environmental Protection Agency's (EPA) Toxic Release Inventory (TRI) listed approximately 9 tons of "lead" and "lead compound" emissions for California in 1990 (SARA, 1994). The TRI is a national database of toxic emissions compiled by the EPA as required by the Superfund Amendments and Reauthorization Act (SARA) enacted by Congress in 1986. The TRI list relies on the reported emissions of basic manufacturing industries which manufacture/process 12.5 tons or more of lead per year or use five tons or more per year. Examples of potential sources that are not included in the TRI report are: mobile sources, utilities, agriculture, and military facilities (CFR, 1986).

Airborne lead particles deposit on soil and other surfaces, accumulate over a period of hours to many years, and may be re-entrained in the atmosphere. Soil and dust emissions from roads and agricultural land are estimated to contribute approximately 390 tons of lead per year to California's atmosphere. Direct and soil/dust emissions estimates are presented separately to prevent "double counting" recent direct emissions.

TABLE III-1
ESTIMATE OF EMISSIONS FROM SOURCES IN CALIFORNIA

SOURCE CATEGORIES	QUANTITY TPY*
MOBILE SOURCES	
Aircraft	149
Mobile Source Except Aircraft	Trace
Subtotal	**149**
STATIONARY POINT SOURCES	
Autobody Refinishing	4.8
Battery Manufacturing (Grid Casting and Lead Oxide Production only)	0.6
Cement Manufacturing	0.4
Cogeneration/Sawmills/Paperboard Mills	1.6
Foundries and Steel Mills	1.0
Fuel Combustion	11.0
Incineration	1.6
Paint and Coatings	0.7
Sand and Gravel	0.3
Secondary Lead Recycling	4.0
Subtotal	**26**
STATIONARY AREA SOURCES	
Fuel Combustion	**0.08 to 6.7**
TOTAL	**175 to 182**

*TPY - Tons Per Year

Since the lead concentrations in non-occupational indoor air environments vary with outdoor concentrations, the primary source of indoor air lead is expected to be outdoor mobile source and industrial emissions.

Other sources of lead exposure include food, water, soil, dust, and paint. The deposition of atmospheric lead significantly contributes to the lead contamination of these sources.

A. PRODUCTION

California contains insufficient quantities of naturally occurring lead ores (e. g., lead sulfide, lead carbonate, and lead sulfite) to make mining profitable. Consequently, California is not expected to have any primary smelters to extract lead from raw ore (ARB, 1992a). However, based on a 1991 survey conducted by the ARB staff, there are two secondary lead recycling facilities located in southern California. Secondary lead recycling facilities recover lead from a variety of previously-manufactured products by melting and separating metallic constituents. These two secondary lead recycling facilities are estimated to produce approximately 193,000 tons of lead per year. Although most of the lead is produced and sold as ingots, some is converted to lead oxide before it is sold (Cook, 1992h).

Approximately 1,264 thousand metric tons of lead were produced by U.S. primary and secondary lead recycling facilities in 1994. During the same year, 113 thousand metric tons were imported and 232 thousand metric tons were exported (U.S. DOI, 1994).

B. USES

According to data from the U.S. Department of the Interior (DOI), California, Oregon, and Washington together used approximately 107 thousand metric tons of lead in 1994 and were the sixth largest consumers Colorado, Indiana, Kansas, Kentucky, Minnesota, Nebraska, Tennessee, and Wisconsin were reported as together having the highest consumption of lead (approximately 442 thousand metric tons in 1994). About 84 percent of the approximately 1,450 metric tons of lead consumed in the United States was used in the manufacture of storage batteries (U.S. DOI, 1994).

Over the years, lead compounds have been used in the manufacture of a variety of products, including: storage batteries, ammunition, bearings, electric cable covering, pipes and pipe caulking, foil, solder, paints, inks, pigments, dyes, curing agents, glass, ceramics, tools, automobiles, machinery, construction materials, plastics and rubber goods, pesticides, and veterinary medicines (ARB, 1992a; Merck, 1983; Needleman, 1980). Due to concerns about adverse health effects, the use of lead has been discontinued or regulated in household paints, plumbing, foil, ceramics, pesticides, and veterinary medicines (Cal/EPA, 1992a; Cook, 1991a;

Cook, 1992d; NRC, 1980; U.S. EPA, 1986). Table III-2 lists some of the current and former uses of inorganic lead and selected lead compounds.

TABLE III-2
CURRENT AND FORMER USES OF INORGANIC LEAD AND SELECTED LEAD COMPOUNDS

Compound	Use
Lead acetate	Dyes, chemical production and analysis
Lead arsenate	Pesticides
Lead chromate	Paints, pigments, inks
Lead dioxide	Battery manufacture, dyes
Lead nitrate	Paints, dyes, inks, manufacture of vinyl, rubber, and plastic
Lead oxide	Battery manufacture, pesticides
Lead phosphate	Plastic manufacture
Lead subacetate	Chemical production and analysis
Lead sulfate	Paints, pigments, manufacture of batteries, vinyl, rubber, and plastic
Lead sulfide	Paints, ceramics, semi-conductors

(CRC, 1988; Merck, 1983)

In addition to the uses listed above, tetramethyl and tetraethyl lead have been used as anti-knock gasoline additives for many years. Although these two lead compounds are organic (contain carbon) rather than inorganic, they are expected to be emitted in motor vehicle exhaust as inorganic lead particulate matter due to conversion during the combustion process. Emissions of lead into ambient air from mobile sources has decreased significantly since 1975 due to the phaseout of leaded-fuel used in automobiles. Between 1978 and 1987, the consumption of leaded-gas decreased by 90 percent and total lead air emissions were reduced by 94 percent (U.S. EPA, 1990b). In California, the use of lead-additives in on-road motor vehicle fuel was eliminated and trace amounts of lead in fuel were limited to 0.05 g/gal beginning in January 1992. However, leaded fuel may still be used in other motor vehicles that are exempt from this regulation which include aircraft, pleasure craft, farm implements, and other off-road vehicles (ARB, 1990; ARB, 1992a, U.S. DHHS, 1991; U.S. EPA, 1986).

C. SOURCES OF INORGANIC LEAD EMISSIONS TO OUTDOOR AIR

1. Mobile Sources

The mobile sources category encompasses all the transportation and mobile equipment used in the state, including: automobiles, trucks, buses, motorcycles, trains, boats, ships, aircraft, snowmobiles, farm equipment, industrial equipment, and garden equipment. Emissions of lead into ambient air from mobile sources has decreased significantly since 1975 due to the phaseout of leaded-fuel used in automobiles. Between 1978 and 1987, the consumption of leaded-gas decreased by 90 percent and total lead air emissions were reduced by 94 percent (U.S. EPA, 1990b). In California, an ARB fuel measure banned the sale of leaded fuel for on-road motor vehicle use after January 1992, further reducing mobile source emissions (Cal/EPA, 1992b). Nationally, the federal Clean Air Act prohibited the use of leaded fuel in on-road vehicles after December 31, 1995. Lead is commonly present in fuel as a trace contaminant and, as described on page 10, may be added to fuel as an anti-knocking agent (ARB, 1992a). Upon combustion, most of the lead in fuel is expected to be emitted in the form of lead halides associated with particulate matter (U.S. EPA, 1986). Although the particle-size fraction for lead emissions has not been determined, more than 90 percent of the total particulate matter emitted by gas-powered mobile sources is less than 1 μm (Houck, et al., 1989).

a. Aircraft

According to data collected from California refiners and gasoline blenders, approximately 149 tons of lead were added to aviation gasoline in 1990 (ARB, 1996) Based on the assumption that all of the lead added to gasoline is emitted, the staff estimates that aircraft emitted approximately 149 tons in California in 1990. Gasoline usage and subsequent lead emissions for aircraft are not expected to change in the near future (ARB, 1992a, ARB, 1992e)

The Federal Aviation Association (FAA) has the responsibility to regulate aircraft fuel Currently, the FAA is developing an unleaded fuel specification for aircraft. These fuel specifications are expected to reduce the cost of aircraft fuel because of the increasing costs of handling lead.

b. Mobile Sources Other than Aircraft

In the early 1970's automobiles that used leaded gasoline were the most significant source of lead emissions to ambient air. Gasoline contained as much as 2.5 grams per gallon (g/gal) during the mid-1970's. In 1970, California adopted an ambient air quality standard for lead of 1.5 $\mu g/m^3$ averaged over 30 days and it was frequently exceeded in many areas of the state by a significant margin. In an effort to reduce the public exposure to lead, in 1976 the ARB adopted

a regulation that set a maximum quarterly average lead content of 1.4 g/gal of lead for the total gasoline pool. Catalyst equipped vehicles that could not use leaded fuel, were also introduced at approximately this same time. In 1982, the ARB adopted a new regulation that limited the amount of lead in the leaded gasoline pool to 0.8 g/gal. The U.S. EPA also passed a lead regulation in 1982 that established an interim value for lead of 1.1 g/gal and a final limit of 0.1 g/gal. This U.S. EPA limit was more stringent than the California limit, so it effectively controlled the content of lead in fuel in California. In January 1992, California banned lead additives in fuels for use in on-road vehicles and limited the trace amount of lead in fuel to less than 0.05 g/gal. Nationally, the federal Clean Air Act (FCAA) prohibited the use of leaded fuel in on-road vehicles after December 31, 1995. As a result of the regulatory efforts to reduce the amount of lead in gasoline and the decreased market for leaded gasoline caused by the introduction of catalyst equipped vehicles, the state is now in attainment of the ambient lead standard at all of our ambient monitoring locations (ARB, 1990).

Based on the assumption that all of the lead added to fuel is emitted upon combustion, the staff estimated that California mobile sources, other than aircraft, emitted approximately 143 tons of lead in 1990. For comparison purposes, mobile sources were estimated to emit approximately 862 tons of lead in 1987. Because on-road motor vehicles, such as cars, trucks, and vans, constitute the majority of vehicles in this source category and lead was eliminated from on-road motor vehicle fuel in January 1992, emissions are expected to have decreased substantially. Leaded-fuel may still be used in off-road vehicles (e.g., racing cars, construction equipment, and farm equipment) although these vehicles are expected to obtain unleaded fuel from on-road vehicle fuel distributors. Lead is also a common trace contaminant of fuels. In addition, many of the lead particles that were emitted by motor vehicles in the past settled on soil and other surfaces. These soil and dust deposits may serve as long-term sources of lead emissions (see page 25) (ARB, 1990; ARB, 1992a; ARB, 1992e; U.S. DHHS, 1991).

As was discussed above, 0.05 g/gal of lead is allowed as a trace contaminant in fuel. However, based on limited compliance testing of lead in fuel, most of the fuel tested contained less than 0.01 g/gal. Therefore, it is expected that emissions of lead from this source category has been virtually eliminated.

2. Stationary Point Sources

The majority of emissions from stationary point sources are discharged to the air from discrete locations or "stacks". Potential stationary point sources for which there is insufficient data to estimate lead emissions include: radiator repair, tin-lead electroplating, circuit board manufacture, plastics manufacture and fabrication, rubber manufacture, and for some industrial uses of lead based paint.

For some source categories, the ARB Technical Support Division staff have collected air toxics data from California facilities as required by the Air Toxics "Hot Spots" and Assessment Act of 1987 (AB 2588) since 1990. Currently, the Air Toxic Emission Data System (ATEDS)

contains emission inventory of 8,700 California facilities in which 1,112 facilities reported emitting lead (ARB, 1996). The year in which the ATEDS inventory for this report was based is 1993. In addition to the ATEDS inventory, the South Coast Air Quality Management District (SCAQMD) staff have provided emission data collected from information provided by facilities as required under the SCAQMD Rule 1420 - Emission Standards for Lead. The SCAQMD Rule 1420 emission inventory is based on source testing and facility reporting requirements for 1996. Since some facilities may have been required to report under both the AB 2588 and the SCAQMD Rule 1420 programs, staff chose to use the facility's SCAQMD Rule 1420 emission estimate over the ATEDS emission estimate since it is the most recent.

Emissions estimates for non-ferrous and ferrous metal melting facilities, industrial fuel combustion, autobody refinishing, cement manufacturing processes, selected types of incineration, cogeneration plants, sawmills, and paperboard mills, paint and coatings, and sand and gravel are discussed below.

a. Non-ferrous and Ferrous Metal Melting

(1) Description of Non-ferrous and Ferrous Metal Melting

Non-ferrous metal foundry and smelting operations melt aluminum, copper, lead, zinc, and other metals in various processes including extraction, recovery, refining, casting (into objects of a desired shape), transforming (e. g., lead oxide production), coating, and soldering. These processes may result in the emission of lead and other metals into the air. Although more lead is expected to be emitted from processes which use lead or manufacture lead products, lead may also be emitted as a result of processing other metals because it is a frequent contaminant of feed materials and is widely-used as an alloying agent. Based on a survey of California secondary lead recycling facilities and foundries conducted by the ARB's Toxic Air Contaminant Control Branch, Stationary Source Division in February 1991, the staff identified 280 non-ferrous metal melting facilities in California (ARB, 1992c; ARB, 1992d).

Lead emissions from non-ferrous metal melting operations are predominantly lead oxides and dioxides in or on small particles (U.S. EPA, 1986). Particle-size distribution studies on aluminum foundry emissions showed that approximately 80 percent of the total particulate matter emitted was less than 1 μm (Houck, et al., 1989). A U.S. EPA study showed that 52 to 84 percent by weight of the lead particles emitted from various secondary lead smelter processes were less than 2.5 μm (U.S. EPA, 1981). In 1991, near source monitoring was conducted near two secondary lead recycling facilities in the South Coast Air Basin and the results showed significant concentrations near the facilities. However, actions have been taken by the facilities to reduce emissions and monitoring results from 1992 show significant improvements (see Chapter IV B.2.).

Ferrous metal melting facilities are secondary lead recycling facilities and foundries which melt and cast metals containing iron. According to a survey of California secondary lead recycling facilities and foundries of California metal melters (described in the discussion of non-ferrous metal melting facilities above) and information provided by local air districts, there are about 68 ferrous metal-melting facilities in California. More than half of these facilities are located in the SCAQMD. Responses from the survey indicated that ferrous metal melting may be a significant source of localized lead emissions (ARB, 1992c; ARB, 1992d).

The lead species and particle size emitted from ferrous metal melters is expected to be similar to those from non-ferrous metal melting operations. The amount of lead particles emitted from any individual ferrous metal melting facility depends on the type of feed and the degree of particulate matter control. The lead content of feed materials, including plate, bar, and scrap metal from diverse sources, varies widely. Most ferrous metal-melting facilities control particulate matter emissions with baghouses. The control efficiency of well-maintained baghouses typically exceeds 90 percent.

(2) Statewide Lead Emissions from Non-ferrous and Ferrous Metal Melting

The non-ferrous and ferrous metal melting source categories include battery manufacturers (grid casting and lead oxide production only), secondary lead recycling facilities, and foundries where processes such as melting, pouring, and molding are sources of lead emissions. Fugitive emission sources such as scrap storage and sorting in smelters, products casting, cutting and polishing in foundries are also sources of lead emissions.

In order to estimate total emissions for these source categories, the ARB staff have collected air toxics data from the ATEDS and the SCAQMD Rule 1420 - Emission Standards for Lead emission inventories. Since some facilities may have reported in both emission inventories, staff estimated the total emissions using the most recent emission estimate reported. The total emissions estimate for secondary lead recycling facilities and foundries and steel mills is 4.0 and 1.0 tons per year, respectively. Total emissions for battery manufacturing is 0.6 tons per year (ARB, 1996; Johnson, 1996a).

Lead emissions from non-ferrous metal melting facilities are expected to *have* decreased as a result of environmental regulations. The ARB adopted an air toxic control measure (ATCM) which requires non-ferrous metal melting facilities such as smelters, foundries, die casters, and galvanizing operations to: 1) collect emissions, 2) vent emissions to the best available control equipment, and 3) reduce fugitive emissions. This ATCM is expected to reduce emissions of lead from the non-ferrous metal melting industry by 45 percent statewide. The SCAQMD has adopted an emissions standard on lead (Rule 1420). This Rule requires best available control technology (BACT) on process emissions, requires control measures for fugitive emissions, and prohibits lead emissions which result in atmospheric concentrations exceeding the current California ambient air quality standard of 1.5 $\mu g/m^3$ averaged over 30 days (ARB, 1992b; ARB, 1992e; SCAQMD, 1992). The SCAQMD has estimated there would be a 77 percent reduction

in emissions of lead, which corresponds to approximately 10.5 tons as of July 1, 1994. Recent near source ambient air monitoring has shown a decrease in annual average concentrations of lead since 1990.

The ARB control measure for toxic metals from metal melting operations does not require a specific type of control technology. This control measure defines BACT as a specific control level, or measured pollutant removal efficiency, across a control device.

The applicability of a given control technology is dictated by the temperature and contents of the emitted air stream. For this reason, the ARB control measure limits the temperature of the gases into the control device to 360 degrees Fahrenheit (°F) or 182 degrees Celsius (°C). This temperature limitation was set to ensure that volatile metals will be sufficiently cool to condense to a particle phase before they enter the baghouse. The efficiency of baghouses is slightly less for smaller particles. A 99 percent reduction of particulate matter translates to approximately a 98 percent control of metals which are associated with smaller particles (ARB, 1992b).

b. Fuel Combustion

Lead is present as a trace contaminant in most fuels. When fuel is burned, lead particles are emitted with other combustion products. The majority of the emissions are in the form of lead halides (U.S. EPA, 1986). There is insufficient data to determine the specific lead particle-size fraction for fuel combustion emissions from stationary point sources; however, the majority of particulate matter emissions from this source are less than 1 μm (Houck, et al., 1989). Based on data from the ATEDS and the SCAQMD Rule 1420 emission inventories, staff estimates total emissions of lead from fuel combustion by stationary point sources to be 11 tons per year. (ARB, 1996; Johnson, 1996a). There are several sources of lead emissions from fuel combustion by stationary point sources. These include residual oil, distillate oil, waste oil, liquid material, wood, gasoline, coal, diesel, and coke. The ARB Technical Support Division staff obtained information on the various types of fuel burned in California from the ARB's Emission Data System (EDS). The following is a brief description of each of these sources.

(1) Residual Oil

Residual oil is a general term for the low-grade oil products which remain after petroleum distillation. According to information provided by the ARB's EDS, approximately 2.2 billion gallons of residual oil (density = approximately 7 lbs per gallon) were burned as fuel by California refineries, utilities, and chemical manufacturers in 1987 (ARB, 1991c). The concentration of lead in residual oil has been reported to range from 0.5 to 9.6 micrograms per gram (μg/g) (Chansky, et al., 1974; EPRI, 1978; Krishnan, et al., 1982; SCE, 1986; U.S. EPA, 1984).

(2) Distillate Oil

Distillate oil is a refinery product of crude oil that is used to fuel boilers at facilities such as refineries and chemical manufacturing plants. When the same product is burned in internal combustion machines, it is known as diesel oil (see section c. 8.). California facilities burned approximately 1.7 billion gallons of distillate oil (density = approximately 7 lbs per gallon) in 1987. Lead concentrations in distillate oil are reported to range from non-detectable to 5 $\mu g/g$ (Krishnan, et al., 1982; Menczel, et al., 1984; SCE, 1986; U.S. EPA, 1984).

(3) Waste Oil

Waste oil is used and unused oil which becomes contaminated with various organic and inorganic substances during storage, handling, and use (U.S. DOE, 1987). There is insufficient data on waste oil in the fuel-use inventory of 1987; however, the ARB staff reported that approximately 13 million gallons were burned in California in 1983. The concentration of lead in waste oil (density = approximately 7.5 lbs per gallon) is reported to range from 220 to 555 $\mu g/g$ (Menczel, et al., 1984; PEDCo, 1984; U.S. EPA, 1984).

(4) Liquid Material

The liquid material source-category of fuels contains those fuels (e.g., crude oil and solvent waste) not specifically mentioned in other fuel categories. According to information from the ARB's EDS, approximately 44 million gallons of liquid material (density = approximately 7 lbs per gallon) were burned in California in 1987 (ARB, 1991c).

(5) Wood

Based on information from the ARB's EDS, industries burned approximately 6.5 million tons of wood for fuel in 1987 (ARB, 1991c). Emission factors reported by the U.S. EPA range from 0.00022 to 0.0004 lbs of lead emitted per each ton of wood burned in industrial processes (U.S. EPA, 1990a).

(6) Gasoline

An estimated 4.6 million gallons of gasoline were burned as fuel by California refineries, secondary lead recycling facilities, foundries, and chemical manufacturing plants in 1987 (ARB, 1991c). See page 11 for a discussion of lead emissions from mobile source gasoline combustion.

(7) Coal

Sources of lead emissions from the combustion of coal in California include: coal-fired co-generation plants, chemical manufacturers, sugar manufacturers, and cement manufacturers. Excluding that used by cement manufacturers, an estimated 150 thousand tons of coal were burned in California in 1987 (ARB, 1991c). The discussion on lead emissions from the use of coal to fuel cement kilns begins on page 20.

(8) Diesel

Diesel is a refinery product of crude oil that is used to fuel internal combustion engines (ICEs). When the same product is burned in boilers, it is known as distillate oil (see section b. 2.). An estimated 2.04 million gallons of diesel (density = approximately 7 lbs per gallon) with reported lead concentrations ranging from non-detectable to 5 μg/g were burned in California ICEs in 1987 (ARB, 1991c; Krishnan, et al., 1982; Menczel, et al., 1984; SCE, 1986; U.S. EPA, 1984). The range of lead concentrations are based on those reported for distillate oil because diesel is a distillate oil. Lead emissions from diesel fuel combustion in mobile sources is not included in the total estimate (see page 12).

(9) Coke

Facilities such as co-generation plants, sugar manufacturers, and cement manufacturers burn coke as fuel and may be sources of lead emissions. Excluding that burned by cement manufacturers, an estimated 40,000 tons of coke were burned in California in 1987 (ARB, 1991c). The lead emissions from the use of coke to fuel cement kilns is discussed in section d.

(10) Other

Other sources of fuel combustion include facilities such as brick manufacturers, sheet metalworks, printing facilities, military bases, and geothermal steam from electric utilities and services. Processes emitting lead in these sources include steel cutting, metal forging, soldering, sandblasting, and engine testing. Geothermal steam is a source of lead emissions from electric utilities and services since lead is a contaminant in the steam. When the steam is used, lead is emitted from the electric generation process (ARB, 1996).

c. Autobody Refinishing

There are approximately five to six thousand autobody refinishing shops located throughout California (Watkins, 1992). Since lead enhances the corrosion protection and durability of surface coatings, products such as paints and primers containing the metal are frequently used to coat autobody surfaces at many of these shops. Based on the national use of lead in autobody surface coatings, California vehicle miles traveled, and information about paint application controls, the staff estimated that autobody refinishing facilities emit approximately 5 tons of lead

per year in the state. The data and assumptions used in this estimate are described in Appendix A-1.

d. Cement Manufacturing

According to information from local air districts, there are 11 cement manufacturing plants in California. Eight of the 11 plants are located in southern California. The amount of lead particulate matter emitted will vary with the lead content of the raw materials and fuels used at each plant (ARB, 1992a; CIWMB, 1992). Studies have shown that approximately 60 percent of the particulate matter emitted from cement production is less than 2.5 μm in size (Houck, et al., 1989). The predominant lead species associated with these particles is expected to be lead sulfide. Lead may be emitted from three different cement manufacturing processes: raw material preparation, kilning, and cement preparation (ARB, 1992a). Each of these processes is briefly described below.

Raw material preparation includes screening and crushing limestone, shale, clay, and diatomaceous earth to obtain the minerals required for cement production: limestone provides calcium carbonate; shale, clay, and diatomaceous earth provide silica, alumina, and iron oxide. Occasionally, it is necessary to add iron ore, slag, or scrap steel to the process to supply sufficient iron content for cement production (CIWMB, 1992). An estimated 2,800 tons of particulate matter were emitted from cement plants as a result of raw material preparation in 1987 (ARB, 1991e). Since the raw materials used in cement manufacture often contain trace amounts of lead, the particulate matter emitted is also expected to contain lead. However, there is insufficient data on the lead content of either the raw material or the particulate matter to estimate emissions for this process (ARB, 1992a)

In the kilning process, the minerals obtained from raw material preparation are heated to about 2,700° F in a rotary kiln to drive off moisture and to form partially fused nodules known as clinker. The most common fuels used to heat the cement kilns in California are coal and coke. Both the mineral material in the kiln and the fuels used to heat the kiln contain trace amounts of lead and are expected to contribute to lead emissions in kiln exhaust. All California cement manufacturers use baghouses or electrostatic precipitators to control particulate emissions (ARB, 1992a; CIWMB, 1992). Lead emissions estimates for kilning were based on particulate matter emissions and baghouse catch analyses provided by local air districts. Cement kilns were estimated to emit approximately 1,500 tons of particulate matter in 1987 (ARB, 1991e). In 1981, the particulate matter from the baghouse catches of nine California cement manufacturers was analyzed and showed lead concentrations ranging from 31 to 1,240 μg/g (Haynes, et al., 1982). Assuming that the lead concentration in the particulate matter of baghouse catches is the same as that emitted, the staff estimated that California cement kilns released about 0.05 to 1.8 tons of lead in 1987 (ARB, 1992a). Lead emissions from kiln exhaust may be underestimated due to fine-particle enrichment (see Glossary, Appendix F) (Cook, 1992i).

