

LEAD AND COMPOUNDS

Inorganic lead was identified as a toxic air contaminant under California's air toxics program (AB 1807) in 1997.

Lead compounds (including inorganic lead) are federal hazardous air pollutants and were identified as toxic air contaminants in April 1993 under AB 2728.

CAS Registry Number: 7439-92-1

Pb

Molecular Formula: Pb

Lead is a bluish-gray, noncombustible metal that occurs naturally in the earth's crust. Lead is malleable, ductile, 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 (ARB, 1997e).

There are four stable isotopes and two oxidation states, divalent (+2) and tetravalent (+4). The divalent oxidation state predominates (Sax, 1987). Most lead compounds have high melting points and low water solubilities. Lead is soluble in nitric acid, hot concentrated sulfuric acid, and dissolves slowly in water containing a weak acid (HSDB, 1995). Lead is a poor electrical conductor but a good sound and vibration absorber (Sax, 1987). Lead is incompatible with sodium azide, zirconium, disodium acetylide, and oxidants (Sax, 1989). See Table 1 for physical properties of lead compounds.

Physical Properties of Lead

Synonyms: lead flake; lead metal; plumbum; glover; Omaha

Atomic Weight:	207.19
Atomic Number:	82
Boiling Point:	1,740 °C
Melting Point:	327.43 °C
Density/Specific Gravity:	11.34 at 20/4 °C
Vapor Pressure:	1 mm Hg at 973 °C

(HSDB, 1995; Merck, 1989; Sax, 1989; U.S. EPA, 1994a)

SOURCES AND EMISSIONS

A. Sources

Lead compounds are used in construction materials for tank linings, piping, equipment for handling corrosive gases and liquids used in petroleum refining, halogenation, sulfonation, extraction, condensation, metallurgy, and for pigments for paints. It is also used in ceramics, plastics, electronic devices, as a component of lead batteries, and in the production of ammunition, solder, cable covering, and sheet lead (HSDB, 1995).

The major identified source of outdoor air lead emissions in California is aircraft fuel combustion. Other sources include autobody refinishing, grid casting and lead oxide production at battery manufacturing facilities, cement manufacturing, cogeneration, sawmills, paperboard mills, foundries and steel mills, stationary source fuel combustion, incineration, paint and coatings manufacturers, sand and gravel facilities, and secondary lead recycling facilities. The Federal Aviation Association is developing an unleaded fuel specification for small aircraft. Industrial metal melting facilities include secondary lead smelters, brass and bronze foundries and smelters, and battery manufacturers (grid casting and lead oxide production only). Lead in the ambient air has decreased significantly since the mid-1970s due to the phaseout of leaded gasoline. Inorganic lead emissions may also deposit and accumulate in soil for many years (ARB, 1997e).

B. Emissions

The total emissions of lead compounds are estimated to be approximately 175 to 182 tons per year, based on information from the Air Resources Board's (ARB) Air Toxics Emission Data System, local air pollution control districts, and surveys conducted by the ARB staff (ARB, 1997e).

Along with district and state regulations in effect that control or contribute to the reduction of lead emissions, the ARB adopted in January 1993 an air toxics control measure for non-ferrous metal melting operations. Although this control measure was written specifically to address emissions of arsenic, cadmium, and nickel, emissions of lead are expected to have been reduced by 45 percent as a side benefit (ARB, 1993f).

C. Natural Occurrence

Lead occurs in the earth's crust as the end-product of the radiometric decay of three naturally-occurring radioactive elements: uranium, thorium, and actinium (Sax, 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 (ARB, 1993f; Merck, 1989).

A common natural means of releasing lead to the atmosphere is via windborne dusts created by the weathering of deposits. Other natural sources of lead emissions are: sea and salt lake

aerosols, forest fires, and volcanic eruptions (HSDB, 1995).

AMBIENT CONCENTRATIONS

Lead compounds are routinely monitored in California by the statewide ARB air toxics network. The network's mean concentration of lead compounds from January 1996 through December 1996 is estimated to be 13.2 nanograms per cubic meter (ng/m^3) (ARB, 1997c). The 1990-91 statewide population-weighted annual average ambient concentration of lead was estimated to be 0.06