Cement preparation includes clinker grinding, bagging, loading, and transferring activities

(ARB, 1992a; CIWMB, 1992). The staff estimated that approximately 2,200 tons of particulate matter were emitted from cement preparation in 1987 (ARB, 1991e). Preliminary AB 2588 source testing data (see Glossary, Appendix F for an explanation of the AB 2588 Air Toxics "Hot Spots" program) from a single batch concrete plant showed an average lead concentration of 9.5 μg/g in clinker samples. Assuming that the lead fraction in particulate emissions is the same as that in clinker, the staff estimated that California cement manufacturers emitted about 0.02 tons of lead as a result of cement preparation in 1987 (ARB, 1992a).

Combined lead emissions from kiln exhaust and cement preparation were estimated to be from 0.07 to 2 tons in 1987 (ARB, 1992a). This estimate does not include lead emissions from raw material preparation.

Any change in the raw material or fuel used in cement manufacture could influence the level of lead emissions. The lead content of raw material is not expected to change substantially in the future; however, there is a trend toward using alternative fuels in kiln operations. Currently, one California cement manufacturing facility is known to supplement coal combustion with tire combustion in kiln operation. Two more facilities have requested permit modifications to use tires as fuel. Since tires have a higher lead content than western coal, the ARB and the California Integrated Waste Management Board (CIWMB) are investigating the possibility that lead emissions may increase with the increased use of tires as a fuel supplement (ARB, 1992e; CIWMB, 1992).

e. Incineration

Many sewage, municipal, and other waste incinerators produce energy and are considered resource recovery facilities. Using available data, the staff estimates that California incinerators emit approximately 1.6 tons of lead per year. This estimate does not include emissions from biomass, hazardous waste, or manure for which there are insufficient data (ARB, 1992a; ARB, 1992e). The lead emissions for hospital waste, sewage, municipal, and tire incinerators are discussed below.

(1) Medical Waste Incineration

There are approximately 150 medical waste incinerators located throughout California according to information provided by the local air districts and an ARB staff survey conducted in 1989. About 80 percent are small, hospital incinerators which burn medical and some municipal-type waste generated on-site. Large, regional incinerators typically burn medical waste collected from numerous generators such as hospitals and other health care facilities, clinical laboratories, and university laboratories. Medical waste includes: human and animal tissues, microbial cultures, needles, chemicals, glass, and plastic. The type of municipal waste burned in medical waste incinerators includes: food, tin cans, cardboard, paper, and plastic. Both medical and municipal waste may contain small quantities of lead. The staff used lead emission factors and the amount of waste burned to estimate that California's on-site and

regional medical waste incinerators emit approximately one ton of lead per year. The basis for this emission estimate is described in Appendix A-2.

Lead emissions from small, on-site medical waste incinerators are expected to decrease as more hospitals choose to steam sterilize and landfill their medical waste, or rely on regional facilities to collect and burn medical waste due to the dioxin air toxic control measure (ARB, 1991a). Therefore, lead emissions to populated neighborhoods near hospitals are expected to decrease. For the large on-site and regional facilities that remain in operation, the overall emissions will decrease due to the control equipment that will be installed in these units.

(2) Sewage Sludge Incineration

Sewage sludge is the semi-solid organic and inorganic material separated from liquid municipal and industrial wastewater at publicly owned treatment works (POTWs). Based on local air district information and an ARB survey conducted for the 1987 inventory year, there are eight POTWs which routinely incinerate sludge in California. The amount of lead in the industrial wastewater discharged into the sewer system usually determines the lead content of the sewage sludge and the subsequent emissions from sludge incineration (ARB, 1991a; ARB, 1992a). There are insufficient data on the species of lead emitted as a result of sewage sludge incineration; however, lead emissions from this source are expected to be primarily associated with the small particles (less than 10 μm) which constitute the majority of particulate matter emitted from combustion processes (Finlayson-Pitts, 1986). The combined controlled lead emissions for all eight sewage sludge incinerators are estimated to be approximately 0.4 tons per year. The methods used to estimate emissions from individual facilities are discussed in Appendix A-3.

(3) Municipal Waste Incineration

Municipal waste incineration is the process of burning municipal solid waste and producing electricity. There are three municipal waste incinerators in California. Two are located in Los Angeles County and one is located in Stanislaus County. Each of these facilities burn from 350 to 1,320 tons of waste per day to generate electricity. Emission guidelines for particulate matter have been developed for municipal waste incineration and represent levels which have been achieved by facilities in California (ARB, 1991a).

Municipal waste consists of variable proportions of commercial and residential waste which may contain lead. Municipal waste includes: food, paper, wood, cardboard, textiles, leather, rubber, plastics, glass, cans, electronic equipment, and yard waste. Residential waste has a higher proportion of yard waste than does commercial waste.

The greatest source of lead in municipal waste is discarded lead batteries. According to the EPA, batteries contributed 50 percent of the total lead discards in 1970, 76 percent in 1980, and 65 percent in 1986. In 1986, the second largest source of lead discards was consumer electronics

contributing approximately 27 percent of the total. Other sources of lead in municipal waste may include light bulbs, plastics, rubber products, solder in food containers, glass and ceramic products, and pigments from printing inks (U.S. EPA, 1989).

The ARB staff estimates 340 lbs (0.17 ton) of lead per year are emitted from the three California municipal waste incineration facilities. This estimate is based on 1988 source test data for all three facilities and assumes that the facilities operate 24 hours a day, 365 days a year. These emission estimates are based solely on the source tests at that point in time when the source test was conducted. Emissions of lead from municipal waste incinerators can be higher or lower than the estimate depending on the lead content of the material being burned (ARB, 1992a).

Since lead acid batteries are the largest source of lead in municipal waste, it is expected that recycling of lead acid batteries can decrease the emissions of lead from municipal waste incinerators by reducing the amount of lead discarded.

(4) Tire Incineration

To date, there is only one tire incineration facility operating in California. Another tire burning facility has been proposed, but has not been constructed (ARB, 1991a).

In 1988, the ARB staff conducted source tests at the operating facility. Lead was not detected from the baghouse outlet of the incinerator. However, the concentration of elemental lead in the tires burned at this facility ranges from 38 to 65 parts per million (ppm) (ARB, 1991a). Therefore, one-half of the detection limit was reported. Based on this assumption, the staff estimated that the operating facility emitted less than 8 lbs of inorganic lead per year.

f. Cogeneration Plants/Sawmills/Paperboard Mills

Most of the sources in this category include saw, planing, pulp, and paperboard mills Fuel combustion is a source of lead emissions at these sources. The wood chips, sawdust, and papers are used as fuels in the boilers. Since lead is a contaminant in these materials, lead is emitted when the fuels are burned. Based on data from the ETEDS and the SCAQMD Rule 1420 emission inventories, staff estimates total emissions of inorganic lead in this source category to be 1.6 tons per year (Johnson, 1996b).

g. Paint and Coatings

The major sources in this category include paint manufacturers and metal coating industries. Processes emitting lead were reported to be paint mixing and blending, can coatings, and fuel combustion. Since lead pigments such as lead chromate and lead oxide are mixed into paints for color enhancement, lead is emitted from this process. Based on data from the ETEDS and the SCAQMD Rule 1420 emission inventories, staff estimates total emissions of inorganic lead in

this source category to be 0.7 tons per year (Johnson, 1996b).

h. Sand and Gravel

This category includes sources such as granite construction sites, rock quarries, highway construction sites, and asphalt paving. Along with excavation, crushing, and grinding at rock quarries, fuel combustion is a source of lead emissions among these sources. Based on data from the ETEDS and the SCAQMD Rule 1420 emission inventories, staff estimates total emissions of inorganic lead in this source category to be 0.3 tons per year (Johnson, 1996b).

3. Stationary Area Sources

Stationary area sources are sources that release small quantities of pollutants from many closely-located sites over a relatively large geographical area. Potential stationary area sources of lead particulate matter include: soil and dust (from roadways, landfills, agricultural, and public lands), industrial fuel combustion, construction and demolition sites (e.g., buildings, bridges), military facilities, and ship, train, and aircraft yards. The ARB staff is currently gathering information on the sources for which there is insufficient data to estimate statewide emissions. Lead emissions from the soil and dust of roadways and agricultural lands, and from area sources of industrial fuel combustion, are discussed below.

a. Soil and Dust

(1) Sources of Lead in Soil and Dust

The primary concern about the presence of lead in soil and dust is the potential for ingestion by children during the course of typical play and activities (see pages 28 through 35). Lead particles in soil and dust may also be resuspended to the atmosphere and inhaled when lead deposits are disturbed by human (e.g., soil tilling, motor vehicle entrainment) and natural (e.g., wind) events (ARB, 1992a; U.S. DHHS, 1991). These activities usually resuspend coarse particles (>2.5 μm) when reentrained into the atmosphere (see Chapter V A.1.).

The "background" concentration of lead in soils located some distance away from emission sources is reported to be approximately 15 to 16 μg/g (milligrams per kilogram (mg/kg) or ppm) (see Chapter V) (U.S. EPA, 1986). Table III-3 shows that soil lead concentrations at or near a smelter, rail road yard, traffic-ways, and a lead paint removal operation may be several thousand-fold greater than background.

(2) Lead Emissions from Roads and Agricultural Lands

There is insufficient data to estimate lead content for all types of soil and dust; however, the staff was able to estimate emissions for California roadways and agricultural lands using 1989 particulate matter emissions estimates and lead weight fractions. The predominant size of

particles from agricultural soil and unpaved roads are coarse particles (Houck, et al. 1989). Airborne lead emissions may deposit, persist, and accumulate in soil for many years. To prevent "double-counting" emissions deposited during the 1989 inventory year, the emissions estimates for roads and agricultural land discussed below are not included with the emission inventory in Table III-1.

TABLE III-3

LEAD IN SOILS AND DUSTS NEAR EMISSIONS SOURCES
(μg/g)

Source	Soil/Dust Lead Concentration	Location	Reference
Smelter (0-200 m)	560 - 11,450	El Paso	Duggan, et al., 1985
Railroad Yard (on site)	405 (mean value)	Sacramento	Cook, 1992a
Street Dust	300 - 18,000	USA (several cities)	U.S. EPA, 1986
Home Paint Removal (adjacent to site)	24,000 - 150,000	SF Bay Area	Schlag, et al., 1991

Lead particles on roadways are largely derived from the combustion of leaded gasoline. Unpaved urban area and paved road dust contributed the highest concentrations of lead in the smallest size fractions (<1 μm and <2 μm). Tire-wear and deterioration of lead chromate traffic paint may also contribute to the lead dust on California roads (Cook, 1992f). The particles may be released to the atmosphere as a result of vehicular entrainment, roadwork, or the wind. The staff used a 1989 paved road particulate matter emission estimate of 1,169,000 tons and a particulate matter lead weight fraction of 0.000199 to estimate that approximately 230 tons of lead were resuspended from 123,000 miles of paved roads in California in 1989.

The staff estimated that approximately 485,000 tons and 50,300 tons of particulate matter were resuspended from 35,800 miles of unpaved and 2,600 miles of primitive California roads, respectively. Using a lead weight fraction of 0.000181 for particulate matter from these two types of roads, the staff estimated that approximately 97 tons of lead were resuspended from unpaved (88 tons) and primitive (9 tons) roads in California in 1989 (ARB, 1991b; ARB, 1991d; ARB, 1992a; Caltrans, 1988).

The soil lead concentrations for agricultural land may be a result of nearby industrial or motor vehicle emissions. In addition, pesticides containing lead were applied to California croplands for many years and contributes to lead in soil (Cook, 1991a). The lead particles (greater than

2.5 μm) are released to the atmosphere primarily as a result of wind erosion. Plowing, tilling, and entrainment by motorized farm equipment may also propel lead particles into the atmosphere. Using estimated 1989 particulate matter emissions of 1,051,000 tons and a particulate matter lead weight fraction for agricultural land of 0.000062, the staff estimated that approximately 65 tons of lead were resuspended from California agricultural lands in 1989 (ARB, 1991b; ARB, 1991d; ARB, 1992a).

Soil and dust may be a significant source of lead emissions. Table III-4 shows that the combined emissions from roads and agricultural land emissions, alone, were 392 tons in 1989 (ARB, 1992a).

As annual rains wash lead particulate matter from the surfaces of roads, emissions from roadways are expected to slowly decrease. Gasoline exhaust from on-road motor vehicles will no longer contain significant amounts of lead due to the ban on leaded-fuel for this category.

TABLE III-4
LEAD EMISSIONS FROM CALIFORNIA
ROAD AND AGRICULTURAL LAND SOIL/DUST

Source	Emissions (tons/year)	Inventory Year
Paved Roads	230	1989
Unpaved Roads	88	1989
Primitive Roads	9	1989
Agricultural Land	65	1989
Total	**392**	

b. Fuel Combustion

Stationary area sources of fuel combustion are industrial plants which burn fuel at many closely-located sites over a relatively large geographical area. The types of fuel these sources burn include: residual oil, distillate oil, liquid material, gasoline, and diesel.

The staff used the amount and lead concentration of each type of fuel burned to estimate lead emissions from stationary area sources. The ARB's EDS provided information on the amount of each type of fuel burned by these sources in 1987 (ARB, 1991c). The lead concentrations in various types of fuel were previously discussed on page 16. Assuming that all the lead was emitted upon combustion, the staff estimated that the combined lead emissions for California stationary area sources of fuel combustion ranged from 0.08 to 6.7 tons in 1987 (ARB, 1992a).

D. SOURCES OF INORGANIC LEAD EMISSIONS TO INDOOR AIR

Usually, most of the lead present in the indoor air of non-occupational environments is from the entry of atmospheric lead; indoor concentrations of airborne lead are typically lower than outdoor concentrations. However, certain activities that disturb lead-based paint, such as remodeling or paint removal, can release large amounts of lead-bearing particles into the air Other potential sources of lead in indoor air are resuspension of lead-bearing dusts and certain hobbies.

1. Infiltration of Outdoor Air

A major source of lead in the indoor air of non-occupational environments is the entry of lead particles from outdoor air. Such particles typically originated from motor vehicle and industrial emissions (U.S. EPA, 1986). Moschandreas, et al. (1979) noted that indoor concentrations of fine particulate lead (smaller than a few micrometers aerodynamic diameter) tended to vary with outdoor concentrations. Lewis (1991) and Lewis, et al. (1989) analyzed fine particulate lead measurements performed simultaneously inside and outside 10 homes and concluded that the indoor lead concentrations in those homes could be attributed solely to the infiltration of outdoor air. Several investigators have noted a correlation between indoor lead concentrations and indoor bromine concentrations, which suggests a common source such as motor vehicle emissions (Lebret, et al., 1987; Lewis, et al., 1989). Similarly, Rabinowitz, et al. (1984) found a correlation between the lead concentrations in indoor air in Boston homes and the amount of lead sold in gasoline in Massachusetts

2. Lead-based Paint

Lead-based paint can be an important source of lead in indoor air when it is disturbed during paint removal or remodeling operations. Many methods used to remove lead-based paint, such as scraping or sanding, generate large amounts of lead-containing particles which can be disseminated throughout the house (U.S. HUD, 1990; NIBS, 1988). Lead fumes, which consist of small, respirable particles, can be formed when lead-based paint is heated during removal using torches or heat guns (Marino, et al., 1990; Fishbein, et al., 1981).

Although data regarding lead concentrations in indoor air during paint removal or remodeling operations are very limited, lead poisoning resulting from such activities is well known, especially in children (NIOSH, 1992; U.S. HUD, 1990). In California, there are an estimated 2.2 million homes built before 1950, which are likely to contain lead-based paint (DOF, 1983). Lead was a major ingredient in many types of house paint prior to the 1950's. In the early 1950's, other pigment materials gained popularity, but lead compounds were still used in some pigments and as drying agents (U.S. HUD, 1990). A portion of the 6.4 million California homes built between 1950 and 1978 may also contain some lead-based paint. In 1973, the U.S. Consumer Product Safety Commission restricted the lead content of house paints (see page 28).

3. Resuspension of Contaminated Dust and Soil

Resuspension of lead-containing dust is another potential, but unquantified, source of lead in indoor air (Yocom, 1982). Everyday activities such as cleaning, making beds, vacuuming, or sitting down on upholstered furniture can resuspend dust particles (Green, 1984). Pellizzari et al. (1992) noted that significantly higher personal exposures to PM_{10} were associated with household activities such as dusting, vacuuming, and cooking. Lead-based paints contribute to house dust when interior paint deteriorates, chalks, or is disturbed, and when exterior paint contaminates the soil and is tracked indoors. Likewise, particles originating from motor vehicle or industrial emissions can become resuspended after settling inside the home or after being tracked in from outside. The California Department of Health Services reported lead levels ranging from 26 to 88,000 ppm in urban California soils with the highest levels in Oakland (CDHS, 1991a). People working in certain occupations can also bring lead dusts into the home on contaminated work shoes and clothing [see section E. 6. (U.S. EPA, 1986)].

Of special note is the frequent proximity of children to potential indoor sources of resuspended dust, such as carpets. Infants and toddlers crawling and playing on the floor can resuspend dust into their breathing zone (Jenkins, 1992). On a given day, 81 percent of Californians under the age of 12 play on indoor floors. For 93 percent of those children, the primary play floor is carpeted (Phillips, et al., 1991).

4. Cigarette Smoke

Cigarette smoke may contain lead, although measurements of the lead content of environmental tobacco smoke are not readily available. However, two recent field studies examined the relationship between smoking and indoor lead concentrations. In a 1992 paper, Koutrakis et al. using data from New York, determined that smoking does not contribute to higher residential concentrations of lead (Koutrakis et al., 1992). Likewise, environmental tobacco smoke did not appear to significantly contribute to indoor or personal exposure concentrations of lead in a field study performed inside 175 homes in Riverside, California (Johnson, 1993).

Trace elements, such as lead, can be incorporated into a growing tobacco plant from many sources. Lead may occur naturally in the growing soil, or can be added as a result of fertilizers, soil mulchers, or polluted rainfall. Airborne particles can be deposited directly onto the plant surface and the lead can be incorporated into the tobacco on a surface or a systemic basis (Watanabe, et al,. 1987; U.S. DHHS, 1989; Jenkins, 1986; Rickert 1992). Rickert showed that average levels of lead in sidestream and mainstream smoke ranged from 0.6 to 1.2 and 0.7 to 1.6 μg/cigarette respectively over a 20-year period. Rickert also reported that lead in the tobacco of Canadian brand cigarettes has decreased by 2.8 percent per year since 1972. Over 10 percent of the lead in tobacco is expected to be transferred to mainstream smoke (Rickert, 1992). Jenkins (1986) reported lead levels in mainstream smoke ranging from 0.017 to 0.29 μg per cigarette. Lead arsenate was once used as an insecticide in tobacco fields and accounted for the high lead

concentrations present in cigarette smoke in older studies (WHO, 1980). See Chapter IV. D. for discussion of exposure to lead from cigarette smoke.

5. Hobbies

A number of products used for certain hobbies contain lead and can potentially contaminate the indoor air. Various glazes, paints, flux, and solder materials used by artists and hobbyists contain lead compounds (WHO, 1980). Hobbyists may become exposed to airborne lead when such materials are heated. Possible examples include: sports fishing enthusiasts and divers who melt and cast their own weights, home jewelry-makers who use microwave ovens as kilns for lead-containing glazes, and potters who use lead-containing glazes in home kilns (Hughett, 1991). Soldering guns used in the home for electronics projects, home repairs, and stained-glass construction heat lead-containing solder and may cause fumes. Data regarding the contribution of these activities to the lead levels in indoor air are not currently available.

E. OTHER SOURCES OF INORGANIC LEAD

In addition to inhaling lead particles from outdoor and indoor air, people and animals may be exposed to the metal through ingestion of, or skin contact with: food, water, soil, dust, and paint. Dermal absorption is not expected to be as important as inhalation and ingestion with respect to total lead exposure.

The most common causes of acute lead toxicity in children is ingestion of lead-based paint and traditional medicines which contain the metal (U.S. DHHS, 1991; U.S. EPA, 1986). Assembly Bill 2038, enacted by the California legislature in 1991, required the California Department of Health Services (CDHS) to establish a program for testing children's blood-lead concentrations and guidelines for the care of children with elevated concentrations (Connelly, 1991).

Air deposition plays a significant role in exposure via food, soil, and dust ingestion since much of the lead in these sources is derived from airborne emissions. Air deposition does not play as significant a role in waterborne ingestion of the metal since most significant exposures from water are a result of the metal leaching from lead-containing materials in water delivery systems.

The sources of lead ingestion are briefly described below.

1. Lead-based Paint

The ingestion of paint containing high concentrations of lead is the source of most cases of acute lead poisoning in children. Pre-school children are the most likely group of individuals to deliberately ingest paint chips from deteriorating painted surfaces.

Children and adults may also be inadvertently exposed by inhaling and/or ingesting paint dust. Due to their outdoor play patterns and increased hand-to-mouth activity, pre-school children have a greater opportunity for this type of exposure than do other groups of people. Lead-paint dust may be directly ingested from the surface of hands and other objects placed in the mouth or inhaled dust particles may lodge in the upper respiratory tract and be swallowed with secretions from the throat, nasal passages, etc. The dust is a result of the abrasion (e.g., opening and closing a window) and natural deterioration of lead-based painted surfaces. Indoors, the dust may settle on food, toys, furniture, carpeting, and other objects. Outdoors, the dust usually deposits on soil which may be tracked indoors (U.S. DHHS, 1991; CDHS, 1991c).

a. Lead-based Paint Regulation

In 1978, the Consumer Product Safety Commission banned the use of paint with more than 0.06 percent (600 μg/g) lead content by weight on the interiors and exteriors of homes, toys, and furniture. The ban does not apply to industrial, military, or marine-uses (U.S. DHHS, 1991). In addition, the regulation does not rule out the use of paint with more than 0.06 percent lead in public institutions (e. g., schools, hospitals) or as traffic paint (Cook, 1991b; Cook, 1992f). Assembly Bill 1659, a program for testing lead levels in paint, water, and soil at California schools, was introduced to the California legislature in 1991 (Speier, 1991).

b. Lead-based Paint in California

Approximately 8.6 million homes in California are likely to contain lead-based paint. Approximately 2.2 million homes built prior to 1950 may contain paint with lead concentrations as high as 0.5 g/g. Table III-5 shows the results of a CDHS study which measured the lead content of paint on the interiors and exteriors of homes in Oakland, Los Angeles, and Sacramento. Table III-5 also shows the percentage of homes with interior paint containing lead concentrations above 5,000 μg/g (mg/kg or ppm). At this level, the federal Department of Housing and Urban Development (HUD) initiates lead abatement in public housing (CDHS, 1991a).

c. Lead-based Paint Removal

The greatest opportunity for lead-based paint exposure occurs when painted surfaces are refinished or remodeled. Guidelines for lead-based paint removal include: 1) the use of protective clothing, respirators, and hand-held scrapers for paint removal, 2) the area surrounding the project should be kept free of dust and debris, 3) sandblasting paint or melting paint with open flames should be avoided, and 4) discarded painted wood should not be used as firewood. The Department of Health Services is currently developing an accreditation program for persons training lead-based paint abatement workers (CDHS, 1991c; Cook, 1992c).

TABLE III-5
HOUSEHOLD PAINT LEAD LEVELS IN THREE AREAS SURVEYED BY CDHS
(μg/g)

	Oakland	Los Angeles	Sacramento
Number of households:	358	343	232
Interior paint:			
Households with at least one interior paint sample	53%	82%	96%
Range	25 - 309,700	20 - 101,000	17 - 201,000
Median	2,546	895	1,284
Percent of tested households with lead concentrations of 5,000 ppm or above	37%	13%	25%
Exterior paint:			
Households with at least one exterior paint sample	60%	78%	94%
Range of median household paint lead levels	9 - 347,900	9 - 216,200	57 - 320,800

Adapted from CDHS, 1991a.

2. Traditional Medicines

Traditional medicines may serve as a major source of lead ingestion for certain groups of people. These medicines are not approved for manufacture or use in the U.S.; nevertheless, they may be found in various ethnic communities (Asian, Arab, Indo-Pakistani, and Latin American). Some of the more common traditional medicines containing lead are: alarcon, azarcon, bali goi, coral, ghasard, greta, kohl (alkohl), liga, pay-loo-ah, and rueda. The concentration of lead in some of these is high enough to cause acute cases of lead poisoning. For example, azarcon and greta, medicines used to treat intestinal illnesses, are about 90 percent lead in composition. Kohl, used as a cosmetic eye-liner and applied to skin infections and the navel of newborns, consists almost entirely of lead sulfide (CDHS, 1992; U.S. DHHS, 1991).

3. Food

The dietary intake of lead in the U.S. has decreased by more than two-thirds since the late 1930's. Over the past twenty years, significant reductions of lead concentrations were achieved through the phaseout of lead solder in canned foods and through reduced ambient air concentrations resulting from leaded-fuel regulation (U.S. DHHS, 1991; U.S. EPA, 1986).

Although concentrations in food have been declining for many years, food remains a major source of lead and is estimated to contribute from about 40 to 90 percent of the total exposure to the metal (Needleman, 1992; NRC, 1980; U.S. EPA, 1986).

a. Canned Food

Prior to the 1970's, the lead-solder used to seal can seams was a major source of lead food contamination. In the 1970's, the U.S. canning industry voluntarily began to phase out the use of lead solder in canned foods. As a result of the phaseout, the amount of lead-soldered canned foods produced in the U.S. from 1980 to 1989 decreased from 47 to about 1 percent. In addition, the canning industry began to coat the inside of tin cans to prevent the metal's leaching from the can itself. Lead solder may still be found in imported canned foods (U.S. DHHS, 1991; U.S. EPA, 1986).

b. Food Processing and Preparation

Studies have shown that lead concentrations in food may increase 2 to 12 fold from harvest to packing. Currently, the majority of food contamination is expected to occur during processing (U.S. EPA, 1986). The sources of contamination during food processing include: equipment, water, dust, and food additives (Hepple, 1973; NRC, 1991). In addition, lead may be introduced during the preparation and serving of food in the home (Hepple, 1973)

Machinery and equipment used for cutting, grinding, cooking, and storing food may contain lead alloys, solder, enamels, or glass. Many modern food-processing plants have eliminated this source of contamination by using stainless steel equipment without lead-soldered joints (U.S. EPA, 1986; Hepple, 1973).

Water may be used to wash, cook, or pack food products during processing. The concentration of lead depends on the water supply (municipal or private well) and distribution system (see Chapter III E. 4.). Factors which may influence the transfer of lead from water to food are: pH, mineral content, and temperature (U.S. EPA, 1986).

Dust from wood and metal surfaces painted with lead-based paint is a potential source of food contamination during food processing. In 1978, the Consumer Product Safety Commission banned the use of paint containing more than 0.06 percent lead by weight on home interiors and

exteriors, toys, and furniture. However, the regulation does not ban the use of lead-based paint in industrial and other applications (U.S. DHHS, 1991).

Food processors often use additives to enhance the texture, flavor, and nutritional value of food. Some food additives contain lead. For example, calcium supplements derived from animal bone may contain lead because animals store the metal in their bones (U.S. DHHS, 1991). The current maximum lead concentration allowed in food additives is 10 μg/g. The Food and Drug Administration (FDA) is considering reducing this concentration (NRC, 1991).

Wine may become contaminated with lead as a result of packaging. In 1989, the Bureau of Alcohol, Tobacco, and Firearms began testing wines to determine lead content. Lead concentrations ranged from 1 to 673 micrograms per liter (μg/L) for non-decanted wines and 3 to 1,980 μg/L for decanted wines. Investigations showed that lead is leached from the foil and deposited as salts around the neck of the bottle. The wine becomes contaminated when the bottle is stored horizontally or when the wine is poured from the bottle (U.S. DT, 1991). In 1991, the use of lead-foil caps was banned in California and wineries now seal bottles with plastic or other types of wrappers (Cal/EPA, 1992a).

The cookware and serving dishes used in homes and restaurants may be sources of lead in food. Lead may leach from: pots and pans lined with lead-alloys, ceramic dinnerware, lead crystal glassware, etc. Leaching is enhanced by heat, acidic pH, and long-term storage (Hepple, 1973; U.S. DHHS, 1991). The FDA has guidelines for the amount of lead which may be leached from ceramic dinnerware, enamelware, and pewter (NRC, 1980).

c. Crops

Airborne lead particle deposition on plant and soil surfaces is the greatest source of lead contamination for unprocessed commercial and home-grown crops. Another source of crop contamination is water (Jones, et al., 1991).

Contamination from air deposition declined during the 1970's and 1980's due to the phaseout of leaded-fuel for use in automobiles. Between 1978 and 1987, the consumption of leaded-gas decreased by 90 percent and total lead air emissions were reduced by 94 percent (U.S. EPA, 1990b). In California, further reductions in mobile source emissions and subsequent crop contamination is expected because an ARB fuel measure which banned the sale of leaded fuel for on-road motor vehicle use after January 1992 (Cal/EPA, 1992b). However, lead emissions from farm equipment and aircraft exhaust are expected to continue to deposit on soil and crops (see Chapter III C. 3.).

Airborne lead particles settle on plants and adhere to their waxy coatings or rough surfaces. Thorough washing reduces the number of particles, but does not remove them entirely. Also, plant root systems may absorb the metal from soil. The concentration of lead in the moisture surrounding soil particles is the most significant factor in determining the amount absorbed by

plant roots. Other factors affecting absorption include: the plant species, soil pH, and soil organic and mineral content (U.S. EPA, 1986; Walker, et al., 1991). Please see Chapter V for additional information on the adsorption and absorption of lead by plants.

Table III-6 shows concentrations measured in a variety of crops. Typically, leafy above-ground crops, e.g., lettuce, spinach, and wheat, have the highest concentrations of lead. Below-ground crops, e.g., carrots, potatoes, and onions, have moderate concentrations of lead. Crops growing above-ground with natural protection from airborne deposits have the lowest concentrations of lead. Examples of these crops are sweet corn (protected by husks) and tomatoes (protected by smooth, non-waxy skins) (U.S. EPA, 1986).

Pesticides containing lead have been recognized as significant potential sources of crop and soil contamination for many years. In 1972, lead was banned in the formulation of all pesticides used in California (Cook, 1991a). In 1991, the federal Food, Drug, and Cosmetic Act was amended to prohibit any residue of lead in domestic or imported crops (Cook, 1992g).

TABLE III-6
TOTAL LEAD IN BASIC FOOD CROPS
(μg/g fresh weight)

Crop	Concentration (before processing)
Carrots	0.009
Corn (sweet)	0.003
Corn (field)	0.022
Lettuce	0.013
Onions	0.005
Peanuts	0.010
Potatoes	0.009
Rice	0.007
Soybeans	0.042
Spinach	0.045
Tomatoes	0.002
Wheat	0.037

Adapted from U.S. EPA, 1986.

d. Meat and Milk

The consumption of meat is not considered to be a significant source of human exposure because most animals store lead in bones rather than muscles (Needleman, 1992; U.S. EPA, 1986). Studies showed that samples of beef and pork available in U.S. markets had lead concentrations of 0.07 ppm (μg/g) and 0.010 ppm (μg/g), respectively (U.S. EPA, 1986).

Livestock may inhale lead particles or ingest the metal in pasture feed, processed feed, soil, or water. In addition, lead may be introduced during the butchering and packaging of meat (see section E. 3. b.) (U.S. EPA, 1986).

Lead concentrations in pasture feed and soil are largely determined by the amount of local airborne emissions and seasonal deposition rates. Pasture feed may become contaminated through surface deposition of lead particles or through absorption of the metal from soil deposits. Studies of livestock forage located 25 meters from roads with high-traffic density have shown lead concentrations ranging from 20 to 950 μg/g (U.S. EPA, 1986). The National Research Council recommends that lead concentrations in livestock feed should not exceed 30 μg/g (Stevens, 1991).

Lead shot used to kill game or other animals may contaminate meat consumed by humans and animal scavengers (Hepple, 1973). For many years, scientists traced the decline of California condors to human predation and loss of habitat. However, studies in the early 1980's showed that the most immediate threat to the remaining condors was the ingestion of lead shot. Autopsies revealed that several condors had died from lead poisoning while blood samples from nearly one-third of the birds tested had higher than normal levels of lead (Toops, 1991). Over the past several years, California counties began gradually phasing out the use of lead shot in hunting water fowl. In 1991, the use of lead shot for this purpose was banned statewide (Cook, 1992b).

Crustacea and shellfish may extract lead from seawater and absorb it into edible tissues (Hepple, 1973). The California Water Resources Control Board (WRCB) monitors the level of lead in the tissues of freshwater fish and mussels. Typically, lead is not detected above the 0.01 ppm (μg/g) detection limit in aquatic animal tissue. However, concentrations as high as 250 μg/g have been measured in mussels collected near sources of lead such as slag piles. Neither the state nor the federal government has standards for lead in shellfish. International standards for total lead in shellfish range from 1.0 to 6.0 μg/g wet weight (CWRB, 1988).

Lead concentrations in bovine milk range from 23 to 79 micrograms per kilogram (μg/kg). Studies have shown that concentrations increase as cows are exposed to controlled doses of lead in their feed. In one study, Holstein heifers were dosed with 500 mg of lead salts daily for three months. This dose is equivalent to 28 μg/g in feed. The lead concentration of milk from this group of cows increased from less than 20 to 56 μg/kg. The rate of biotransfer appears to be influenced by the form in which metal is introduced. For example, lead administered as a

constituent of sewage sludge resulted in lower milk lead levels than did dosing with metallic salts (Stevens, 1991).

4. Water

Although air emissions and waste water discharges significantly add to natural concentrations of lead in surface and ground water, the greatest source of waterborne human exposure is contaminated drinking water (U.S. EPA, 1986). Drinking water becomes contaminated when lead is leached from pipes, connectors, soldered-joints, and fixtures in the water distribution system. The Safe Drinking Water amendments of 1986 banned the use of lead in public water distribution systems (U.S. DHHS, 1991).

a. Surface and Ground Water

The natural concentration of lead in surface water is estimated to range from 0.005 to 0.02 μg/L. Anthropogenic emissions and discharges have contributed significant amounts of lead to many surface waters. Lead concentrations in U.S. surface waters range from less than one to about 900 μg/L with a mean of 4 μg/L. Concentrations of 100 μg/L and above are measured near sites of sewage treatment, industrial waste disposal, and urban runoff (U.S. EPA, 1986). Discharges from recreational boats may also contribute to elevated concentrations in surface water (Hepple, 1973).

The lead concentrations in U.S. ground water range from 1 to 100 μg/L. Ground water concentrations are usually determined by the geochemical composition of the bedrock through which the water flows. Elevated concentrations may result when contaminated agricultural runoff recharges local ground water supplies (U.S. EPA, 1986)

b. Drinking Water

Although municipal water treatment is not intended to remove metals, processes such as flocculation and sedimentation do remove lead particles associated with suspended solids These processes reduce the total lead in surface and ground water by about 85 percent (U.S. EPA, 1986). In California, from January 1984 through December 1989, approximately 5,860 samples from surface water intakes and wells were analyzed for lead. The metal was detected above 5 μg/L (parts per billion (ppb)) in six percent (361) of the samples. The lead concentrations in positive samples ranged from 5.1 to 620 μg/L or ppb with a mean of 24 μg/L or ppb (Cook, 1992e). The current national action level for lead in drinking water is 15 μg/L or ppb (CDHS, 1991b).

Local water distribution systems may introduce significant amounts of lead to water drawn from the tap. Lead is leached from pipes, connectors, lead-soldered joints, and brass faucets and fixtures containing lead alloys. Water fountains and coolers may also contain lead alloys or lead-soldered joints. The amount of lead leached from these sources varies with the water's pH,

mineral content, standing time, and temperature (U.S. DHHS, 1991). For example, chemical soft-water treatment increases the solubility of lead and enhances leaching. Elevated concentrations have been demonstrated to drop significantly with flushing at 10 liters of water per minute for five minutes. Thus, the levels of lead in tap water vary among delivery systems, households, and even within the same household depending on usage (U.S. EPA, 1986). In 1991, the EPA declared a maximum contaminant level goal (MCLG) of zero lead in water and required that appropriate state agencies work with local public water systems to implement a household tapwater monitoring program. Public water systems are required to evaluate households with tapwater concentrations exceeding 0.015 milligrams per liter (mg/L) lead for service line replacement and/or corrosion control. In addition, public water systems must develop public education programs to inform citizens about the risk of exposure to lead in drinking water (FR, 1991).

Lead-soldered joints in copper plumbing are considered the most widespread source of lead in water distribution systems. Studies have shown that contamination of water from this source decreases with increasing age of the joint. The average lead concentration in standing water in homes no older than 18 months old was about 70 μg/L or ppb. Homes less than five years old had an average concentration of 31 μg/L or ppb. Homes five years or older and homes without lead-soldered pipes had average concentrations of 6 μg/L or ppb. Since the use of lead solder in plumbing has been discontinued as a result of the 1986 amendments to the Safe Drinking Water Act, this source of lead in drinking water is expected to become less and less significant (U.S. EPA, 1986).

5. <u>Soil</u>

The ingestion of lead particulate matter in soil may be a significant source of widespread, low-level exposure. Children are particularly prone to exposure via soil due to their play patterns and increased hand-to-mouth activities. In addition to direct soil ingestion, small particles may be inhaled, lodged in the upper respiratory tract, and subsequently swallowed with throat and nasal secretions (CDHS, 1991a).

Much of the lead in soil is derived from airborne particulate matter containing the metal Particles from mobile source exhaust, industrial emissions, and flaking lead-based paint deposit on soil and persist for many years (CDHS, 1991a; U.S. EPA, 1986). Most of the deposited particles are retained in the upper five centimeters of the soil's surface. To a lesser degree, the decomposition of plant material contaminated with lead may add the metal to soil (U.S. EPA, 1986).

The typical soil lead concentration is about 15 to 16 μg/g (mg/kg or ppm); however, soils near emissions sources may have concentrations 100-fold or more higher (see section C. 3.). Due to the persistent nature of the metal, the majority of lead in soil was emitted and deposited over a period of many years (Needleman, 1980).

6. Occupational

The Occupational Safety and Health Administration (OSHA) is responsible for regulating workplace exposure to toxic substances, including lead. The California Occupational Safety and Health Administration (Cal/OSHA) is the state agency responsible for ensuring that workplace exposure standards are not exceeded. The OSHA General Industry Lead Standard requires employers to conduct monitoring when the presence of lead is suspected in the workplace. The General Industry Lead Standard permissible exposure limit (PEL) for airborne lead is 0.05 milligrams per cubic meter (mg/m^3) over eight hours. A medical monitoring program is required for workers exposed to airborne lead concentrations exceeding 0.03 mg/m^3 for more than 30 days per year. Construction workers (including those involved in lead-paint abatement) and agricultural workers are not covered by the General Industry Lead Standard. Construction workers are covered by a separate Construction Industry Standard with a PEL for airborne lead four times higher than the General Industry Standard PEL (CDHS, 1990). In addition, there are no provisions for medical monitoring in cases of suspected lead exposure. The health-protectiveness of these standards is currently under review by OSHA (U.S. DHHS, 1991).

Table III-7 lists the industries in which workers are most likely to be exposed to lead. As previously mentioned in section D. 3., workers may carry lead particles home on their bodies and clothing. Other family members may be exposed to the metal via contact with clothing or housedust (U.S. DHHS, 1991).

TABLE III-7

INDUSTRIES EXPOSING WORKERS TO LEAD

Ammunition manufacturers	Industrial machinery and equipment
Automotive repair and refinishing	Metal smelting and refining
Battery manufacturing and recycling	Mining
Brass/copper foundries	Motor vehicle parts and accessories
Chemical manufacturing	Paints, inks, pigments, etc.
Construction	Plumbing
Firing ranges	Pottery manufacturing
Glass manufacturing	

Adapted from U.S. DHHS, 1991.

7. Hobbies

In section D. 5., hobbies were discussed as a source of indoor air lead. They may also be a source of lead ingestion.

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IV.

EXPOSURE TO INORGANIC LEAD

A. AMBIENT AIR EXPOSURE

1. Ambient Air Monitoring

The exposure assessment for atmospheric lead is based on ambient air monitoring data collected from April 1990 through March 1991 at 27 sites in the ARB's Criteria Pollutant Monitoring Network. These monitoring sites, shown in Figure IV-1, are located in five California air basins: South Coast, San Diego, Southeast Desert, San Francisco Bay Area, and Sacramento Valley. Two of the air basins, Southeast Desert and Sacramento Valley, had single monitoring stations.

During the one-year ambient air lead monitoring study, 24-hour samples of total suspended particulate matter (TSP), including lead particulate, were collected by high volume samplers onto glass fiber filters at six-day intervals (ARB, 1992c). The entire amount of particulate lead collected was expected to be inorganic lead because common organic lead compounds (e.g., tetramethyl-, tetraethyl-, tetrabutyl-, and hexaethyl-) are volatile and would not be captured by the filters (Cook, 1991). Sections of the filters were digested in dilute nitric acid using ultrasonification. The resulting solution was analyzed by atomic absorption spectrometry using an air acetylene flame. Please see Appendix B for the ARB Monitoring and Laboratory Division's analytical method.

A total of 1,630 samples were analyzed during the study period. Approximately nine percent (141) were below the limit of detection (LOD) (see Appendix C for the method used to determine the LOD). The LOD for the South Coast and San Francisco Bay Area air basins was 0.01 $\mu g/m^3$. The LOD for the other three air basins was 0.02 $\mu g/m^3$ (ARB, 1992c) Since observations below the LOD represent the lowest ambient concentrations, any mean annual concentration calculated without accounting for these observations would be an over-estimate. Therefore, a maximum likelihood estimation algorithm was used to estimate a mean annual concentration and standard error for each monitoring site (Shumway, et al., 1989).

2. Ambient Air Concentrations

Table IV-1 shows the minimum, maximum, and mean annual 24-hour averaged ambient lead concentrations for 27 California monitoring sites from April 1990 through March 1991. In addition, the table also includes mean values from January 1992 to June 1992 which will be discussed below. Standard errors are included in Table IV-1 for the April 1990 through March 1991 data to indicate the degree of relative variability within each monitoring station's dataset. The 24-hour averaged ambient lead concentrations ranged from less than the LOD at 20 monitoring sites to 0.30 $\mu g/m^3$ at Hawthorne. Mean annual ambient concentrations ranged from 0.02 $\mu g/m^3$ at Bethel Island to 0.12 $\mu g/m^3$ at Richmond. It is important to note that these ambient values are far below the federal

FIGURE IV-1
MONITORING SITES FOR LEAD EXPOSURE ASSESSMENT
(April 1990 - March 1991)

1. Fremont
2. Livermore
3. Bethel Island
4. Concord
5. Pittsburg
6. Richmond
7. San Rafael
8. Napa
9. San Francisco
10. Redwood City
11. San Jose*
12. San Jose**
13. Vallejo
14. Santa Rosa
15. Sacramento
16. Burbank
17. Hawthorne
18. Los Angeles
19. Lynwood
20. Pico Rivera
21. Anaheim
22. Rubidoux
23. San Bernadino
24. Upland
25. El Cajon
26. San Diego
27. Trona

* Moonpark Avenue Station
**San Carlos Avenue Station

and State ambient air quality standards for lead. The federal ambient air quality standard is 1.5 $\mu g/m^3$ for a calendar quarter and the California standard is 1.5 $\mu g/m^3$ based on a running 30-day average.

The ambient lead data from January 1992 to June 1992 is shown in Table IV-1. The data is generally lower than the 1990-91 data. Several conditions may cause the concentrations to be lower. Meteorology conditions such as inversion layers, wind, and precipitation can significantly affect the concentration of lead in ambient air and make it difficult to establish a trend (see Chapter V). Further, monitoring is only performed every six days and this data only represents part of a year which does not include all of the seasonal variations. In addition, the use of lead in fuel was banned in January 1992 and is no longer added to fuel in California. Based on all the lead added to fuel in 1990, emissions have been reduced by 143 tons. It is expected that more recent measurements of ambient concentrations of lead are lower. Further updates of ambient concentrations will be conducted after inorganic lead is identified as a toxic air contaminant by the Board.

TABLE IV-1
SUMMARY OF AMBIENT LEAD MONITORING DATA
April 1990 - March 1991
($\mu g/m^3$)

Site Location	Min.[1]	Mean	Max.	Standard Error	Sample Size	Jan.-June[2] '92 Mean
SOUTHERN CALIFORNIA						
South Coast Air Basin:						
Burbank	LOD	.05	.12	.004	61	.08
Hawthorne	.02	.08	.30	.011	60	.03
Los Angeles	LOD	.08	.17	.004	60	.09
Lynwood	LOD	.10	.23	.012	61	.06
Pico Rivera	LOD	.11	.26	.012	56	.07
Anaheim	LOD	.04	.12	.004	61	.02
Rubidoux	LOD	.04	.09	.003	60	.03
San Bernardino	LOD	.05	.09	.003	60	.03
Upland	LOD	.05	.09	.003	61	.03
San Diego Air Basin:						
El Cajon	LOD	.03	.07	.002	61	.02

Site Location	Min.[1]	Mean	Max.	Standard Error	Sample Size	Jan.-June[2] '92 Mean
San Diego	LOD	.04	.11	.003	61	.03
Southeast Desert Air Basin:						
Trona	LOD	.02	.13	.003	59	.01
NORTHERN CALIFORNIA						
San Francisco Bay Area Air Basin:						
Fremont	.03	.06	.13	.003	61	.01
Livermore	.03	.07	.12	.003	61	.01
Bethel Island	LOD	.02	.04	.002	61	.01
Concord	LOD	.04	.06	.004	61	.01
Pittsburg	LOD	.05	.20	.006	61	.03
Richmond	.02	.12	.24	.006	61	.02
San Rafael	01	.08	.15	.003	60	.01
Napa	LOD	.03	.16	.004	61	.02
San Francisco	LOD	.03	.08	.002	61	.02
Redwood City	LOD	.11	.29	.015	61	.02
San Jose-Moorpark	.01	.04	.07	.002	61	.02
San Jose-San Carlos	LOD	.05	.07	.005	61	02
Vallejo	.03	.06	.16	.003	61	.01
Santa Rosa	LOD	.03	.06	.004	60	.01
Sacramento Valley Air Basin:						
Sacramento	LOD	.04	.15	.003	57	.02

[1]The limit of detection in the San Francisco Bay Area and South Coast air basins is 0.01 micrograms per cubic meter, while the limit of detection is 0.02 micrograms per cubic meter for all other basins listed.

[2]This data represents ambient lead data after the January 1992 full ban on lead in automobile fuel.

3. Population Exposure Estimates

The ARB's Technical Support Division staff estimated population exposure to lead using the mean annual ambient concentrations described above and 1985 population census data. For the more populous areas of the South Coast and San Francisco Bay Area Air Basins, exposure was estimated by interpolating mean annual monitoring station concentrations to census tract centroids. For the other air basins, the annual mean lead concentrations for all the monitoring stations in a given air basin were averaged and the entire population of each monitored county in the basin was assumed to be exposed to this average concentration.

Table IV-2 shows the estimated population-weighted mean annual ambient lead concentrations in five air basins from April 1990 to March 1991. For the air basins with more

TABLE IV-2
POPULATION EXPOSURE ESTIMATES
April 1990 - March 1991
($\mu g/m^3$)

Site Location	Mean	Population
SOUTHERN CALIFORNIA SITES:		
Population-weighted Exposure for South Coast Air Basin	0.07	10,080,200
Population Exposure for San Diego Air Basin	0.04	2,131,600
Population Exposure for Southeast Desert Air Basin[1]	0.02	205,700[2]
NORTHERN CALIFORNIA SITES:		
Population-weighted Exposure for San Francisco Bay Area Air Basin	0.06	4,394,400
Population Exposure for Sacramento Valley Air Basin[1]	0.04	893,800[3]
STATE WIDE ESTIMATE:		
Population-weighted Exposure for All Study Areas	**0.06**	**17,683,900**

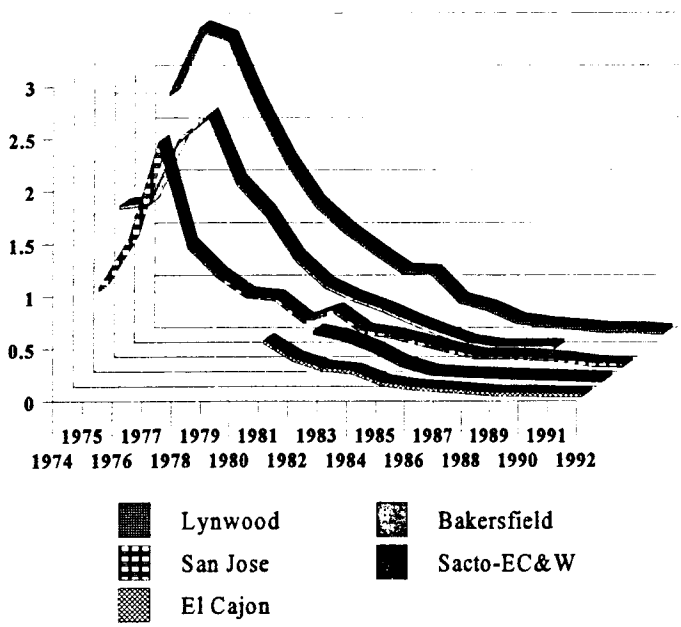
[1]The results for the Southeast Desert and Sacramento Valley air basins are based on measurements from single monitoring stations: Trona in San Bernadino County (Southeast Desert Air Basin) and Sacramento in Sacramento County (Sacramento Valley Air Basin).
[2]The estimated portion of San Bernadino County's population residing in the Southeast Desert Air Basin and potentially exposed to the mean annual lead concentrations measured at the Trona monitoring station.
[3]The estimated portion of Sacramento County's population potentially exposed to the mean annual ambient lead concentrations measured at the Sacramento monitoring station.

than a single monitoring site, the annual means ranged from 0.04 $\mu g/m^3$ for the San Diego Air Basin to 0.07 $\mu g/m^3$ for the South Coast Air Basin. The statewide mean annual population-weighted concentration was estimated to be 0.06 $\mu g/m^3$ (ARB, 1992c).

4. Ambient Air Trends in California

Ambient air trends of particulate lead have decreased significantly since the mid-1970's to 1992 as shown in Figure IV-2. This figure shows the dramatic effect of phasing out lead in fuel on inorganic lead ambient concentrations. The data represents concentrations from sites located in the five corresponding air basins: Lynwood, in the South Coast Basin; San Jose, in the San Francisco Bay Area Air Basin; Sacramento, in the Sacramento Valley Air Basin; Bakersfield, in the San Joaquin Valley Air Basin; and El Cajon, in the San Diego Air Basin. These sites were chosen because they are within the criteria pollutant monitoring network, they have the longest period of record and the highest concentration within the individual air basin, and approximately 85 percent of Californians live in these five air basins. The most dramatic reduction was observed at the Lynwood site, which shows nearly a 50-fold decrease when comparing the averages from 1976 to 1992.

FIGURE IV-2
DECREASE OF PARTICULATE LEAD IN AMBIENT AIR
Annual Mean Concentrations from 1974 to 1992



B. NEAR-SOURCE EXPOSURE

The most significant exposures to atmospheric lead are expected to occur in populations near emission sources. In order to estimate the potential impact of near-source emissions on ambient concentrations in nearby populated areas, the ARB's Technical Support Division staff used emissions and meteorological data for a South Coast secondary lead recycling facility in a computerized dispersion model. As shown in Figure IV-3, this facility was located near Vernon. Emissions from this facility were modeled for two reasons. First, secondary lead recycling facilities were identified as sources of lead emissions in California (see Chapter III). Secondly, SCAQMD/EPA monitoring conducted near the Vernon facility indicated that the lead emissions showed averaged monthly ambient lead concentrations as much as 52-fold higher than the mean annual South Coast Air Basin ambient concentration of 0.07 $\mu g/m^3$ (see section IV. A.) and more than double the state's air quality standard of 1.5 $\mu g/m^3$ for a running 30-day average. The modeling data presented below is a summary of information provided by the ARB's Technical Support Division (ARB, 1991; ARB, 1992a; ARB, 1992b). A summary of SCAQMD/EPA monitoring data provided by William G. Bope, Atmospheric Measurements Manager, Applied Science and Technology Division, SCAQMD, follows the modeling information (Cook, 1992).

FIGURE IV-3

LOCATION OF SECONDARY LEAD RECYCLING FACILITY NEAR VERNON

Map copyrighted in 1995 by DeLorme, Street Atlas USA Version 3.0
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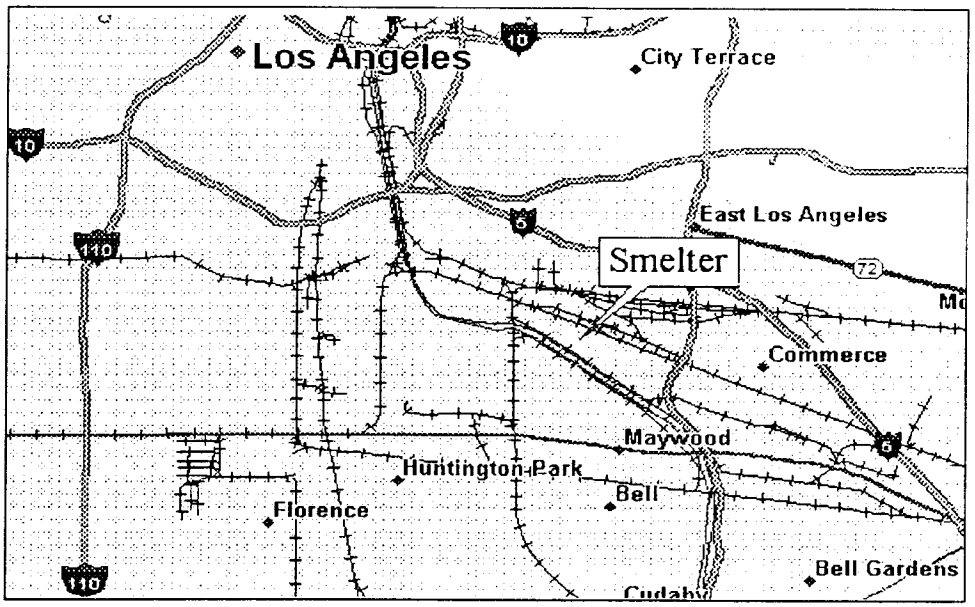

1. Modeling Study of Secondary Lead Recycling Facilities

Emissions and meteorological data are used in dispersion models to predict ambient concentrations of substances at specific locations within designated areas or "modeled regions" around facilities. Unlike monitoring results, which are limited by the time and location of sampling, modeling results can be used to estimate annual average concentrations to which people may be exposed. Because costs preclude a large number of monitoring stations, for this study we augmented the limited monitoring data with a modeling analysis to estimate potential near source exposure.

The secondary lead recycling facility smelter modeled by the staff recovers lead from a variety of previously-processed materials and products by melting and separating metallic constituents. The recovery of lead in this manner reduces emissions from the mining and primary smelting of lead ore. The maximum monthly, maximum quarterly, maximum annual, and population-weighted annual average ambient lead concentrations predicted near the Vernon secondary lead recycling facility are shown in Table IV-3. These estimates include only the lead contributed to the atmosphere by the facility and do not include background lead contributed by other sources, day to day carry-over from the facility and/or other sources, and lead particles re-entrained from nearby soil deposits. The information and dispersion model used to estimate the concentrations shown in Table IV-3 are described below.

TABLE IV-3
ABOVE BACKGROUND LEAD CONCENTRATIONS ESTIMATED FROM MODELING NEAR THE VERNON SECONDARY LEAD RECYCLING FACILITY[1]
($\mu g/m^3$)

	Concentration	Distance from Stack Centroid (meters)[2]
Max. Monthly Average[3]	0.35	190
Max. Quarterly Average	0.32	180, 190, 250[4]
Max. Annual Average	0.20	210
Population-weighted Annual Average	0.001	Approx. 3.5 million people exposed within 30 by 30 km[5] modeled region

[1]Total estimated lead emissions = 1.95 tons per year
[2]All modeled locations are outside the facility's fence-line.
[3]Businesses, but no residences, currently exist at predicted locations of maximum impact.
[4]The maximum quarterly average is the mean of three consecutive maximum monthly averages predicted at three distances from the stack centroid.
[5]km : kilometer

a. Emission Data Used in Modeling

The staff used AB 2588 (see Glossary, Appendix F) and SCAQMD source testing data on the Vernon secondary lead recycling facility for the emission inputs required by the dispersion model. Based on available information, the staff estimated that the Vernon facility emits 1.95 tons of lead per year.

b. Meteorological Data Used in Modeling

Meteorological data obtained from the SCAQMD's monitoring station at Vernon in 1981 were used to model emissions from the secondary lead smelter located near that city. The ARB modeling section used the SCAQMD's 1981 meteorological data because it is the only year in which a complete set of upper air soundings data are available for the area in which the facility is located.

c. The Modeled Region

In the study of the Vernon secondary lead recycling facility, the modeled region consists of a gridded 30 by 30 kilometer (km) area centered on the facility. Each cell in the gridded area was one kilometer square to provide uniform one-kilometer spacing between receptors. Receptors may represent individuals in the population exposed to predicted ambient concentrations in the center of each cell of the grid. The population contained in each grid cell is assumed to be exposed to the annual average concentration estimated for the receptor. A three by three kilometer fine scale receptor grid with 100 meter spacing was modeled to obtain higher resolution of annual concentrations near the facility. For maximum ambient concentration estimates, a 600 by 600 meter fine-scale grid was used to provide 20 meter spacing between receptors.

d. The Model Used

Different computerized dispersion models are used depending on the terrain in which a modeled facility is located. Since the modeled region for the facility near Vernon is entirely located in flat terrain, the Industrial Source Complex Short Term (ISCST) model was used to model emissions from this facility.

e. Population Exposure

To estimate exposure levels for the population residing near the Vernon secondary lead recycling facility, the predicted ambient lead concentrations for each cell in the modeled region were evaluated with forecasted 1985 census data. As previously mentioned, only the atmospheric lead contributed by the facility was included in the predicted concentrations. In reality, other emission sources are expected to contribute to the total ambient exposure of the modeled population.

Table IV-3 shows that a maximum annual average ambient concentration of 0.2 $\mu g/m^3$ above background was predicted to occur approximately 210 meters from the Vernon secondary lead recycling facility. There are no known residences at this location. Table IV-3 shows that the average person in the approximately 3.5 million people in the entire modeled region may be exposed to an annual population weighted average concentration of at least 0.001 $\mu g/m^3$ above background and to a range of concentrations from 0.0001 to 0.03 $\mu g/m^3$ above background (see Table IV-4). Assuming that the age distribution for the modeled region is the same as that for Los Angeles County, eight percent of the studied population (approximately 280,000) are children under five years of age (DOF, 1983).

2. SCAQMD/EPA Ambient Air Measurements of Two Secondary Lead Recycling Facilities

The SCAQMD, in cooperation with the EPA, made ambient measurements for lead near the Vernon and City of Industry secondary lead recycling facilities. For the dataset reported in this document, samples were collected February 5, 1991, through March 31, 1992, at a site 1.7 kilometers from the Vernon facility and April 19, 1991, through March 31, 1992, at a second site 0.6 kilometers from the Vernon facility. Samples were collected in February 17, 1991 through March 31, 1992 at a site located 0.3 kilometers from the City of Industry facility. Twenty-four-hour samples were collected once in every six days at all three of the sites.

TABLE IV-4
INORGANIC LEAD MODELED ABOVE
AMBIENT ANNUAL AVERAGE CONCENTRATION
POPULATION EXPOSURE - VERNON

Exposure Greater Than ($\mu g/m^3$)	Cumulative Population Exposure
0.0001	3,477,207
0.002	3,300,924
0.004	181,587
0.007	25,424
0.03	2,011
0.2 max.	0

Tables IV-5 and IV-6 show the 24-hour averaged range, highest monthly, and highest quarterly averages for samples collected near each of the secondary lead recycling facilities. The ambient measurements reflect the following: emissions from these facilities including the

construction activities at one of the facilities, lead contributed from other sources, and lead re-entrained from deposits near the facilities. However, these results can only represent the ambient concentrations for the time and place at which the measurements were conducted. Although every effort was made to place samplers near the expected site of maximum ground levels, it is unlikely that measurement results represent annual maximum concentrations because of frequent variations in local meteorology and because samples were not collected daily.

According to the federal standard, ambient concentrations may not equal or exceed 1.5 $\mu g/m^3$ averaged over a calendar quarter. According to the state standard, ambient concentrations may not equal or exceed 1.5 $\mu g/m^3$ averaged over 30 days. As shown in Tables IV-5 and IV-6, the state ambient air quality standard for lead was exceeded near both of the secondary lead recycling facilities and the federal standard was exceeded by one of the facilities in mid-1991. South Coast basin-wide average concentrations were well below both ambient standards during the time period when exceedances occurred near the secondary lead recycling facilities. The most likely causes of the exceedances are improper housekeeping, inadequate fugitive dust control, and inadequate baghouse maintenance. The reduction in lead concentrations seen in 1992 is likely attributable to improved housekeeping and controls at the facilities. In addition to these actions taken by the facilities, meteorological conditions may have contributed to reduced concentrations. Also, the measured concentrations near the Vernon and City of Industry secondary lead recycling facilities may reflect re-entrainment of soil deposits and emissions from other sources as well as facility emissions.

To date, the SCAQMD, in cooperation with the EPA, continues to monitor the secondary lead recycling facilities near Vernon and the City of Industry and the California Department of Health Services is planning to test blood lead levels of children living in the vicinity. More recent data taken near the Vernon secondary lead recycling facility show an annual average concentration on the order of 0.24 $\mu g/m^3$.

Using a conservative modeling approach, the District estimated that a facility which emits 0.5 lbs per day (lb/day) has the potential to exceed the state's ambient air lead standard of 1.5 $\mu g/m^3$ for a running 30-day average. Therefore, in 1992 the South Coast Air Quality Management District adopted a rule to reduce emissions of lead from stationary sources. Rule 1420 - Emission Standards for Lead. Rule 1420 requires facilities that use or process more than two tons of lead per year and have maximum daily lead emissions of 0.5 lb/day or more to install or upgrade emission controls on equipment and processes to certain specifications. The District estimated that approximately 125 facilities have emissions at this rate or greater and it requires these facilities to also conduct modeling or monitoring to assure that the remaining emissions do not cause exceedances of the ambient air quality standard. The rule also requires facilities to practice good housekeeping to minimize lead emissions from fugitive dust sources.

In addition to the air toxic control measure and Rule 1420, several other programs may have contributed to emission reductions. As part of our efforts to implement the Air Toxics "Hot Spots" Information and Assessment Program (AB 2588), the ARB staff is aware that many

facilities have taken voluntary steps to reduce emissions of air toxics. This may also be the case for facilities subject to Proposition 65 and Superfund Amendments and Reauthorization Act of 1986 Title III requirements. However, comprehensive information on the voluntary emission reductions from these other programs is not available at this time.

TABLE IV-5
LEAD CONCENTRATIONS MEASURED
NEAR THE VERNON SECONDARY LEAD RECYCLING FACILITY
($\mu g/m^3$)

	Monitor 1		Monitor 2	
	1991	1992	1991	1992
Data Collection	2/5 - 12/26	1/1 - 3/31	4/19 - 12/26	1/1-3/31
Dist. from Source (km)	1.7	1.7	0.6	0.6
24-hour Average Range	0.06 - 1.0	0.03 - 0.16	0.17 - 6.06	0.05 - 0.72
Max. Monthly Range	0.42	0.10	3.66	0.30
Max. Quarterly Average	0.28	0.09	2.31	0.24

TABLE IV-6
LEAD CONCENTRATIONS MEASURED
NEAR THE CITY OF INDUSTRY SECONDARY LEAD RECYCLING FACILITY
($\mu g/m^3$)

	Monitor 1	
	1991	1992
Data Collection	2/17 - 12/26	1/1 - 3/31
Distance from Source (km)	0.3	0.3
24-hour Average Range	0.10 - 5.38	0.07 - 1.37
Max. Monthly Average	1.84	0.60
Max. Quarterly Average	1.21	0.46

C. INDOOR AIR EXPOSURE

1. Indoor Air Concentrations of Lead

A number of studies conducted in various areas of the United States have measured airborne lead concentrations inside residences. In contrast, there is very little information regarding lead concentrations inside public buildings. Selected studies are reviewed here with emphasis on those conducted in California and those conducted most recently. Recent studies, conducted in 1986 or later, are used to estimate indoor concentrations in order to reflect reductions in ambient lead concentrations due to the phase-out of lead in gasoline. Limits on the lead content of gasoline used in California and other states were imposed by the EPA beginning in the late 1970s, with a significant reduction in 1986 (U.S. EPA, 1990b).

a. Residential Indoor Air Concentrations

A survey of 175 randomly-selected residences was conducted in Riverside, California in the fall of 1990. The investigators sampled the air inside and outside each home for two consecutive 12-hour periods, collecting both PM_{10} and $PM_{2.5}$ size fractions. Analysis for metals was performed using x-ray fluorescence (Pellizzari, et al., 1992). Table IV-7 presents the results from that study, which show that the average (arithmetic mean) indoor lead concentration of the PM_{10} size fraction was 0.027 $\mu g/m^3$ and the corresponding outdoor average was 0.031 $\mu g/m^3$. The maximum values (the 99th percentile of the data distribution) show an indoor concentration of 0.10 $\mu g/m^3$ and an outdoor concentration of 0.10 $\mu g/m^3$ (Pellizzari, et al., 1992). Daytime and nighttime measurements were averaged to obtain the values presented above. A sample was deemed "measurable" if its value exceeded three times the reported uncertainty in the x-ray fluorescence measurements. Different uncertainty limits were associated with each reported sample concentration and were dependent on the magnitude of the concentration. The uncertainty limits ranged from approximately 0.012 to 0.12 $\mu g/m^3$. A range of 64 to 81 percent of the indoor and outdoor samples were "measurable" (Pellizzari, et al., 1992, Ota, 1991).

Table IV-7 also presents the lead concentrations measured in a pilot study of nine homes in the San Gabriel Valley area of southern California in the spring of 1989. The sampling and analysis methods used in the pilot study were similar, although not identical, to those used in the Riverside study. Also included in Table IV-7 are the lead concentrations measured in other recent studies performed in Idaho and New York.

Although the data from the different studies presented are not directly comparable due to differences in study designs, sample sizes, and sampling methods, a few general statements regarding the data can be made. First, it is not known if the data obtained in Riverside during one season (the best California data available) are representative of the state as a whole. As observed in outdoor air, the data presented in Table IV-7 support the possibility that there may be regional and/or seasonal variations in indoor lead concentrations. Comparing the two California studies, there appear to be some differences between the indoor (and outdoor) lead

concentrations measured in Riverside and the San Gabriel Valley. Also, the two New York counties appear to have different indoor and outdoor lead concentrations.

On the other hand, Table IV-7 indicates that the Riverside data provide at least a reasonable estimate of statewide indoor lead concentrations. It is apparent that the average indoor concentrations measured in all of the studies listed in the table are of the same order of magnitude. This suggests that average indoor lead concentrations do not vary grossly across regions or seasons.

Elevated airborne lead concentrations can occur during lead-based paint abatement work. Although data regarding indoor concentrations during abatement work are extremely limited, some are included here to provide a general picture of what the magnitude of indoor lead levels may be.

In 1989 and 1990, the U.S. Department of Housing and Urban Development conducted a lead-based paint abatement demonstration project in 172 vacant homes located in seven cities across the nation. A number of abatement methods were used on the interior and exterior surfaces of the homes. Airborne lead levels were measured in the vicinity of the abatement work. The reported geometric mean airborne lead concentration was 2.0 $\mu g/m^3$ with a maximum concentration of 1,296 $\mu g/m^3$. Unfortunately, certain important variables, such as length of the sampling time and the exact location of the air samples (indoors or outdoors) were not reported by the sub-contractor (NIOSH, 1992). However, it is clear that very high airborne lead levels can be generated during lead paint abatement procedures.

b. Non-residential Indoor Air Concentrations

There is very little information regarding lead concentrations inside public access buildings. In two studies, Sheldon, et al. (1988a and 1988b) measured lead concentrations inside a total of 10 public access buildings located on the east coast. Those studies were conducted prior to the 1986 reduction of lead in gasoline and may not reflect present conditions, but are recent enough to provide a general idea of lead concentrations in public access buildings. The first study, conducted in 1983 and 1984, monitored lead levels inside two homes for the elderly, a school, and an office building over a two to three day period. Several different sampling methods were employed which had the capability of collecting particles above approximately 0.3 micron in size. Many concentrations were below measurable levels. Mean indoor concentrations ranged from below measurable levels to 0.15 $\mu g/m^3$. Mean outdoor concentrations ranged from below measurable levels to 0.16 $\mu g/m^3$. The investigators noted that lead was found at measurable levels more frequently outdoors. High limits of quantitation, which are defined as four times the limit of detection, limit the usefulness of the data obtained; median limits of quantitation ranged from 0.036 to 0.27 $\mu g/m^3$ for indoor measurements and from 0.025 to 0.27 $\mu g/m^3$ for outdoor measurements. The limit of detection was determined using field blank measurements combined with an estimate of the variability of the measurements. If no lead was detected on the blanks, the limit of detection was calculated using information on the operating parameters of the

instrument (Sheldon, et al., 1988a).

The second study, conducted in 1984 and 1985, monitored lead levels inside six buildings which included offices, nursing homes, and a hospital. Three consecutive 24-hour samples were obtained using a sampler that collected particles greater than 0.3 microns. Mean indoor concentrations ranged from below measurable levels to 0.039 $\mu g/m^3$. Mean outdoor levels ranged from below measurable levels to 0.24 $\mu g/m^3$. The investigators noted that lead levels were higher outdoors except on two occasions. Again, many concentrations were below measurable levels, but median limits of quantitation, which ranged from 0.005 to 0.035 $\mu g/m^3$, were lower than those of the first study. The limit of detection was calculated using an estimate of the variability of the field blank measurements. If no lead was detected on the blanks, the limit of detection was calculated using an estimate of the amount of material that could be measured with a precision of 50 percent (Sheldon, et al., 1988b).

One noteworthy indoor environment which might be visited by some hobbyists is the indoor firing range. Lead can enter the air when a gun is fired due to the heating of lead-containing priming compounds, the friction of leaded bullets against the gun barrel, and the fragmentation of leaded bullets as they hit the target area (Olmez, et al., 1985). Very high airborne concentrations have been measured in indoor firing ranges; for example, a concentration of approximately 4,000 $\mu g/m^3$ was recently measured in one firing range (Robbins, et al., 1990).

Available measurements of airborne lead concentrations inside public access buildings are too limited to be used directly to estimate indoor lead concentrations in such environments. Although no firm conclusions can be drawn, it appears that available concentration measurements in public access buildings are generally comparable to those measured in residences, with the exception of indoor environments with unusual sources such as firing ranges.

2. Personal Air Measurements

In the Riverside study discussed above, personal PM_{10} air samples were obtained for one member of each household concurrently with the residential indoor and outdoor samples Personal lead concentrations averaged 0.040 $\mu g/m^3$ in the daytime and 0.026 $\mu g/m^3$ in the nighttime. The maximum (99th percentile) personal concentration was 0.15 $\mu g/m^3$ in the daytime and 0.39 $\mu g/m^3$ in the nighttime. The average daytime personal concentration appears to be somewhat higher than the corresponding average indoor and outdoor concentrations, suggesting that there may have been additional exposure which was not measured separately, such as from occupational activities or from exhaust intrusion into vehicles. The average nighttime personal concentration appears to be similar to corresponding indoor and outdoor values.

3. In-vehicle Concentrations

Measurements of lead concentrations inside vehicles are included here to facilitate consideration of people's total air exposures to lead. A study which measured lead levels in the cars of volunteers during their daily commute to and from an office complex in El Monte, California was conducted in 1987 and 1988. Samples were collected of total suspended particulate matter and were analyzed by x-ray fluorescence. The mean lead concentration of 80 total samples was 0.22 $\mu g/m^3$ and the maximum concentration was 0.45 $\mu g/m^3$. The mean in-vehicle level was comparable with ambient lead levels measured during the study during peak commuting hours (0.21 $\mu g/m^3$) but was approximately 60 percent higher than the average ambient concentration of the air basin (Shikiya, et al., 1989). Higher lead concentrations have been measured near roadways due to heavier concentrations of motor vehicle emissions (U.S. EPA, 1986).

4. Comparison of Indoor and Outdoor Lead Concentrations

Airborne lead concentrations are usually lower indoors than outdoors. Indoor/outdoor ratios calculated from the results of a number of different residential studies are variable, with indoor levels ranging from 33 to 87 percent of outdoor concentrations (Pellizzari, et al., 1992; Pellizzari, et al., 1990; Ota, 1991; Lebret, et al., 1987; Kim and Stock, 1986; Sexton, et al., 1984; Tosteson,
et al., 1982).

Indoor/outdoor ratios measured in public access buildings also appear to be similar to those of residences. In a study conducted in 1974, Halpern (1978) found no significant difference in the indoor/outdoor lead concentration ratio between two museum buildings and two apartments. Other investigators have reported indoor/outdoor lead concentration ratios obtained from measurements of various public buildings and residences (Yocom, et al., 1971; Alzona, 1979; Cohen and Cohen, 1980). The reported indoor/outdoor ratios ranged from approximately 0.3 to 1.0. Inspection of the data showed no obvious differences between the ratios reported for the residential and the non-residential buildings. The reasons behind the large variability in indoor/outdoor lead concentration ratios cannot be conclusively explained, but may be due to several factors including differences in the amounts of lead contributed by indoor sources, differences in building ventilation rates and other factors that affect particle entry into buildings, and differences in study design or methods.

5. Summary of Indoor Concentration Data

Indoor airborne lead concentrations are generally lower than outdoor concentrations; indoor/outdoor ratios range from about 0.3 to 1.0.

Available information regarding indoor airborne lead concentrations in California residences is limited. Results from a recent survey of residences conducted in Riverside, California show

an average indoor airborne PM_{10} lead concentration of about 0.027 $\mu g/m^3$ and a maximum (99th percentile value) of about 0.10 $\mu g/m^3$. It is not known whether data obtained from Riverside during one season are representative of statewide levels over all seasons, since regional and seasonal variations in indoor lead levels may occur. However, these variations are probably not large; the Riverside data probably provide a reasonable estimate of statewide indoor lead concentrations. Indoor airborne lead concentrations may become highly elevated during lead-based paint abatement work.

Information regarding airborne lead concentrations inside public access buildings is even more limited. Based on a few measurements made in other states, airborne lead concentrations inside public access buildings appear to be similar to those inside residences, except when unusual indoor lead sources are present such as in indoor firing ranges.

Personal exposure concentrations can sometimes be higher than either indoor or outdoor air concentrations, suggesting additional exposure such as from occupational activities or from exhaust intrusion into automobiles. Relatively high lead concentrations (average of about 0.22 $\mu g/m^3$, maximum of about 0.45 $\mu g/m^3$) have been measured in total suspended particulate samples obtained inside vehicles during commute driving in Southern California.

6. Estimates of the Amount of Lead Inhaled from Indoor Air and Inside Vehicles

Estimates of average and high amounts of lead inhaled from indoor air and the air inside vehicles are presented in Table IV-8. Those estimates were developed using the estimates of indoor and in-vehicle concentrations described above, time-activity data for Californians, and estimates of the amount of air typically inhaled in different exposure environments. It is assumed that airborne lead concentrations inside public access buildings are similar to residential concentrations (see section C. 1.).

It should be noted that the indoor and in-vehicle concentration estimates are based on measurements made in southern California, which are the only California data available. However, those data do not necessarily represent the whole state. Seasonal and regional differences in indoor concentrations may exist (see section C. 1.). Nonetheless, in the case of the indoor residential data, there is evidence that these variations are probably not large; so the available data probably provide a reasonable estimate of statewide indoor lead concentrations.

Indoor concentrations have been estimated using residential lead data obtained from the PM_{10} size fraction, which is the fraction believed to reach the lower respiratory system where it can adversely affect health (ARB, 1982). The in-vehicle concentrations were estimated using lead data obtained from samples of total suspended particulate matter, so they are not directly comparable to the PM_{10} data. However, most atmospheric lead is present in fine particles (U.S. EPA, 1986); thus, it is reasonable to assume that most of the lead measured in the in-vehicle study is in the smaller particle size range and would reach the lower respiratory tract where it could impact health.

On a given day, adult Californians spend, on average, about 87 percent of their time indoors, 7 percent of their time in enclosed transit, and 8 hours sleeping or resting (Jenkins, et al., 1992). The average adult inhales about 20 cubic meters (m^3) of air per day (International Commission on Radiological Protection, 1975). Less air is inhaled per hour during rest; approximately 3 m^3 air is inhaled during 8 hours of rest (Ibid.). If the remaining 17 m^3 is apportioned equally over the remaining 16 hours, then an average of 1.06 m^3 of air is inhaled per hour during waking hours. Thus, for the 87 percent of the day (20.9 hours) spent indoors, 3 m^3 is inhaled during 8 hours of rest and 13.7 m^3 (12.9 hours X 1.06 m^3/hr) is inhaled while awake for a total of 16.7 m^3. For the 7 percent of the day (1.7 hours) spent in enclosed transit, about 1.8 m^3 of air is inhaled.

The activity patterns of children and the daily amount of air inhaled are, of course, different from adults. Relevant data specific to children under the age of 7, the population most sensitive to the adverse effects of lead, are very limited. For the purposes of this report, we have used available data regarding the activity patterns of children under 12 and the daily amount of air inhaled by an average 10 year old. On a given day, Californians under 12 spend, on average, about 86 percent of their time indoors and 4 percent of their time in enclosed transit (Phillips, et al., 1991). An average 10 year old is estimated to inhale about 15 m^3 of air per day (International Commission on Radiological Protection, 1975). During 8 hours of rest, approximately 2.3 m^3 of air is inhaled (Ibid.). If the remaining 12.7 m^3 is apportioned equally over the remaining 16 hours, then an average of 0.79 m^3 of air is inhaled per hour during waking hours. Thus, for the 86 percent of the day (20.64 hours) spent indoors, 2.3 m^3 is inhaled during 8 hours of rest and 10.0 m^3 (12.64 hours X 0.79 m^3/hr) is inhaled while awake for a total of 12.3 m^3. For the 4 percent of the day (0.96 hours) spent in enclosed transit, about 0.76 m^3 of air is inhaled.

An estimate of the amount of lead inhaled by adults and children from indoor air and inside vehicles was derived by multiplying the estimated air concentration of lead in a given exposure environment by the estimated amount of air inhaled in that environment. Thus, adults' average exposure to airborne lead is estimated to be about 0.45 micrograms per day (μg/day) from indoor air and 0.40 μg/day from in-vehicle exposure. Persons exposed to high air concentrations could inhale about 1.7 μg of lead per day from indoor air and about 0.81 μg/day inside vehicles. Higher non-occupational exposures to lead are also possible if, for example, a person drives for long periods of time or performs certain activities such as removing lead-based paint or engaging in certain hobbies (see Chapter III, D.).

Childrens' average exposure to airborne lead is estimated to be about 0.33 μg/day from indoor air and 0.17 μg/day from in-vehicle exposure. Children exposed to high air concentrations could inhale about 1.2 μg of lead per day from indoor air and about 0.34 μg/day inside vehicles. This estimate does not account for the possibility that, because their breathing zones are closer to the ground, small children may inhale higher concentrations of airborne lead during playing or crawling on carpets or similar sources of resuspended lead dust.

TABLE IV-7
INDOOR AIR CONCENTRATIONS OF LEAD
($\mu g/m^3$)

Location	Average Indoor Concentration	Maximum Indoor Concentration	Particle Size	Number of Homes	Average Outdoor Concentration	Comments	References
RESIDENCES:							
Riverside, CA	0.027 0.019	0.101[a] 0.058[a]	PM_{10} $PM_{2.5}$	175	0.031 0.022	Fall 1990	Pellizzari, et al., 1992
San Gabriel Valley, CA	0.034 0.022	-- --	PM_{10} $PM_{2.5}$	9	0.049 0.033	Pilot study: Spring 1989	Pellizzari, et al., 1990
Boise, ID	0.029 0.022	0.176 0.163	$PM_{2.5}$	10-with wood stoves 10-without wood stoves	0.043	Preliminary data: Winter 1986/87	Highsmith, et al., 1988& Highsmith, 1991
Suffolk Co., NY	0.035 - 0.071[b]	--	$PM_{2.5}$	171	0.073[b]	Early 1986	Leaderer, et al., 1992
Onondaga Co., NY	0.015 - 0.027[b]	--	$PM_{2.5}$	186	0.030[b]	"	"
INSIDE VEHICLES:							
Southern California	0.218	0.447	TSP	80 samples	--	1987/88	Shikiya, et al., 1989

[a]99th percentile of the distribution [b]Geometric means

D. INDOOR AIR CONTRIBUTION TO TOTAL EXPOSURE

The Health and Safety Code Section 39660.5 directs the Board to assess exposures to TACs in indoor as well as outdoor environments and to identify the relative contribution of indoor air exposure to the total air exposure. Because a major source of indoor airborne lead is the infiltration of outdoor air, indoor airborne lead concentrations are generally expected to be less than outdoor concentrations with an indoor/outdoor concentration ratio of 0.3 to 1 (see Chapter III. D.)

There are some indoor situations and activities that can increase the lead concentrations considerably. For example, small lead particles may be emitted into the air during lead-based paint abatement. In addition, concentrations of lead have been measured as high as 4,000 $\mu g/m^3$ in an indoor firing range. Certain hobbies may cause an increased exposure to lead from indoor air. Home potters and jewelry makers may be exposed to lead from the lead-containing glazes that are used in these hobbies. Fumes from soldering guns used by electronics hobbyists, stained glass construction, and home repairs may also cause elevated indoor lead concentrations. Although mainstream smoke contains some lead (Jenkins, 1986), recent field studies conducted in New York and Riverside show that environmental tobacco smoke does not contribute to higher residential or personal exposure to lead (Koutrakis, et al., 1992; Johnson, 1993).

E. MULTIPATHWAY EXPOSURE

Inhalation is not the only pathway by which people residing near emission sources, such as the Vernon secondary lead recycling facility, are exposed to atmospheric lead. Airborne lead particulate matter deposits onto water, soil, vegetation, and other surfaces (see Chapter III, section D. and Chapter V) and people may be exposed by ingesting the contaminated water, soil/dust, and food or by dermal absorption. Dermal absorption may result from skin contact with lead-contaminated soil or dust; however, dermal absorption is not expected to be a significant route of exposure for lead as long as the skin is not damaged

In addition to the five primary or direct exposure pathways [i.e., inhalation, water ingestion, crop ingestion (deposited lead), soil ingestion, and dermal absorption] mentioned above, there is a potential for additional secondary or indirect exposure pathways as a result of lead assimilation into food sources. These secondary pathways include ingestion of mother's milk, dairy products, crops (root uptake, see Chapter III section D. and Chapter V), eggs, and meat (e.g., poultry, cattle, goats, pigs, and sheep).

Exposure via primary or secondary pathways depends on the geography and specific human activities at a given location near an emission source. For example, there may be no waterways in the area or the local population may avoid exposure from water ingestion by drinking treated groundwater from a public system located miles away (CAPCOA, 1992).

In Part B of the "Proposed Identification of Inorganic Lead as a Toxic Air Contaminant," the

OEHHA staff estimated unit risk factors which relate adverse neurobehavioral and I.Q. effects in children, blood pressure effects in males aged 20 to 70, and heart attacks in males between the ages of 40 to 59 to changes in blood lead levels and atmospheric lead concentrations. The unit risk estimates for these non-cancer adverse health effects were based on epidemiological studies which included inhalation and non-inhalation exposure pathways. The OEHHA staff's cancer risk estimate was based on animal studies and does not account for exposure via non-inhalation routes.

TABLE IV-8
ESTIMATED AMOUNTS OF LEAD INHALED FROM INDOOR AIR AND INSIDE VEHICLES
(μg/day)

	Indoor Concentration ($\mu g/m^3$)		Percent of Time in Location		Average Air Volume[1] (m^3/day)		Inhaled Amount[2] (μg/day)			
							Average		High Value	
	Average	High Value	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Indoors	0.027	0.10[4]	87	86	16.7	12.3	0.45	0.33	1.70	1.20
In-Vehicle	0.22	0.45[5]	7	4	1.8	0.76	0.40	0.17	0.81	0.34

[1]Average air volume inhaled in that location per day.
[2]Amount of lead inhaled in given location (μg/day) = indoor concentration ($\mu g/m^3$) X the average volume of air inhaled (m^3/day) in that location per day
[3]Includes residences and public access buildings. Estimate assumes that airborne lead concentrations in public access buildings are similar to residential concentrations.
[4]99th percentile of the distribution
[5]Maximum value

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V.

ATMOSPHERIC PERSISTENCE AND FATE OF INORGANIC LEAD

Inorganic lead from both natural and anthropogenic sources is emitted and atmospherically transported in the form of small particles. During transport, chemical transformations from one lead species to another may occur. Eventually, the particles are physically removed from the airstream by dry and wet deposition. The speed of atmospheric removal is largely determined by the size of individual particles and local meteorological conditions.

Lead is typically associated with airborne particles which range from 0.002 to 10 micrometers (μm) in size (U.S. EPA, 1986). Particles less than 10 μm are important atmospherically and biologically because they: 1) are not removed from the atmosphere as rapidly as larger particles, and 2) show a greater tendency to lodge in lung tissue as a result of bypassing the natural filtration system of the upper respiratory tract (Finlayson-Pitts, 1986).

Particulate matter can be classified as fine or coarse particles. Fine particles have a diameter of less than 2.5 μm and are generally emitted from combustion sources. Coarse particulate matter has a diameter greater than 2.5 μm and is usually generated by physical processes such as grinding and wind erosion (Finlayson-Pitts, 1986).

Once deposited on water or soil, lead replaces other cations on existing organic and inorganic mineral complexes. Small soil particles containing the metal may be reintroduced into the atmosphere as a result of mechanical disturbance and/or meteorological conditions.

This chapter briefly describes atmospheric lead's sources, transport, transformation, and removal as well as its deposition on soil, water, and plants. Some of the information in this chapter was obtained from the U.S. Environmental Protection Agency's (U.S. EPA) 1986 document: Air Quality Criteria for Lead Volume II.

A. NATURAL AND ANTHROPOGENIC SOURCES

1. Natural Sources

Lead occurs in the earth's crust as the end-product of the radiometric decay of three naturally-occurring radioactive elements: uranium (206), thorium (208), and actinium (207) (Hawley, 1987). Lead, primarily in the form of lead-sulfide in galena ore, constitutes approximately 10 to 17 milligrams per kilogram (mg/kg) or 0.001 to 0.002 percent of the earth's crust (Bohn, et al., 1985; Merck, 1983). Please see section D. Inorganic Lead in Soil, for concentrations in California soils.

A common natural means of releasing lead to the atmosphere is via wind-borne dusts created

by the weathering of deposits. Other natural sources of lead emissions include: sea and salt lake aerosols, forest fires, and volcanic eruptions. At any given location, the amount of lead released to the atmosphere from natural sources is determined by the size of local deposits, terrain, weather patterns, and geologic activity. However, on average, natural sources are estimated to contribute about one percent of atmospheric lead[1]. Course particles that may contain lead are typically released by wind and erosion associated with weathering while fine particles are released from combustion processes such as forest fires and some volcanic eruptions (Finlayson-Pitts, 1986).

2. Anthropogenic Sources

Anthropogenic sources of lead emissions are those involving human industrial or transportation activities. They are estimated to contribute about 99 percent of atmospheric lead (see footnote 1) (U.S. EPA 1986).

The major identified anthropogenic sources of direct emissions in California are: mobile source and industrial fuel combustion, battery manufacturing, and metal melting processes. Particles emitted from combustion sources tend to be fine particles (less than 2.5 μm). Much of the lead from these sources settles on soil and is re-introduced to the atmosphere when deposits are disturbed. Particles associated with unpaved roads and agricultural land are coarse particles (greater than 2.5 μm). The ARB's Technical Support Division staff used the lead weight-fraction in particulate emissions from paved road dust, unpaved road dust, and agricultural land to estimate that these sources contribute approximately 45 percent of the total annual lead emissions in the state. The lead content of the dust may be derived from airborne emissions that were made recently or years ago (see Chapter III for an emissions inventory of sources in California)(ARB, 1992).

In urban areas, monitoring shows that most atmospheric lead is in the form of fine particles which suggests that anthropogenic combustion sources contribute the majority of lead to urban atmospheres (Finlayson-Pitts, 1986; U.S. EPA, 1986).

[1]0.0005 $\mu g/m^3$ = Estimated natural (non-anthropogenic) contribution to airborne inorganic lead (U. S. EPA, 1986)
0.06 $\mu g/m^3$ = Statewide ambient average, inorganic lead (ARB, 1989)
~1% = 0.0005 $\mu g/m^3$/0.06 $\mu g/m^3$ (Please see Chapter IV A.3.)

B. TRANSPORT AND TRANSFORMATION

1. Transport

The direction and distance lead particles travel through the atmosphere are determined by several interrelated factors: wind currents, particle-size, atmospheric mixing, and wet and dry deposition. These factors, and the amount of lead emitted, determine the ambient concentration of lead downwind from a source.

Typically, the greatest atmospheric concentrations of lead particulate matter are found closest to sources. Wind currents of various speeds and directions transport particulate matter in airstreams away from sources. Generally, smaller particles remain entrained longer and are dispersed over a larger area than larger particles, which tend to settle out near the source of emissions.

Atmospheric mixing dilutes lead particle-laden airstreams. The degree of atmospheric mixing depends on atmospheric stability and the speed and turbulence of the wind. Atmospheric stability is related to the change in the temperature of the air with changing altitude. More vertical mixing occurs during unstable conditions when air temperature decreases with increasing altitude. Under unstable conditions, a rising warm air parcel surrounded by cooler air will continue to rise. Turbulence is influenced by the surface roughness or topographical obstacles that force wind to change direction. Generally, the greater the surface roughness, the greater the turbulence. Windspeed and turbulence also influence dry deposition which, in combination with wet deposition, removes lead particles from airstreams (U.S. EPA, 1986). Dry and wet deposition are described in section C., Atmospheric Removal of Inorganic Lead.

2. Transformation

Lead is emitted from motor vehicles as lead halides such as lead bromochloride and double salts of ammonium halides. Mines and secondary lead recycling facilities emit lead oxides and sulfates. Further information on the species of lead emitted from various source-categories is in Chapter III of this document.

In ambient monitoring, lead is found primarily in lead-sulfate complexes, and to a much lesser degree in lead-halide complexes. Lead halides may react with acidic gases or aerosols to form sulfate salts; however, it is unclear whether this reaction occurs in the atmosphere or on collection filters during monitoring (U.S., 1986).

For the purpose of the proposed identification of inorganic lead as a toxic air contaminant, the staffs of the ARB and the OEHHA assume that adverse health effects may result from exposure to any lead species.

C. ATMOSPHERIC REMOVAL OF INORGANIC LEAD

Particles in which inorganic lead are associated are generally removed by wet and dry deposition. Deposition may be affected by many factors which include particle diameter and density, as well as meteorological conditions.

1. Dry Deposition

The proportion of lead particles removed by dry deposition depends on the weather patterns in a particular region. Dry deposition is the movement of lead particles from an airstream to a surface such as water, soil, or vegetation. Particle size, windspeed, and turbulence effect the rate of deposition. Deposition occurs by several processes including: sedimentation, wind-eddy diffusion, impaction, interception, and Brownian diffusion.

The lifetime of lead particulate matter specifically is not well documented in the literature. However, it may be expected to have a similar lifetime as other particulate matter. There are several references on the lifetimes of particles with different diameters. Table V-1 lists average lifetimes cited by Graedel et al., 1981. In addition, Hidy, 1973 indicates that the smallest particles (less than 0.1 μm) have short residence times due to a rapid coagulation process. Also, the U.S. EPA reports that particles smaller than 0.1 μm can remain suspended in the atmosphere for 7 to 30 days (U.S. EPA, 1986).

Sedimentation and wind-eddy diffusion are responsible for the greatest amount of deposition. In sedimentation, particles greater than a few micrometers in size settle on surfaces with only minor influence from horizontal windspeed or surface characteristics. In wind-eddy diffusion, particles are driven out of the airstream and transported by downward turbulent eddies. Since turbulence is a result of surface roughness, topography influences the amount of deposition. Deposition is low in smooth-surfaced deserts and oceans, medium in grassland and tundra, and high in forests. The denser the vegetation, the greater the deposition. In the case of forests, larger particles deposit at the forest edge while smaller particles are transported deeper into the forest before deposition.

Impaction is the process where particles in an airstream strike and deposit on obstacles such as leaves and tree branches. In interception, particles are deposited when they pass within one particle-radius of an object's surface. In Brownian diffusion, small particles traveling at low windspeeds drop out of airstreams and deposit on nearby surfaces (U.S. EPA, 1986).

2. Wet Deposition

The proportion of lead particles removed from the atmosphere by wet deposition depends on the weather patterns in a particular region. Wet deposition occurs chiefly by rainout where small (0.1 to 0.2 μm) particulate matter in a supersaturated cloud attracts small droplets which grow into raindrops. In washout, falling raindrops collect particles on their way to the surface. Wet

deposition also occurs when particles in snow and cloud droplets are captured by vegetation (U.S. EPA, 1986).

TABLE V-1
AVERAGE ATMOSPHERIC LIFETIMES FOR PARTICLES DUE TO DRY DEPOSITION

Diameter (μm)	Lifetime (days)
0.002	0.010
0.020	1.000
0.200	10.000
2.000	10.000
20.000	1.000
200.000	0.010

(Graedel and Weschler, 1981)

3. Estimated Global Deposition

The proportion of dry versus wet lead deposition varies with climate and weather within a particular region. In Air Quality Criteria for Lead Volume II, 1986, the EPA staff estimated total global lead deposition at approximately 452,000 tons (410,000 metric tons) per year. Table V-2 shows that approximately 62 percent of deposition occurs to water and 38 percent to land and vegetation. This is largely due to the fact that about two-thirds of the earth's surface is covered by oceans and other bodies of water (U.S. EPA, 1986).

D. INORGANIC LEAD IN SOIL

Since lead is generally tightly-bound in soil complexes and undergoes minimal leaching into surface or ground water, the amount of the metal in most soils is directly related to its rate of deposition (U.S. EPA, 1986; Zimdahl, 1977). In studies from the 1970's, measurements on continental U.S. soil samples taken at depths of 20 centimeters showed a median concentration of 15 to 16 mg/kg of soil (U.S. EPA, 1986). In 1982 soil samples collected throughout the San Joaquin Valley at depths of zero to 12 inches had lead concentrations ranging from three to 99 mg/kg with a mean of 17 mg/kg. During this soil study, efforts were made to avoid collecting samples near obvious sources of lead emissions (Cook, 1992). Soils sampled near emission sources, such as roadways, secondary lead recycling facilities, and lead paint removal operations may be several thousand fold higher than "background" concentrations (please see Chapter III.,

C. 3.).

TABLE V-2
ESTIMATED GLOBAL DEPOSITION OF ATMOSPHERIC LEAD

	Mass of Water 10^{17} kg/yr	**Lead Concentration 10^{-6} g/kg**	**Lead Deposition 10^{6} kg/yr**
Wet:			
To oceans	4.1	0.4	164
To continents	1.1	0.4	44
	Area, 10^{12} m^2	**Deposition Rate, 10^{-3} g/m^2 x yr**	**Deposition, 10^{6} kg/yr**
Dry:			
To oceans, ice caps, deserts	405	0.22	89
Grasslands, agricultural areas, and tundra	46	0.71	33
Forests	59	1.5	80
		Total dry:	**202**
		Total wet:	**208**
		Global:	**410**

U.S. Environmental Protection Agency. 1986. Air Quality Criteria for Lead Volume II

Lead and other trace metals exist in dynamic equilibrium between liquid and solid soil phases. The type and relative solubility of lead complexes depends on: whether the soil is in a liquid or solid phase, the presence of organic matter, and soil pH (U.S. EPA, 1986). The presence of competing ions, such as calcium, may also play a role in metal retention in soils; however, this has not been conclusively shown in the case of lead (Walker, et al., 1991).

In the liquid phase of typical soil with pH 4.5 to 8, lead forms relatively soluble complexes with organic compounds such as fulvic and humic acid. A soil pH ranging from 6 to 8 favors the formation of less soluble organic compound-lead complexes while a pH ranging from 4 to 6

favors more soluble organic compound-lead complexes. In liquid, phase soils with low concentrations of fulvic and humic acid, lead forms soluble complexes with inorganic substances such as carbonate ion, phosphate ion, or iron and manganese hydrous oxides. Rarely, lead and other trace metals exist as free ions in the liquid soil phase. Lead is most mobile and potentially available for plant root uptake as a free ion in a thin layer of moisture around soil particles.

In the solid phase of soil, lead is incorporated into minerals, precipitated as insoluble organic or inorganic complexes, or adsorbed to the surface of clay or other solid inorganic and organic matter. Lead is least mobile when incorporated into crystalline minerals where it may remain for millions of years (U.S. EPA, 1986).

E. INORGANIC LEAD IN WATER

Since lead ore is not typically leached into surface or ground water, it reaches these water sources primarily in industrial effluent or run off from deposits on roadways, soil, and vegetation. In addition, airborne lead is directly deposited into water. See section E of Chapter III for a discussion of lead concentrations in water.

Once lead reaches water, an equilibrium between dissolved and particulate phases is established. The amount of the metal that remains dissolved decreases with increasing salt concentrations and pH. Typically, a small amount of lead remains dissolved and may assimilate into the roots,

stems, and filaments of aquatic plants. Most lead forms insoluble precipitates with the hydroxide, carbonate, sulfide, and sulfate anions present in natural water. These lead precipitates, or salts, may adsorb to suspended solids, or settle and adsorb to aquatic plants and the sediment.

The amount of lead removed from natural waters by suspended solids or sediment depends on pH, redox conditions, salinity, and anion concentrations in the water and on the organic composition of suspended solids and sediment (U.S. EPA, 1986). Studies performed by Tada, et al. showed that increased organic content at the bottom of sediment significantly increased sediment adsorptivity and the removal of lead from water (Tada, et.al, 1982). Invertebrates (e.g., mussels and oysters) have been shown to accumulate lead and are expected to remove the metal from ocean sediment as they feed on sediment particles (Schulz-Baldes, et al., 1983).

When water evaporation exposes sediment to drying and subsequent erosion, lead particles are likely to re-enter the atmosphere through wind re-entrainment (U.S. EPA, 1986).

F. INORGANIC LEAD IN AND ON PLANTS

Plants are exposed to lead via air, soil, and water. Typically, plants accumulate more lead

from the atmosphere than they do from other media. This was demonstrated in a study in which crops were exposed to air, soil, and water containing controlled amounts of lead (Jones, et al., 1991).

Airborne lead particles accumulate on plant surfaces as a result of dry or wet deposition and are retained by electrostatic attraction or by the waxy coating on some vegetative material. Studies show that neither rainfall nor washing the plants removes all the adsorbed particles (U.S. EPA 1986).

Typically, lead is not readily taken up by plant roots. Studies have shown that the ratio of the lead concentration in plants to the concentration in soils in which the plants were grown was 0.001 to 0.03 (Jones, et al., 1991). In general, plant root absorption of metals from soil and water depends on: the metal absorption characteristics of the root, the growth rate of the root, and the amount of metal available. In soils, plant root uptake is also influenced by the availability of moisture. In addition, several studies have shown that metal uptake by plants increases with decreasing pH; however, the role of pH in the uptake of lead is not clear (Walker, et al., 1991).

G. SUMMARY OF ATMOSPHERIC PERSISTENCE AND FATE OF INORGANIC LEAD

This chapter briefly described how lead continually cycles through environmental media compartments. The metal is removed from the air by dry and wet deposition to soil or water where it replaces other cations in organic and inorganic complexes. Small amounts of the metal may leach from water into soil. Weathering and human activities, such as mining and farming, disturb the soil surface and increase the rate of re-entrainment

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APPENDIX A

ESTIMATION OF LEAD EMISSIONS FROM:

1. AUTOBODY REFINISHING
2. MEDICAL WASTE INCINERATION
3. SEWAGE SLUDGE INCINERATION

1. Estimation of Lead Emissions from Auto-Body Refinishing

According to a U.S. Paint Industry data base, an estimated 1,333,200 pounds of lead were used by U.S. autobody refinishers in 1989 (Connolly, et al., 1990). Since 12.2 percent of national vehicle miles are traveled in California, the staff estimated that approximately 162,650 pounds of lead are used in California each year and that individual small, medium, and large shops use, on average, approximately 10, 30, and 106 pounds of lead per year, respectively (Caltrans, 1989; Connolly, et al., 1990).

According to the U.S. EPA, medium autobody refinishing shops use three times, and large shops use 10.6 times, more paint than do small shops. Assuming that California has the same distribution of shops as the U.S. EPA reported for the U.S. in 1988, the staff estimated that there are approximately 2200 (40 percent) small, 2750 (50 percent) medium, and 550 (10 percent) large shops in the state (U.S. EPA, 1988).

To estimate statewide emissions, the staff assumed that medium and large autobody refinishing ships use spray booths that provide 95 percent control efficiency. The staff also assumed that these shops use high-volume, low-pressure (HVLP) spray guns with 65 percent paint-transfer efficiency. Small autobody refinishing shops were assumed to use HVLP guns but no controls. The staff used the following general formula to calculate emissions for the various types of facilities:

$$\frac{\text{lbs. Lead Used}}{\text{Year}} (1.00 - \%\ \text{Control Efficiency})(1.00 - \%\ \text{Transfer Efficiency}) = \frac{\text{lbs. Lead Emitted}}{\text{Year}}$$

Based on the information and assumptions briefly discussed above, the staff estimated that large and medium facilities emit approximately 2,341 pounds of lead per year while small facilities emit approximately 7,315 pounds of lead per year. The staff estimated that total lead emissions from California autobody refinishing shops are about 9,656 pounds (4.8 tons) per year (Cook, 1992j).

2. Estimation of Lead Emissions from Medical Waste Incineration

The staff used source testing results on seven California medical waste incinerators to determine lead emissions factors for this source. The source test samples were collected and analyzed by the ARB staff from 1987 through 1990. Three of the seven incinerators had no emission control equipment; three incinerators had scrubbers and one incinerator had a baghouse. The following formula was used to determine the emission factor for each sample run on individual incinerators:

$$\frac{\text{Controlled and Uncontrolled Emission Rate lbs/Hour}}{\text{Tons of Waste Burned in Each Sample Run}} = \text{Controlled and Uncontrolled Emission Factor}$$

No significant difference in controlled and uncontrolled emission factors were found for two of the incinerators with scrubbers. The single incinerator/scrubber combination with an average controlled emission factor significantly (approximately 75 percent) less than its average uncontrolled factor is not widely used in medical waste incinerators throughout California. Therefore, the staff averaged the emission factors for all the sample runs on single and multiple chamber incinerators (with and without scrubbers) and determined that the mean emission factor for these types of incinerators was 0.0911677 pounds of lead emitted per ton of waste burned. The mean emission factor for California's only known multiple chamber incinerator with a baghouse was 0.0000653 pounds of lead emitted per ton of waste burned.

According to information provided in a 1989 survey, California's on-site and regional medical waste incinerators burn approximately 14,660 and 8,700 tons of waste per year, respectively. Using the emission factors discussed above and the amounts of waste burned, the staff estimated that on-site and regional facilities emit approximately 1,145 and 793 pounds of lead per year, respectively. Total emissions for all California medical waste incinerators were estimated to be approximately 1,940 pound (one ton) per year (Cook, 1992k).

3. Estimation of Emissions from Sewage Sludge Incineration

The staff used the amount of dry feed incinerated per year and emission factors to estimate lead emissions for seven of the eight sewage sludge incinerators. According to an ARB staff survey, from 19 to 12,584 tons of dry feed were processed by the seven individual incinerators in 1987. In selecting emission factors, the staff considered the emissions associated with multiple hearth furnaces and fluidized bed combustors and the efficiency of the various control devices used with each of these incinerators. Six of the seven facilities used multiple hearth furnaces and one sued a fluidized bed combustor for incinerating sludge The facilities employed baghouses, Venturi scrubbers, and/or packed column scrubbers to control particulate emissions (ARB, 1987). The staff selected controlled emission factors of 0.0377 and 0.0218 pounds of lead per tone of dry feed for multiple hearth furnaces and fluidized bed combustors, respectively (Bennett, et al., 1982; Greenberg, et al., 1981; PEI, 1989; U.S. EPA, 1990a). The combined lead emissions estimated for the seven incinerators was approximately 640 pounds per year with individual incinerator emissions ranging from 0.7 to 474 pounds per year. The emissions were calculated using the general formula below:

$$\text{Dry Feed } \frac{\text{Tons}}{\text{Year}} \times \text{Controlled Emission Factor } \frac{\text{lbs Lead}}{\text{Ton of Feed}} = \frac{\text{lbs of Lead Emitted}}{\text{Year}}$$

(ARB, 1992a)

The staff used source testing data provided by a local sanitation district to estimate lead emissions for the remaining California sewage sludge incinerator. Testing was conducted in January and February of 1989 by an independent contractor certified by the local air district. During the testing period, the facility used a fluidized bed combustor for incineration and multiple cyclones, a baghouse, and a three-stage wet scrubbing system to control particulate matter emissions. Analysis showed a lead concentration of 0.61 $\mu g/m^3$ in the scrubber exhaust. A flow rate of 9,729 dry standard cubic feet per min (dscfm) or 275.6 cubic meters per minute was obtained from AB 2588 source test data (see Glossary, Appendix F for an explanation of the AB 2588 Air Toxics "Hot Spots" Program) collected in May 1989. Assuming that the facility operated 16 hours per day, 365 days per year, the staff estimated that controlled lead emissions were approximately 130 pounds per year. The formula below was used to estimate lead emissions from this facility:

$$275.6 \frac{m^3}{min.} \times 0.61 \frac{\mu g \text{ Lead}}{m^3} \times 960 \frac{min.}{day} \times 365 \frac{days}{year} \times \frac{1 \text{ kg}}{10^6 \mu g} \times \frac{1 \text{ lb}}{0.45 \text{ kg}} = 130 \frac{lbs}{Year}$$

(Haug, et al., 1990; Cook, 1992h)

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APPENDIX B

AIR RESOURCES BOARD'S STANDARD OPERATING PROCEDURE FOR THE DETERMINATION AND QUANTIFICATION OF ATMOSPHERIC LEAD

CALIFORNIA AIR RESOURCES BOARD
MONITORING AND LABORATORY DIVISION
NORTHERN LABORATORY BRANCH

S.O.P. No. NLB 005

STANDARD OPERATING PROCEDURE FOR THE DETERMINATION OF SELECTED HEAVY METALS (LEAD) IN FILTER MEDIA BY ATOMIC ABSORPTION

1. Scope

This document describes a method for the determination of lead in hi-vol filter media after sampling ambient air. This procedure has been tailored to concentrations normally found in ambient air.

2. Summary of Method

After the sample is collected with a suitable device (e.g. hi-vol sampler), the 8"x10" hi-vol filter is cut such that one-eighth of the filter is available for analysis. The one-eighth section is digested in dilute nitric acid using ultrasonication. The digestate is filtered and diluted to 40.0 ml. This solution is then analyzed by atomic absorption spectrometry using an air-acetylene flame.

3. Interferences/Limitations

There are no known chemical interferences using this technique. The solution matrix can interfere with the analysis due to background absorption; however, matrix matching and standard addition techniques keep these interferences to a minimum.

4. Apparatus

4.1 Perkin-Elmer: Model 3030B Atomic Absorption Spectrophotometer, and PR-100 Printer

4.2 Mettler Electronics Model ME 5.5 ultrasonic cleaner.

4.3 Gelman 0.45 um membrane filters.

4.4 500 ml side-arm vacuum flask

4.5 Teflon lined, screw-capped Pyrex test tubes, 25 x 150 mm.

5. Reagents

5.1 Acids

a. Nitric acid, Ultrex Grade, concentrated (15.6M)

b. Extraction acid; dilute 192 ml of concentrated HNO3 to 1.0 liter with Nanopure (Cap IV) deionized water.

c. 0.45M nitric acid, dilute 29 ml concentrated HNO3 to 1.0 liter.

5.2 Stock standard, 1000 ppm available from commercial sources that are certified and traceable to NBS standards.

5.3 Intermediate Stock Standard (ISS)

Dilute 10.0 ml lead stock standard with .45M HNO3
Remake standard monthly

Lead - 50 mg/l

5.4 Analytical Standard

Calibration Standard: Dilute 5.00, 2.50, and 1.00 ml of ISS to 50.0 ml each with 0.45M HNO3

Calibration Standard Concentrations:

5.00 mg/l
2.50 mg/l
1.00 mg/l

6. Sample Preparation

6.1 Upon receipt of the filter and data sheet, check to insure that the filter number corresponds to the filter number listed on the data sheet.

6.2 Cut the filter section into 1"x10" strips. Place strip into labelled 25 x 150 mm teflon-lined, screw-capped test tubes.

6.3 Add 15 ml of 3M HNO3. Cap loosely to prevent contamination or pressure build up. Place the test tube in the ultrasonic cleaner. The cleaner must contain sufficient hot water to cover the test tubes to a level higher than the acid. All work is to be performed in a suitable fume hood.

6.4 Ultrasonicate the samples for 45 minutes.

6.5 Add 25 ml of Nanopure deionized water. Cap test tubes tightly and mix contents well. Allow the samples to stand for 30 minutes. This step is of extreme importance and can not be omitted.

6.6 Transfer digestate to a vacuum filter flask that has been prerinsed with nitric acid and DI water. The filter flask should be equipped with a 0.45 micron filter. Use several small volumes of DI water to rinse the filter. Discard this waste solution.

6.7 Store samples in clean 60 ml polyethylene bottles and label with laboratory ID, date, and analyst initials.

6.8 Carry a filter "spike" and blank filter through the digestion procedure for each batch of samples processed.

6.9 All glassware must be cleaned, acid stripped with 1+1 HNO3, and deionized water rinsed before reuse.

7. <u>Instrument Set-up</u>

7.1 Insert the Model 3030B system disk and User disk into the disk drives.

7.2 Turn instrument on. After initialization is complete, select "user index" with the "soft" keys.

7.3 Select Pb method from the user index. Adjust lamp current, slit width, and wavelength settings to those recommended . These settings will be displayed with the method in the user index.

7.4 Open lamp compartment cover and install Pb hollow cathode lamp in the four-lamp turret.

7.5 Turn on acetylene tank. Verify the tank has at least 80 psi pressure and the supply pressure is 10 psi. The compressed air should have a pressure of 40-100 psi.

7.6 Check that the oxidant and fuel flows are set at 45 and 20 units respectively.

7.7 Press "flame on/off" to ignite the flame. It is possible that the flame will not light initially due to air in the supply lines. Repeat ignition procedure until the flame ignites.

7.8 Allow burner head to warm up. The flame should be stable and uniform throughout its length.

7.9 Optimize the instrument for flame analysis of lead following the manufacture's instructions.

7.10 Calibrate the instrument using three different concentrations of analytical standards.

7.11 Determine the least squares fit to the calibration data, the correlation coefficient should be 0.995 or greater.

7.12 Analyze the control sample. Results must be within control limits of the known value. Record results on control chart. Reanalyze every ten samples. Restandardize if drift is apparent

7.13 Analyze samples. Ten percent of the samples must be analyzed in duplicate.

7.14 Calculate ambient lead concentrations as follows:

$$\text{Conc., ug/m}^3 = \frac{\text{conc., ug/ml} \times 8 \times 40 \text{ ml}}{\text{air volume sampled m}^3}$$

8. Method validation

The method sensitivity, precision and accuracy were determined using analytical standards in a dilute nitric acid matrix. The correlation coefficient for the lead calibration curve was: 0.999 with an x-intercept of -0.1.
The limit of detection (LOD) is 0.12 mg/l or 0.02 ug/m^3 assuming a 2000 m^3 sample volume.

LOD calculation: [intercept +(3 RSD intercept)]
slope = 0.021
x intercept = - 0.1
RSD = 18 %

9. Method Recovery

Hi-vol filter strips (1" x 10") were spiked with known amounts of analyte in dilute nitric acid, allowed to dry, and then analyzed by this procedure. Table I summarizes the results of this testing. The data represents four spiked levels prepared in triplicate.

TABLE I
LEAD METHOD RECOVERY DATA

Spike ug/ml	Concentration* ug/m3	Average Recovery percent %	RSD** %
5.00	2.0	100	1.8
2.00	0.8	101	1.3
1.00	0.4	103	2.8
0.50	0.2	102	4.7

* Assumes 2000 m^3 sampled
** RSD = relative standard deviation, n = 9

'tate of California

M E M O R A N D U M

To : Bob Kuhlman, Manager
Laboratory Services Section

Date : September 14, 1988

Subject : Revision to SOP NLB 005
Heavy Metals (Lead)
Analysis on Filters

Thru: Mike Poore
Spectroscopist

Roxana Walker
Air Pollution Specialist
From : Air Resources Board

Attached is a revision #3.2 to SOP NLB 005 - The Determination of Heavy Metals (Lead) in Filter Media by Atomic Absorption. This method will be used to initiate a new HiVol Pb analysis program in the Northern Laboratory Branch.

The significant differences in revision #3.2 are as follows:

1. The use of a new Perkin-Elmer, Model 3030B, atomic absorption spectrophotometer to replace the Varian 375.

2. The revised procedure is specific for Pb only - spike recoveries and limit of detection data were gathered for Pb only.

3. The sample preparation uses 3M Nitric acid as the extraction solution.

Attachment

State of California

ATTACHMENT 1

M E M O R A N D U M

To : Don Crowe, Chief
Northern Laboratory Branch

Bill Oslund, Chief
Air Quality Surveillance Branch

Thru : Bob Kuhlman, Manager
Laboratory Services Section

Roxana Walker
Air Pollution Specialist
From : Air Resources Board

Date : 4/12/88

Subject: Updated Proposal to Transfer TSP Pb Analysis to NLB and to Initiate PM10 Pb Analysis

The following details a proposed plan to have the Northern Laboratory Branch begin analysis for lead (Pb) on hi-vol filter samples from four NAMS TSP sites. Samples from these sites are currently being analyzed at AIHL. In addition, I include a proposal to demonstrate equivalency between measurements of Pb on PM10 filters and values obtained for Pb from TSP filters. I propose this in anticipation of a transfer of EPA's Pb standard from a TSP-based to a PM10-based criteria.

Rationale for Initiation of NAMS Pb Analyses and Sites Involved

EPA is concerned about the timeliness of our NAMS data submittals. The regional office requires receipt of our NAMS data within 100 days of the end of the calendar quarter. This allows for internal processing and submittal to EPA's National Aerometric Data Bank within 120 days of the end of the calendar quarter. To meet these schedules, we propose to transfer the Pb analysis of four NAMS sites, currently performed by AIHL, to Sacramento. The four sites are as follows:

San Diego-Island Avenue
Oceanside-1701 Mission Avenue (the NAMS designation of this site is in question and is being investigated)
Sacramento-Stockton
Sacramento-El Camino/Watt

Sample Delivery and Analysis Load

ARB Air Quality Surveillance staff will need to contact operators at the San Diego and Sacramento County agencies and instruct them to deliver the exposed TSP filters from the four NAMS sites to the ARB Sacramento laboratory. These TSP filter samples are currently delivered to AIHL after post-weighing by the district staff. Delivery to the ARB Sacramento laboratory should be initiated by 4/30/88.

In order to conserve resources, our staff will accumulate the samples and analyze them in one batch at the end of each calendar quarter. Analysis will be by atomic absorption spectroscopy (AA) and will require one-fourth of the filter sample. Standard operating procedure NLS005 will be used for preparation and analysis of the samples once it is revised to reflect the use of the Perkin-Elmer 3030B atomic absorption spectrophotometer. Sample load will total 60 per quarter, or 240 determinations per year.

Equipment and Staffing Resource Requirements

Laboratory equipment to initiate the Pb analysis program will be available due to the planned transfer of our hexavalent chromium analysis program to the El Monte laboratory.

It is estimated that initial method development and validation will require 160 person-hours of effort.

The subsequent follow on program will require a continuing 0.1 person effort.

Assurance of TSP Pb Data Base Continuity

In order to assure that the NAMS TSP Pb data [illegible] Sacramento Laboratory is comparable to that produced by AIHL, we will request from AIHL portions of archived TSP filters for which historical Pb data is available. TSP samples are analyzed by AIHL using x-ray fluorescence spectroscopy (XRF). We will attempt to obtain 12 filter samples, three from each of the four sites listed above. These will be analyzed in our laboratory using atomic absorption spectroscopy and the results reported prior to initiating routine analyses. By analyzing these archived samples, comparisons can made between TSP/XRF and TSP/AA.

Investigation of PM10 Pb vs. TSP Pb Analysis

In an attempt to demonstrate the equivalency of PM10 Pb analysis to TSP Pb analysis, I propose to analyze 18 archived PM10 filter samples for Pb. These PM10 samples will be chosen on the basis of the availability of TSP Pb data for the same site and sample date. Candidate sites are as follows:

San Rafael
San Francisco-Arkansas
San Jose-4th Street (collocated)
Oceanside (collocated)

TSP samples from the first three sites in this list are analyzed by the Bay Area Air Quality Management District using AA. TSP samples from the Oceanside site are analyzed by AIHL using XRF. By analyzing three PM10 samples from each of these sites (including collocated samplers), comparisons can be made between PM10 and TSP lead analyses.

SOP NLS005 Validation for Pb

To assure the validity of our Pb analysis using SOP NLS005, we will begin submitting quarterly results to NIOSH for Pb on PAT samples. We will also conduct interlaboratory atomic absorption testing for Pb on PM10 filters. PM10 samples will be split, then prepared and analyzed independently by our laboratory and by a contract laboratory .

Time Schedule

GOAL	MILEPOST DATES (assuming 4/1/88 START)
AQS staff to instruct San Diego and Sacramento County staff to begin mailing TSP filters for the four NAMS sites to ARB's Sacramento Lab as of 4/1/88	4/15/88
NLB staff to request from AIHL portions of archived TSP filters from the four NAMS TSP Pb sites of interest	4/15/88

Operator training and generation of calibration curves	4/25/88
Determination of method recovery and LOD	4/25/88
Report on QC results and SOP NLS005 revision	4/29/88
Begin analysis of archived PM10 samples for interlab comparison; send split samples to contract laboratory	5/1/88
Begin analysis of archived PM10 samples from Bay Area and Oceanside sites for comparison to TSP Pb data	5/1/88
Begin Pb PAT sample analysis with Round 92	5/1/88
Begin analysis of archived TSP filters from AIHL	5/1/88
Report on results of inter-laboratory split sample study	6/1/88
Report on Pb data comparison between PM10/AA and historical TSP/AA and TSP/XRF values	6/1/88
Report on comparison of ARB Lab TSP Pb data to historical AIHL TSP Pb data	6/1/88
Implementation of routine NAMS TSP Pb analyses	7/15/88
Initiate routine data reporting to TEALE	8/15/88

B.R. P21240, 5/18/92

California Air Resources Board
Monitoring and Laboratory Division

S.O.P. MLD 005, REV. 4.0

STANDARD OPERATING PROCEDURE FOR THE ACID DIGESTION AND ANALYSIS OF METALS FROM THE TOTAL SUSPENDED PARTICLES (TSP) COLLECTED ON EXPOSED, GLASS-FIBER FILTERS

1.0 SCOPE

This document details the acid digestion and analysis of metals from the total suspended particulates (TSP) collected on exposed, glass-microfiber filters. In addition to lead (Pb) analysis by flame atomic absorption (flame-AA), this revision includes an overview of the methods used for the analysis of arsenic (As), beryllium (Be), and cadmium (Cd) by graphite atomic absorption (GFAA). The same digestion solution is used for the atomic absorption analysis of As, Be, Cd, and Pb.

2.0 SUMMARY OF METHOD

Total suspended particulate (TSP) matter is collected from ambient air over a 24-hour period on a glass-microfiber filter. A 3 1/2" x 4 1/2" section is cut from the exposed, glass-microfiber filter. Metals from the TSP deposited on this section are extracted in dilute nitric acid by sonication with heating. The digestion solution is vacuum filtered, bottled, and stored at room temperature for later analysis by flame and graphite atomic absorption.

3.0 INTERFERENCES OF SAMPLE PREPARATION

3.1 Contamination of samples can occur from failure to clean the cutting board, scissors, and glassware. All cutting apparatus should be wiped thoroughly with a dry, laboratory wipe prior to each use. All glassware and digestion apparatus should be rinsed with a ten percent nitric acid solution prior to final rinsing with conductivity monitored D.I. water.

3.2 Unexposed filter pieces are used as the background media for method blanks and spikes; individual, unexposed filters should be quartered, and the pieces placed together in a glassine enclosure. Careful storage of these pieces is essential for quality control. Each enclosure should be placed in a labelled, manila folder for identification purposes in the event a blank is found to be contaminated. (Label each folder with the filter's factory number, for example, 00567345.)

3.3 During sample preparation and digestion rinsing, use only deionized (D.I.) water that is conductivity monitored, such as the Nanopure Brand from Barnstead. Regular tap water or deionized tap water may cause contamination. Always rinse the end of the Nanopure delivery tube with clean Nanopure water prior to each use.

3.4 Sampling using glass-fiber filters should be limited to using only filters from manufacturer-defined lots which have been determined with reasonable certainty by analysis to not interfere with the quality of the elemental analysis of the ambient samples collected on them. If the level of contamination varies from lot to lot and/or is greater than the limit of detection, the blank value assigned each lot should be subtracted from the final result of each exposed filter for each analyte.

4.0 INTERFERENCES OF ANALYSIS BY INSTRUMENTATION

4.1 Note the possible chemical, ionization, matrix, emission, and background interferences. An adequate description of the correction procedures for each is outlined in the Perkin-Elmer instrument manual.

5.0 APPARATUS AND MATERIALS

5.1 Atomic Absorption Spectrophotometer, non-Zeeman, with flame and graphite furnace capability, deuterium arc background correction, an autosampler, HGA furnace unit, forked platforms and pyrolytically-coated graphite tubes, and appropriate hallow cathode or electrodeless discharge lamps for the desired elements.

5.1.1 A Perkin-Elmer Model 3030B AA spectrophotometer, AS-60 autosampler, an HGA-600 furnace unit, and a PR-100 printer are used in this procedure.

5.2 Sonication bath with heating capability to 70 °C, built-in timer.

5.3 Glassware: Test tubes, 50-100-ml, equipped with screw-on, teflon lined caps; vacuum-filtration flask, 250-ml or 500-ml, with sidearm tubulation; storage bottle, 4-L, equipped with an adjustable, automatic dispensing unit with 50-ml capacity; storage bottle, 1-L, amber glass, equipped with an adjustable, automatic dispensing unit with 25-ml capacity.

5.4 Sample bottles, 60-ml, polypropylene, equipped with screw-top caps.

5.5 Cutting board with ruled edges; scissors, long edge.

5.6 Filtration membranes, 47 mm in diameter, 0.45 um pores, non-cellulose composition.

5.7 Magnetic filter funnel, polysulfone, 300-ml capacity, for use with 47 mm filtration membranes.

5.8 Laboratory Information Management System (LIMS) generated digestion worklist (Section 7).

5.9 Micropipets with polysulfone disposable tips, 10 to 1000 ul capacity.

5.10 Disposable laboratory wipes (kimtowels); self-adhesive labels; waterproof ink pen.

6.0 CHEMICALS AND REAGENTS

6.1 Nitric acid, HNO_3, concentrated, trace pure grade, double-distilled

6.1.1 Nitric acid diluted, 0.50 N

6.1.2 Nitric acid diluted, 0.25 N

6.2 Atomic Absorption Grade Reference Standards, NBS traceable material, 1000 ug/mL, in 2% HNO_3, two separate sources (1 standard, 1 control)

6.2.1 Stock dilution of standard and control for As, Be, and Cd, 1 ug/mL; calibrating standards and control diluted from 1 ug/mL stock dilutions

6.2.2 Stock dilution of standard and control for Pb, 100 ug/mL, calibrating standards and control diluted from 100 ug/mL stock dilutions

6.3 Matrix modifiers, atomic absorption grade: Palladium (5000 ug/mL) in nitric acid; magnesium (10,000 u/mL) in nitric acid, and nickel (50,000 ug/mL) in nitric acid

6.3.1 As, Be, and Cd analyses modifiers for TSP samples: see Section 12.

6.3.2 Pb analysis modifier for TSP samples: none

6.4 Argon gas cylinder, 99.999% purity

6.5 Air, compressed, with Perkin Elmer particulate, oil, and water filter

6.6 Acetylene gas cylinder (acetone base), Grade 5

6.7 Cooling water system capable of maintaining a 2.5 L/min flow

7.0 LABORATORY INFORMATION MANAGEMENT SYSTEM (LIMS)

7.1 Prior to beginning sample preparation (Section 11), a "Digestion Worklist for SACDG," which lists the TSP samples to be prepared for analysis, must be generated. See Appendix A, "LIMS Operations for SSI/PM10 Mass Analysis and Extraction," April, 1990, for a general description of worklists. At present, additional and/or detailed information regarding LIMS must be gathered from the laboratory LIMS coordinator.

8.0 GLASSWARE AND SAMPLE BOTTLE PREPARATION PROCEDURE

8.1 All glassware and sample bottles, including caps, should be washed thoroughly with laboratory detergent, rinsed with D.I. water, rinsed with a ten percent nitric acid solution, and final rinsed three times with D.I. water. Allow the clean test tubes to dry upright overnight lightly covered by a kimtowel.

8.2 A ten percent (1:10, concentrated nitric acid: D.I. water) nitric acid solution should be prepared in bulk for rinsing, and put in a 4-L, polyethylene bottle equipped with a dispenser.

9.0 REAGENT AND SPIKE SOLUTION PREPARATION

9.1 Carefully prepare a 0.50 N nitric acid solution in a 1-L volumetric flask by diluting 31.5-mL of concentrated nitric acid in D.I. water. In addition, prepare a 0.25 N nitric acid solution in a 1-L volumetric flask by diluting 15.8-mL of concentrated nitric acid in D.I. water. Store these solutions in labelled, amber bottles.

9.2 Prepare a 1000 ug/mL stock solution of each metal and store in acid washed, labelled, polyethylene bottles.

9.2.1 For example, dilute 100 ul of 1000 ug/mL arsenic to a final volume of 100 mL to yield a 1000 ng/mL solution of arsenic.

9.3 Prepare a set of standards of the above stock solutions to produce a spike solution, mix, and store in an acid washed, labelled, polyethylene bottle. The final concentration of each metal in this solution should yield a concentration at least five times the limit of detection when a 1 mL aliquot is diluted to 40 mL during digestion.

10.0 METHOD SPIKE AND BLANK PREPARATION

10.1 Method blanks are prepared by cutting a 3 1/2" by 4 1/2" section from an unexposed glass-microfiber filter per Section 11. (Note Interference 3.2). This section should be taken through the digestion procedures listed in Section 11. One method blank should be digested along with the samples listed on the digestion worklist.

10.2 Method spikes are prepared by cutting a 3 1/2" by 4 1/2" section from an unexposed glass-microfiber filter per Section 11.6. (Note Interference 3.2). A method spike should be prepared and digested with each group of samples.

Pipette a 1-mL aliquot of the spike solution (Section 9.0) onto the filter pieces in the test tube. Allow the filter pieces to air dry for 3 to 4 hours. Digest these with the samples as described in Sections 10.6 through 10.9.

11.0 SAMPLE PREPARATION PROCEDURE

11.1 For each sample to be extracted, clean a test tube as described in Section 8.0.

Affix each of the previously prepared labels, including the method blanks, onto individual test tubes. The labels should adhere confidently, but should be removeable.

11.2 Use a water-proof pen to prepare self-adhesive labels for each digestion sample. On each label clearly write the sample's assigned laboratory identification number, the digestion date, and the analyst's initials.

The method blank and spike are extracted with each set of samples. Prepare these labels as "SPIKE" and "BLANK" Indicate the preparation date or group, and analyst's initials. For the spike samples, also note the concentration of each metal (i.e., Pb = 20 ppm; As = 30ppb; etc.).

11.3 Thoroughly wash and rinse a 1-L amber glass bottle fitted with an adjustable dispensing unit.

11.4 Fill this bottle with 0.50 N nitric acid. Adjust the dispenser for 20-mL aliquots; verify dispensed volume by weight. (Consider the dilute acid solution to be the same density as pure water).

11.5 Using a dry, disposable kimtowel, thoroughly clean all cutting apparatus. Place clean, open kimtowels around the immediate cutting area to prevent contamination.

11.6 Repeat the following steps (11.6.1 through 11.6.5) for each sample listed on the digestion worklist.

11.6.1 Use the cutting board to cut a 3 1/2" x 4 1/2" section of the exposed part of each filter (Figure 11.6.1). Place the filter exposed-side up when cutting. Cut the filter in half, retaining the portion without the factory stamped number. Make certain that the cut halves the exposed area, and not just the entire filter. (Note: The filter may not have been exposed symmetrically, and thus cutting the filter in half may not always cut the exposed area in half.) Cut the retained half in half. Again, make certain that the cut

halves the exposed area, and not just the entire half of filter. The resulting product should be a section one-quarter in size of the original, exposed area of the filter and should measure 3 1/2" x 4 1/2".

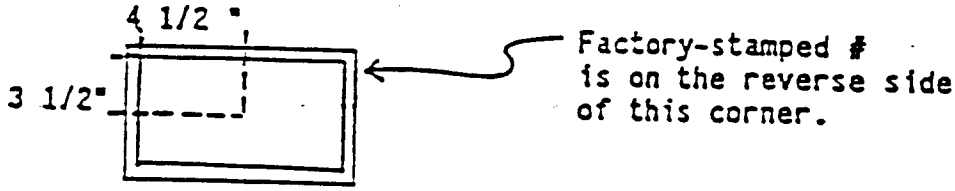
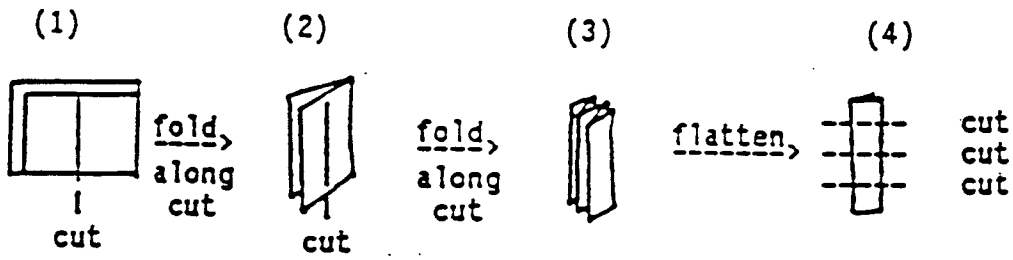


Figure 11.6.1, Exposed Filter Section.

The section removed should not be the corner with the factory-stamped number. Retain the factory-stamped corner for identification purposes. Place the remaining three quarters of the filter back into the glassine enclosure.

11.6.2 For duplicate samples, use the diagonal corners adjacent to the factory-stamped corner.

11.6.3 Using the long-edge scissors, cut the 3 1/2" by 4 1/2" section into half centimeter squares. This is accomplished by the following steps of cutting and folding:



The 3 1/2" by 4 1/2" section should be cut in half (step1). Follow steps 2 through 4 for each half created in step 1. Cut the squares (step 4) directly into the labelled test tube which has the corresponding LIMS number.

11.6.4 Next, dispense a 20 ml aliquot of 0.50 N nitric acid into the test tube with the filter pieces. Be certain the acid covers all the pieces of filter. Seal the test tube with a Teflon-lined cap, place the test tube in a rack, and allow to stand 12 hours at room temperature.

11.6.5 After twelve hours, place the filled racks 2-3 cm apart in the sonication bath; prior to sonication, slightly loosen each test tube cap prior to sonication.

11.7 Each of the samples should sonicate for one full hour at 60 ± 5 °C. Follow the manufacturer's suggestions for effective operation of the sonication bath.

After the samples have sonicated with heating for one hour, dispense a 20 mL aliquot of Nanopure D.I. water into each test tube using a 4-L bottle equipped with a dispensing unit. Gently mix the sample solutions. Return them to the sonicating bath. Sonicate an additional hour at 70 ± 5 °C.

11.8 In addition to the samples on the worklist, follow steps 11.6.1 through 11.6.5 for the method blanks and spikes.

11.9 After the samples, blanks, and spikes have finished sonicating the second time, allow the solutions to cool to room temperature. The digestion solutions should be vacuum filtered using the set-up in Figure 11.9.1.

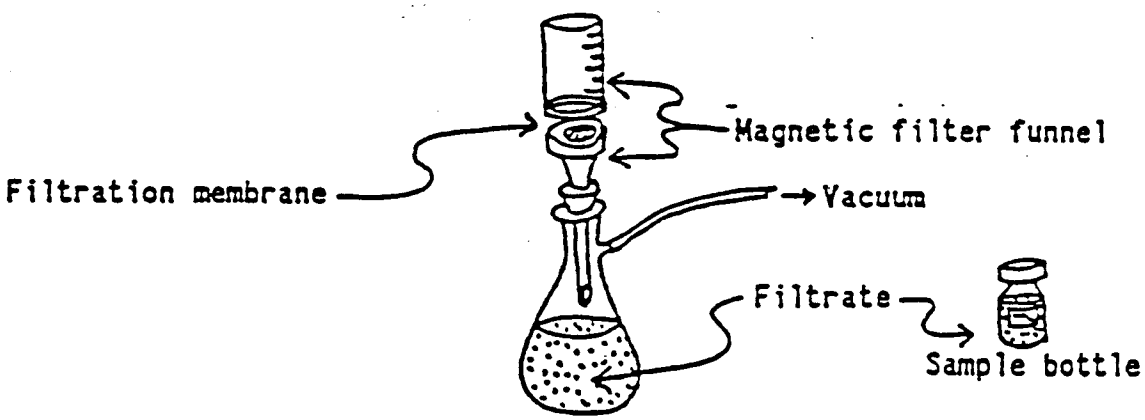


Figure 11.9.1, Vacuum Filtration Apparatus.

11.10 Repeat the following steps (11.10.1 through 11.10.5) for each sample listed on the digestion worklist, and the method blank and spike.

Note: The filtering apparatus should be clean prior to use.

The spikes and blanks should be filtered after filtering all the samples listed on the digestion worklist.
The filtration membrane should be rinsed with a few milliliters of D.I. water followed by a few milliliters of 0.25 N nitric acid prior to filtering the digestion solutions, and should be changed after every filter.

11.10.1 Transfer the label from the test tube directly to the individual sample bottle in which the filtrate will be stored. The label should be adhered firmly and completely to the bottle, but should be easily removable.

11.10.2 With the filtration membrane in place, pour the digestion solution into the magnetic filter funnel. Let the vacuum pull the liquid through. Any filter fragments or large particles should remain in the funnel.

11.10.3 After almost all of the liquid has been pulled through, gently lift one side of the upper section of the filter funnel from the lower section in a slight up and down motion several times, and then disconnect the apparatus carefully.

11.10.4 Pour the filtrate from the vacuum test tube into the sample bottle, and seal the bottle with a clean lid.

11.10.5 Rinse the filtering funnel several times with Nanopure D.I. water to remove any particles or residue. In order to rinse the apparatus thoroughly, send a 50-ml aliquot of Nanopure D.I. water through the filtering apparatus with the membrane in place. Discard all rinse solutions, and reconnect the apparatus. Replace the old membrane. When replacing the old membrane, remember to discard the acid used to moisten and prepare the new membrane.

11.11 The digestion solution is now ready to be analyzed by atomic absorption (Section 12). Store the filled sample bottles in shallow, labelled boxes at room temperature.

11.12 Enter the digestion date for each sample on the digestion worklist (Section 7). The worklist should be filed appropriately.

12.0 INSTRUMENT OPERATION

12.1 Follow the manufacturer's operation manual for a detailed description of the set-up and operation of the spectrophotometer and attached peripherals.

12.2 Flame-AA:

Insert the Model 3030 Systems disk and the User Methods disk for flame analysis. Switch POWER to ON. It takes approximately 45 seconds for the Element Select Mode to appear.

Assuming a method is pre-defined for the element to be detected, press USER INDEX to recall all stored programs for Flame-AA. After the entire program page is displayed, find the desired element. Press the number corresponding to the element desired; wait about 5 seconds for the program to be loaded. Note that the Programming Mode screen will now be displayed. If a method is not pre-defined, consult the operation manual for assistance.

Using the ADVANCE soft key at the bottom of the screen, scan through the numbered parameters and change any specifications necessary. Lamp energy should be at zero.

Install the desired lamp into the lamp turret. If the lamp is a hallow cathode, simply connect the HCL to the HCL socket at the back of the lamp compartment; use ADVANCE to move to the lamp energy adjustment line on the programming page; enter the recommended energy on the keypad and press the ENTER soft key located at the bottom of the screen.

If the lamp is an electrodeless discharge, the Power Supply Module must be turned on; connect the EDL to the EDL line to the Power Supply Module; connect the EDL output line from the Power Supply Module to the EDL socket located at the back of the lamp compartment; adjust the wattage output on the Power Supply Module to the recommended level. Depending upon lamp age, it generally takes about 15 minutes to warm up a lamp, HCL or EDL.

Press SETUP. Fine tune the wavelength to obtain a maximum energy by using the coarse and fine wavelength controls. The energy is maximum when the bar graph is maximum. Adjust the energy to maximum by using the turret orientation screws. Press GAIN if necessary to maintain a mid-range value.

Press RUN to enter the Run Mode. Assuming the impact bead or flow spoiler is in place, the burner head has been aligned with a copper lamp and standard, the aspirator tube has been checked, the burner chamber is clean and the nebulizer properly adjusted, and the gases are turned on and adjusted to the proper flow, light the flame by pressing FLAME ON. Aspirate a blank solution for a couple minutes to verify the condition of the flame.

While aspirating the blank, press the AUTO ZERO soft key. Aspirate the first standard and press the STD 1 soft key. When the display changes from Wait Mode to Read/Mean Mode, calibration using the first standard is complete. Continue until all standards have been defined. When complete, determine the validity of the calibration. If the calibration is acceptable, proceed to the determination of the samples.

Aspirate a sample and press READ. The concentration will appear on the main display. Press PRINT to print all pre-defined information output to the printer each time READ is pressed.

12.3 The following is a checklist of some items to be aware of when operating the Flame-AA. The information provided here is not intended to replace the operator's manual, but does include information not clearly or readily presented in the manual.

12.3.1 Lamp energies. The energy of each lamp should be recorded when used. This will highlight any lamp malfunctions or alignment problems by indicating a substantial drop in energy.

12.3.2 Lamp alignment. The selected line and the lamp position should be fine tuned based on the maximum energy output. Consult manual for sensitivity discussion of each line for each element. Also, note the slit width for each element.

12.3.3 Burner head. Positioning the burner at a 45 degree angle may be helpful for highly sensitive elements. The 10 cm head provides the best sensitivity for air-acetylene flames.

12.3.4 Nebulizer adjustment. Usually, the nebulizer only needs to be adjusted after cleaning the burner's mixing chamber. Consult operator's manual for proper adjustment of the internal spring system.

12.3.5 Gas flow adjustment. In addition to determining the acetylene/air ratio which gives the maximum sensitivity, be aware of analyzing elements requiring a yellow-rich flame versus a lean-blue flame. Also, be aware of the correct acetylene flow and the available tank pressure.

12.3.6 Impact bead and flow spoiler. The impact bead improves sensitivity for solutions generally regarded as "clean." Solutions which are high in solids or alkalines should be analyzed using the flow spoiler.

12.3.7 Deuterium lamp. Fluctuation in energy indicates possible deterioration. Replace only when necessary.

12.4 Graphite-AA:

Insert the Model 3030 Systems disk and the User Methods disk for graphite analysis. Switch POWER to ON. It takes approximately 45 seconds for the Element Select Mode to appear.

Assuming a method is pre-defined for the element to be detected, press USER INDEX to recall all stored programs for Graphite-AA. After the entire program page is displayed, find the desired element. Press the number corresponding to the element desired; wait about 5 seconds for the program to be loaded. Note that the Programming Mode screen will now be displayed. If a method is not pre-defined, consult the operation manual for assistance.

Using the ADVANCE soft key at the bottom of the screen, scan through the numbered parameters and change any specifications necessary. Lamp energy should be at zero.

Install the desired lamp into the lamp turret. If the lamp is a hallow cathode, simply connect the HCL to the HCL socket at the back of the lamp compartment; use ADVANCE to move to the lamp energy adjustment line on the programming page; enter the recommended energy on the keypad and press the ENTER soft key located at the bottom of the screen.

If the lamp is an electrodeless discharge, the Power Supply Module must be turned on; connect the EDL to the EDL line to the Power Supply Module; connect the EDL output line from the Power Supply Module to the EDL socket located at the back of the lamp compartment; adjust the wattage output on the Power Supply Module to the recommended level. Depending upon lamp age, it generally takes about 15 minutes to warm up a lamp, HCL or EDL.

Press SETUP. Fine tune the wavelength to obtain a maximum energy by using the coarse and fine wavelength controls. The energy is maximum when the bar graph is maximum. Adjust the energy to maximum by using the turret orientation screws. Press GAIN if necessary to maintain a mid-range value.

Set argon pressure to 45-65 psig. Turn on water cooling system. Turn POWER on the HGA Power Unit to ON. Spectrophotometer should be turned to ON.

Verify that graphite tube and platform are properly positioned. Note that new tubes should be conditioned prior to use. Program the recommended heat and cool sequence to condition the tube.

The furnace should be aligned for maximum energy output. The autosampler tip should be adjusted to new tube position.

From the HGA Programming Mode screen, enter all operating parameters. The autosampler must be programmed from the Autosampler Programming page. Go into CONT Mode to set-up the autosampler. It is recommended that a calibration be stored every ten samples for high noise elements.

Program the calibration and matrix modifier positions on the sample holder. Start with a single mean calibration to determine the accuracy of the standards. The control and standard checks can be programmed on the Autosampler Programming Mode screen.

Consult the operator's manual for a detailed description of all programming and operating instructions. See Section 12.6 below for an outline of specific elements.

12.5 The following is a checklist of some items to be aware of when operating the Graphite-AA. The information provided here is not intended to replace the operator's manual, but does include information not clearly or readily presented in the manual.

12.5.1 Lamp energies. The energy of each lamp should be recorded when used. This will highlight any lamp malfunctions or alignment problems by indicating a substantial drop in energy.

12.5.2 Lamp alignment. The selected line and the lamp position should be fine tuned based on the maximum energy output. Consult manual for sensitivity discussion of each line for each element. Also, note the slit width for each element.

12.5.3 Platform and tube. The NLB currently uses a forked platform in an effort to obtain an improved performance over the L'vov platform. Forked platforms have shown good repeatability, smoother drying, and more even wear of the tubes. Most elements require a platform and should not be volatilized directly off the wall of the tube. Gently wipe the cylinder with a kimwipe before replacing tube.

12.5.4 Drying/pyrolysis/atomization setup. Consult manual for approximate temperatures and ramp times. Drying should be a smooth melt. Fine tuning of the initial pyrolysis and atomization settings can be obtained by plotting absorbance versus temperature to find the maximum absorbance.

12.5.5 Quartz windows. Clean with D.I. water or methanol to remove dust build-up. If windows are splattered, the drying step needs to be adjusted. Be certain windows are dry before replacing.

12.5.6 Matrix modifiers. Modifiers should be used to volatilize interferences prior to atomization of the analyte, and to increase the amount of analyte atomized. Palladium/magnesium mixtures, and nickel/magnesium mixtures are currently used by the NLB. Literature indicates significant differences in preferred combinations. Plot modifier:standard ratios versus absorbance to determine maximum absorbance and minimum background.

12.5.7 Contact rings. If random peaks appear or drying times become insufficient, blow out the graphite cylinder to clear the inlet gas flow. If condition persists, change the contact rings.

12.5.8 Deuterium lamp. Fluctuation in energy indicates possible deterioration. Replace only when necessary.

12.6 Table 1 below outlines the instrument setup for some specific elements.

Table 1. OUTLINE OF THE ANALYSIS OF AS, BE, & CD BY FLAMELESS ATOMIC ABSORPTION

ARSENIC

Matrix modifier: 0.052 mg $Ni(NO_3)_2$ + 0.017 mg $Mg(NO_3)_2$
Instrument calibration: linear to 50 ng/mL **
Furnace conditions:

STEP	TEMP	RAMP	HOLD
Drying	250	20	30
Pyrolysis	1300	5	20
Cooling	20	1	20
Atomization	2400	0	2
Cleaning	2600	1	3

BERYLLIUM

Matrix modifier: 0.015 mg Pd + 0.01 mg Mg(NO3)2
Instrument calibration: linear to 3 ng/mL **
Furnace conditions:

STEP	TEMP	RAMP	HOLD
Drying	250	30	20
Pyrolysis	1500	1	10
Atomization	2500	0	4
Cleaning	2600	1	2

CADMIUM

Matrix modifier: 0.015 mg Pd + 0.01 mg Mg(NO3)2
Instrument calibration: linear to 5 ng/mL or
second coefficient to 15 ng/mL **
Furnace conditions:

STEP	TEMP	RAMP	HOLD
Drying	250	30	20
Pyrolysis	700	1	20
Atomization	1600	0	4
Cleaning	2600	1	3

** Indicates the range of standards used and the character of the calibration; actual ranges of linearity and second order character may be higher.

Stop flow of argon gas during the atomization step; other steps require a continuous argon flow of 300 ft3/min. Ramp rate equals zero at this step for maximum power heating. An argon gas flow of 10 to 30 ft3/min may be required during analysis of samples with a high background interference. Generally, the background for regularly collected TSP samples is considerably low and does not require an argon purge; deuterium lamp correction is suggested.

13.0 ANALYSIS

13.1 Note Section 14.0 for a description of analysis quality control. A detailed listing of quality control data can be located in the "NLB-Inorganic Section's Quality Control Reports."

13.1.1 For the analysis of TSP samples for lead:

- Calibrate linearly to 5 ug/mL. Verify calibration with a mid-range standard. Verify accuracy with a non-standard control within the calibration range: Control should be within ± 10 % of the expected value. If the control is out of range, re-calibrate or prepare a new set of standards and a new control.

- A check of a mid-range standard should be made every ten samples. Should a standard check be greater than ± 10 % of the expected value, recalibrate and re-analyze samples back to the point where the calibration was known to be in control.

- The method spike and blank should be treated as samples and should be analyzed along with the ambient-exposed filter samples.

13.1.2 For the analysis of TSP samples for arsenic, beryllium, and cadmium:

- Calibrate linearly to 50 ng/mL for arsenic and to 3 ng/mL for beryllium; calibrate by second coefficient to 15 ng/mL for cadmium. It should be noted that use of the second coefficient calibration allows for a higher range in order to avoid diluting a large number of samples. Verify calibration with a mid-range standard. Verify accuracy with a non-standard control within the calibration range: Control should be within ± 10 % of the expected value. If the control is out of range, re-calibrate or prepare a new set of standards and a new control.

- A check of a mid-range standard should be made every ten samples. Should a standard check be greater than ± 10 % of the expected value, recalibrate and re-analyze samples back to the point where the calibration was known to be in control.

- The method spike and blank should be treated as samples and should be analyzed along with the ambient-exposed filter samples.

14.0 PERFORMANCE CRITERIA

14.1 In addition to the method blanks and spikes described in Section 11.1, every tenth sample should be extracted in duplicate to verify the method. The sample identification label for a duplicate should be marked with a "D," along with the other necessary information. The duplicates should be extracted following the steps outlined in Section 11, SAMPLE PREPARATION PROCEDURE.

The atomic absorption results for duplicates must be within ten percent relative difference for samples greater than ten times the instrument detection limit. Ten times the detection limit is usually defined as the limit of quantitation (LOQ). The maximum allowable differences are not applicable to samples less than the LOQ.

14.3 The atomic absorption results for the method blanks must be less than the detection limit for As, Be, Cd, and Pb.

14.3.1 The limit of detection (LOD) is calculated as follows:

LOD = X-intercept + (3 x standard deviation)(% rsd low standard)

Analyte	Detection Limit
As	0.4 ng/m3
Be	0.02 ng/m3
Cd	0.2 ng/m3
Pb	0.02 ug/m3

14.4 The characteristic mass, m_o, of each element represents the mass of analyte that yields a one percent absorbance or a 0.0044 absorbance. The characteristic mass should be determined for each new method. The characteristic mass should be within ± 20 % of the manufacturer's expected value - the "cookbook" value.

$$m_o \text{ (GFAA)} = \frac{[(\text{uL standard analyzed x conc. analyzed x } 0.0044)]}{\text{Absorbance-Seconds}}$$

14.4.1 Table 2 lists some characteristic masses for some specific elements.

Table 2. Characteristic Masses for Specific Elements.

	Arsenic	Beryllium	Cadmium
m_o (lit) *	15.0	0.5	0.5
m_o (NLB)	15.53	0.59	0.56

* Literature values are based upon Perkin-Elmer data.

14.5 For Flame-AA, the characteristic concentration of the low standard should be determined for each element analyzed.

$$\text{Char conc.} = \frac{\text{conc. of standard X } 0.0044}{\text{measured absorbance}}$$

14.5.1 The characteristic concentration for Pb was determined to be 0.15 for the NLB's Model 3030B - Flame-AA. After cleaning the burner chamber and adjusting the nebulizer, the characteristic concentration should be within 20 % of the maximum known for the instrument.

Perkin-Elmer literature gives a value of 0.19. However, nebulizer sensitivities vary from one unit to another. Also, sensitivities using a corrosive resistant nebulizer are lower than with the standard stainless steel nebulizer.

15.0 TROUBLESHOOTING

15.1 Graphite-AA:

After a method has been developed and confirmed to be accurate and precise, it should not be necessary to make adjustments in the method. Changes in the drying or peak shape are indicative of possible problems. The items below are assuming the method has already been accurately developed.

Problem	Possible reason
High m_o	Tube aging
Low m_o	Contaminated standards or matrix modifier
Temperature error	Water flow low; water too hot
Tube error	Workhead is open; tube damaged; contact rings damaged or dirty
Furnace error	Windows out; tube missing; BG off
Baseline dip	Dirty windows
Multiple peaks or sudden poor drying	Contact rings damaged
Flattened peak	Tube aging
Peak shifted to left	Tube damaged or autosampler tip clogged
Gas pressure error	Cylinder low; pressure low
Negative results	Autozeroed incorrectly
Poor precision	Autosampler tip clogged or contaminated or standards contaminated

15.2 Flame-AA:

Problems associated with the Flame-AA are significantly less than with Graphite-AA. The items below are assuming the method and program definement have already been accurately developed.

Problem	Possible reason
Gas pressure error	Cylinder low; pressure low
Negative results	Autozeroed incorrectly

Poor precision	Standards contaminated
Low sensitivity	Burner head alignment or standards contaminated; lamp alignment wrong or lamp energy wrong
Drain error	Waste water level too high or low; drain connected improperly

16.0 INSTRUMENT MAINTENANCE

16.1 Routine maintenance of Flame-AA:

- Check condition of aspirator tubing before each use.
- Run business card in burner slot to remove lodged materials before each use. Confirm with visual inspection of even flame.
- Verify lamp energies are consistent.
- Check drainage tubing and drain reservoir level.
- Clean burn chamber every six months. Re-adjust nebulizer per manual's instructions.
- Check burner alignment after instrument changeover.

16.2 Routine GFAA maintenance:

- Clean quartz windows with kimwipe and methanol.
- Condition (high temperature burn) new tubes.
- Wipe contact rings with kimwipe before replacing tube.
- Check condition of contact rings.
- Check water flow inlet/outlet.
- Check argon tank pressure.
- Verify lamp energies are consistent.
- Check flushing system tubing for clogs or leaks.
- Check furnace alignment after instrument changeover.

17.0 INSTRUMENT OUTPUT

17.1 Figures 17.1.1 through 17.1.4 are representations of the standard output for the analysis of arsenic, beryllium, cadmium, and lead.

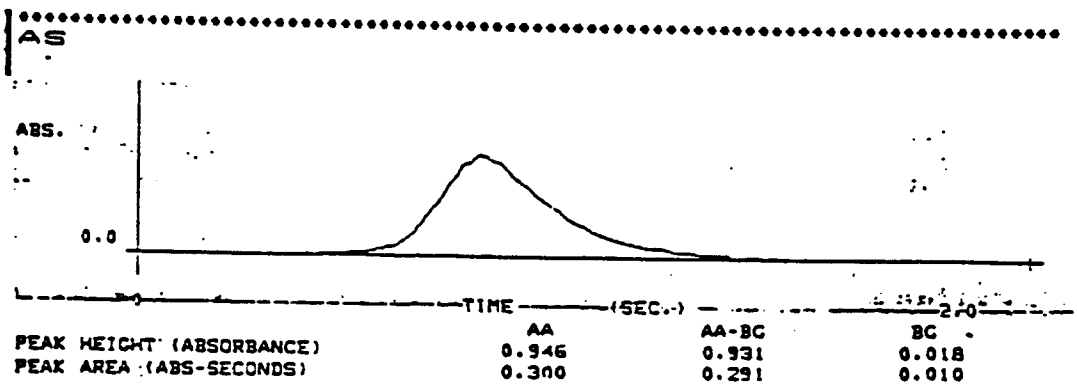


Figure 17.1.1. Arsenic peak output.

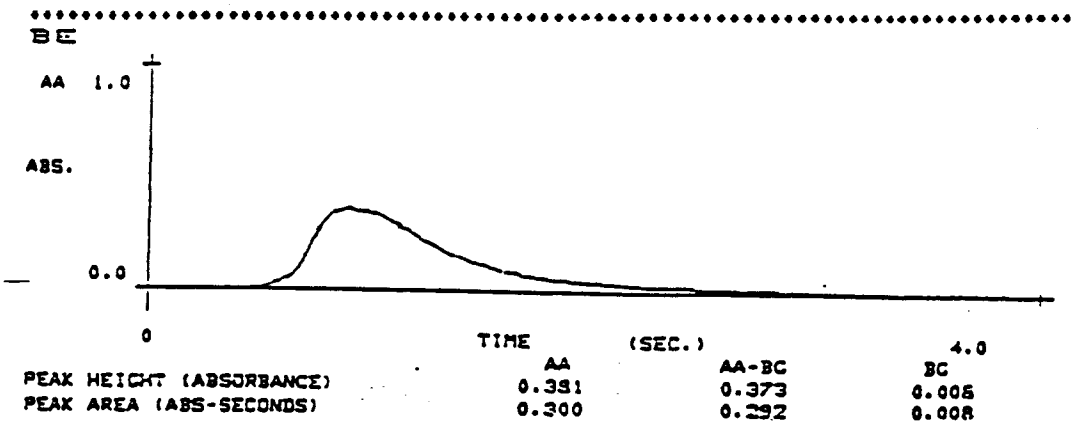


Figure 17.1.2. Beryllium peak output.

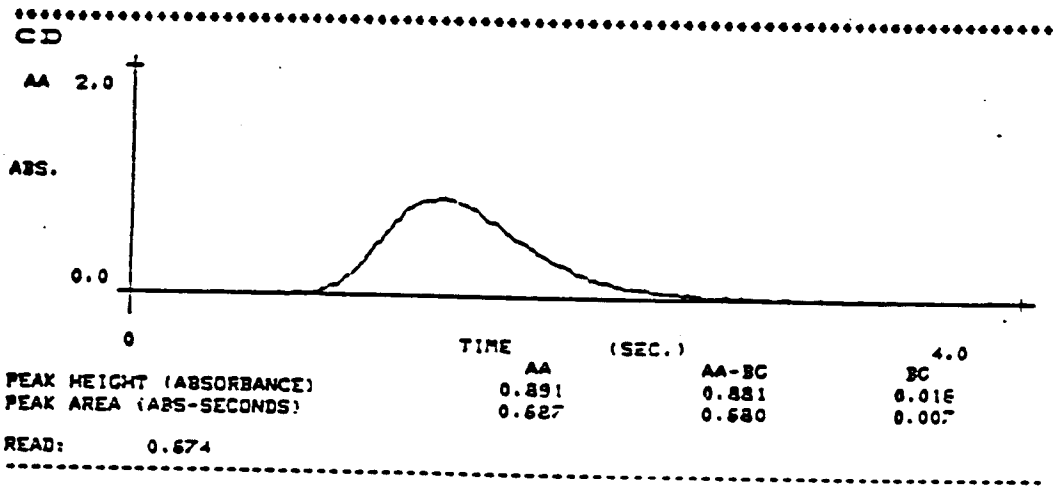


Figure 17.1.3. Cadmium peak output.

PB

	AA	AA-BC	BC
ABSORBANCE	0.156	0.155	0.001

0.155

	AA	AA-BC	BC
ABSORBANCE	0.155	0.154	0.001

0.154

	AA	AA-BC	BC
ABSORBANCE	0.156	0.154	0.002

0.154

MEAN= 0.154 STD.DEV.= 0.001 COEF.VAR.= 0.35 %

5.00 STANDARD 1

Figure 17.1.4. Lead data output.

18.0 ATOMIC ABSORPTION SCHEMATIC

18.1 The principle of operation for analysis by atomic absorption is graphically represented in Figure 18.1.1 below.

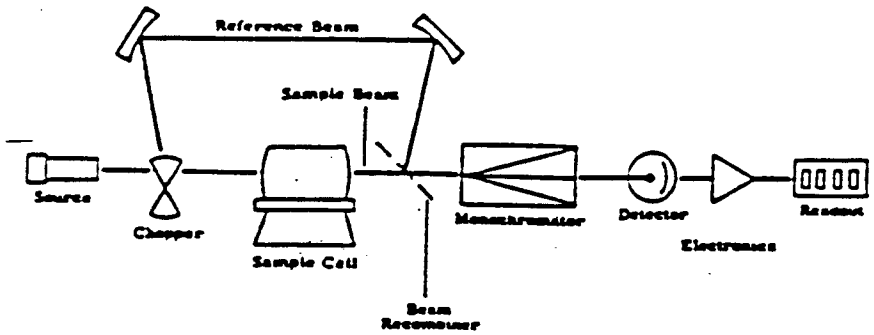


Figure 18.1.1. Atomic Absorption Schematic.

APPENDIX C

THE AIR RESOURCES BOARD'S MONITORING AND LABORATORY DIVISION'S METHOD FOR DETERMINING THE LIMT OF DETECTION

Analytical Limits of Detection (LOD) must be calculated. The LOD for each method must be calculated by the following equation (reference):

LOD = A + 3S

where

A is the least squares intercept calculated from the multipoint data (section 4.1.2).

S is the standard deviation of replicate determinations of the lowest standard. At least 3 replicates are required. The lowest standard must be run at 1 to 5 times the estimated detection limit. If data is not available in the concentration range near the detection limit, S may be estimated by:

S = RSD x A

where RSD is the relative standard deviation of the lowest standard analyzed.

The equation as listed above was obtained from the Compendium of Methods for the Determination of Toxic Organics in Ambient Air. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency; 1984 April: Method T)1. Publication No. EPA-600/4-84-041.

Note that the Laboratory Services Section policy is to report all analysis results above the analytical limits of detection. However, data errors may approach ± 100% at levels < 10 x LOD.

All analysis methods must be written in detail as a Standard Operating Procedure to be used in the laboratory. Any subsequent revisions or improvements are documented. The procedures are reviewed yearly by laboratory management and the Quality Assurance Section to insure that they are being followed properly.

APPENDIX D

PUBLIC INFORMATION REQUEST LETTER

STATE OF CALIFORNIA
AIR RESOURCES BOARD
1102 Q STREET
P.O. BOX 2815
SACRAMENTO, CA 95812

PETE WILSON, Governor

March 15, 1991

Dear Sir or Madam:

Request for Information Regarding Inorganic Lead

I am writing to request information on the atmospheric chemistry, sources, total exposure to, and health effects of inorganic lead. The California Air Resources Board (ARB) is requesting this information as part of our toxic air contaminant program. This program is mandated by California Health and Safety Code Section 39650 et seq. A summary of this program is contained in Attachment 1, which also describes the statutory basis of the program.

The information that you provide will be considered in an evaluation of inorganic lead as a candidate toxic air contaminant; the evaluation will be conducted jointly by the ARB and the state's Department of Health Services (DHS). As part of the evaluation, we will consider all available health and exposure information regarding inorganic lead.

In January 1991, we conducted a reference search on inorganic lead exposure and health effects using several data bases from the Dialogue data retrieval system. These references include material published from 1978 to late 1990. The attached bibliography (Attachment 2) lists the most recent and relevant references from this information search. We are requesting additional, pertinent information on inorganic lead health effects and exposure, including any material that may not be available to the public or that is not included in the attached bibliography.

We are also requesting information relevant to human exposure to inorganic lead in California through media other than outdoor ambient air. Specifically, we are requesting information concerning total exposure to inorganic lead through inhalation, ingestion, and skin absorption, with special emphasis on inhalation exposure in the indoor environment. This includes inorganic lead concentrations in various media, consumption information, bioadsorption rates, body burden studies, etc. We are also requesting data on emission sources responsible for inorganic lead exposures in media other than outside air.

The information that you provide with the exception of trade secrets may be released to the public. The ARB's procedure for handling information claimed to be trade secrets is explained in Attachment 3.

If you believe that any of the information you are providing is a trade secret or otherwise exempt from disclosure under any other provision of law, you should identify it as such at the time of submission (Health and Safety Code Section 39660(e)). The ARB may ask you to provide documentation of your claim of trade secret or exemption at a later date.

I would appreciate receiving by April 10, 1991 any relevant information you wish to submit. Your help in expediting our review will be greatly appreciated. Please send the information to the attention of:

Genevieve Shiroma, Chief
Toxic Air Contaminant Identification Branch
Re: Inorganic lead
California Air Resources Board
P.O. Box 2815
Sacramento, California 95812

If you have further questions regarding indoor inorganic lead exposure, please contact Peggy Jenkins at (916) 323-1504. For other questions, please contact Barbara Cook at (916) 327-5625.

If you are not the person to whom this request should be addressed, please forward it to the appropriate person in your organization. Also, please let us know whether you would like to continue to receive information inquiries for other candidate substances, and if not, if there is anyone in your organization to whom such requests should be sent.

Sincerely,

Peter D. Venturini, Chief
Stationary Source Division

Attachments

cc: George Alexeeff, Department of Health Services
Henry Voss, Department of Food and Agriculture
Ron Oshima, Department of Food and Agriculture
James Ryerson, President, California Air Pollution Control Officers Association
Stew Wilson, Executive Secretary, California Air Pollution Control Officers Association
David Howekamp, Environmental Protection Agency (EPA), Region 9
Mike Stenburg, EPA, Region 9
Kathy Diehl, EPA, Region 9
Assemblywoman Sally Tanner, Chairwoman
Committee on Toxic Materials
Senator Ralph Dills, Chairman
Committee on Governmental Organization
Senator Art Torres, Chairman
Committee on Toxics and Public Safety Management
Genevieve Shiroma, ARB
Peggy Jenkins, ARB
Barbara Cook, ARB
Scientific Review Panel Members
Air Pollution Control Officers

ATTACHMENT I

State of California
AIR RESOURCES BOARD

Toxic Air Contaminant: Program Statutory Basis and Process

California's toxic air contaminant program is established by Health and Safety Code sections 39650-39674. This law sets forth the process for:

1. assessing the risk posed by substances;
2. identifying by regulation substances determined to be toxic air contaminants; and
3. managing the risk by adopting control measures for the identified toxic air contaminant.

The law defines a toxic air contaminant as an air pollutant which may cause or contribute to an increase in mortality or an increase in serious illness, or which may pose a present or potential hazard to human health.

Two reports are prepared during this risk assessment and risk management process. The first report, which is prepared by the Air Resources Board (ARB) and the Department of Health Services (DHS) staffs, contains information on the health effects of the substance. This report is used to determine whether a substance should be identified as a toxic air contaminant. We refer to this report as the "ID" report. The second report, which is prepared by the ARB staff after a substance has been identified as a toxic air contaminant, is on the need for an appropriate degree of regulation of that substance. We refer to this report as the "regulatory needs" report. Both reports are made available to the public for review and comment.

Before the ARB can formally identify a substance as a toxic air contaminant, several steps must be taken. First, the ARB must request the DHS to evaluate the health effects of the candidate substance. Second, the ARB staff must prepare the "ID" report that includes the estimate of exposure levels and also the health effects evaluation and then submit the report to the Scientific Review Panel (SRP) for its review. The report submitted to the SRP will be made available to the public. Information submitted by interested parties will be considered in the report to the Panel. The SRP reviews the sufficiency of the information, methods, and data used by the DHS in its evaluation. Last, after review by the Scientific Review Panel, the report with the written findings of the SRP will be considered by the ARB and will be the basis for any regulatory action to identify a substance as a toxic air contaminant.

The attached information request is the first step in preparing the "ID" report on whether a substance should be identified as a toxic air contaminant. Before either the ARB or DHS begin their analysis of a substance, the ARB provides an opportunity for interested parties to submit information on the atmospheric chemistry, sources, exposure to and health effects of that substance. You are encourage to submit any information that you believe would be important in DHS' and ARB's evaluation.

ATTACHMENT II

Inorganic Lead Health and Exposure Related References

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Agency for Toxic Substances and Disease Registry, Atlanta, GA.
Health Assessment for Berkley Products Dump, Denver, Lancaster County, Pennsylvania, Region 3. CERCLIS No. PAD980538649
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Corp. Source Codes: 092477000
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(Final rept)
Corp. Source Codes: 092477000
4 Aug 88 13p
Journal Announcement: GRAI9007

Agency for Toxic Substances and Disease Registry, Atlanta, GA.
Health Assessment for Tonolli Corporation, Nesquehoning, Carbon County, Pennsylvania, Region 3. CERCLIS No. PAD073613663
(Preliminary rept)
Corp. Source Codes: 092477000
16 Nov 90 17p
Journal Announcement: GRAI9104

Agency for Toxic Substances and Disease Registry, Atlanta, GA.
Health Assessment for Jacks Creek/Sitkin Smelting and Refining Company, Maitland, Mifflin County, Pennsylvania, Region 3. CERCLIS No. PAD980829493 (Preliminary rept)
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Journal Announcement: GRAI9104

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ATTACHMENT III

State of California
AIR RESOURCES BOARD

Procedure for Handling Trade Secret Information

The information that you provide to the Air Resources Board may be released (1) to the public upon request, except trade secrets which are not emission data or other information which is exempt from disclosure or the disclosure of which is prohibited by law, and (2) to the federal Environmental Protection Agency, which protects trade secrets as provided in Section 114(c) of the Clean Air Act and amendments thereto (42 USC 7401 et seq.) and in federal regulations and (3) to other public agencies provided that those agencies preserve the protections afforded information which is identified as a trade secret, or which is otherwise exempt from disclosure by law (Section 91000 Title 17, California Administrative Code and California Health and Safety Code Section 39660).

Trade secrets, which are defined in California Government Code Section 6254.7, are not considered public records and therefore will not be released to the general public. However, the Public Records Act (Government Code Section 6250 et seq.) provides that air pollution emission data are always public records, even if the data come within the definition of trade secrets. On the other hand, the information used to calculate air pollution emissions data may be withheld from the public if the information is a trade secret.

If you believe that any of the information you are providing is a trade secret or otherwise exempt from disclosure under any other provision of the law, you should identify it as such at the time of submission (Health and Safety Code Section 39660 (e)). The Air Resources Board may ask you to provide documentation of your claim of trade secret of exemption at a later date.

APPENDIX E

HEALTH EFFECTS EVALUATION LETTER OF REQUEST TO THE CALIFORNIA ENVIRONMENTAL PROCTECTION AGENCY'S OFFICE OF ENVIRONMENTAL HEALTH HAZARD ASSESSMENT (FORMERLY THE DEPARTMENT OF HEALTH SERVICES)

State of California

MEMORANDUM

To : Ed Mendoza, Assistant Deputy Director
Public Health
Department of Health Services
714 P Street
Sacramento, California 95814

Date : February 21, 1991

Subject : Request for Health Effects Evaluation of Inorganic Lead

From: James D. Boyd
Executive Officer
Air Resources Board

This memorandum is a formal request that the Department of Health Services (DHS) evaluate the health effects of inorganic lead as a candidate toxic air contaminant (TAC) in accordance with Health and Safety Code Section 39650 et seq.

In the past, we provided health effects references and responses to the public information request at the same time we requested a compound's health effects evaluation. For inorganic lead, your staff are aware that the references from our literature search on health effects will follow this request in a few weeks and that we will forward you responses from the public information request as we receive them.

Ambient monitoring data on lead is available from our Ambient Air Quality Data Reports. Due to the sampling method used, we expect that these measurements primarily represent ambient inorganic lead concentrations. Please let us know if you intend to identify particular inorganic lead species of health interest as we will need to adjust our monitoring method.

According to Health and Safety Code Sections 39660-62, the DHS has 90 days from receipt of this letter to submit a written evaluation to the Air Resources Board (ARB) with recommendations on the health effects of inorganic lead. If necessary, you may request a 30-day extension.

If you have questions regarding this request, please contact me at (916) 445-4383 or have your staff contact Peter D. Venturini, Chief of the Stationary Source Division, at (916) 445-0650.

cc: Jananne Sharpless, Chairwoman, ARB
George Alexeeff, DHS
Richard Jackson, DHS
Henry Voss, DFA
Members of the Scientific Review Panel
Assemblywoman Sally Tanner
Senator Ralph Dills
Senator Art Torres

bcc: Bill Loscutoff
Gary Agid

APPENDIX F

GLOSSARY

GLOSSARY

AB 2588: Air Toxics "Hot Spots" Information and Assessment Act of 1987 (Health and Safety Code Section 44360 et seq.) established a statewide program which includes the inventory of toxic air emissions from individual facilities among its requirements.

Anion: A negatively charged atom, group of atoms, or molecule.

Anthropogenic: Man made or unnatural source.

Atmospheric mixing: The mixing of an air mass that usually dilutes the pollutants to a lower concentration.

Brownian diffusion: The act of diffusion or mixing by brownian motion or molecular vibration.

Cation: A positively charged atom, group of atoms, or molecule.

Dry Deposition: The removal of particulate matter from the air by settling out of the air.

Entrained: The act of a particle being suspended into the air.

Fine Particle Enrichment: Certain metals have a tendency to deposit on smaller sized particles that are emitted from a source.

Impaction: Particles in an air stream strike and deposit on the surface of objects like filter media.

Interception: Particles deposit when they pass within one particle-radius of an objects surface.

ISCST: Industrial source complex short term dispersion model. This model is a steady-state Gaussian plume model which can be used to assess pollutant concentrations from a wide variety of sources associated with an industrial complex. This model can account for settling and dry deposition of particulates, downwash area, line and volume sources, plume rise as a function of downwind distance, separation of point sources, and limited terrain adjustment. It operates in both long- and short-term modes (see reference below).

Isotope: A variation in mass of atoms of the same element due to differing numbers of neutrons in the atoms.

Kilometer: A measurement of distance equivalent to 1000 meters and approximately equal to 0.622 miles.

Leaching: To be dissolved or washed out by a percolating liquid.

LOD: Limit of Detection. For an analytical method, it is an amount of analyte that yields a response that is significantly different than that of background.

Organic: For chemistry, substances containing carbon.

pH: A measure of acidity or alkalinity of a solution.

Pica: The deliberate ingestion of non food substances.

REDOX: Oxidation/Reduction. Chemical reactions involving the transfer of electrons from one atom or molecule to another atom or molecule.

Radiometric: The decay of radioactive elements until a stable element is produced.

Reentrained: The act of resuspending something that was previously suspended

Turbulence: Random fluctuations in wind speed

Wet deposition: The removal of pollutants from the air by rain, sleet, snow, hail, or fog.

Wind-eddy diffusion: Particles are driven out of an airstream and transported downward by wind currents.

Reference for model:

EPA (1987) "Industrial Source Complex (ISC) Dispersion Model Users Guide-Second Edition (Revised)", EPA-450/4-88-002a, Research Triangle Park. NC.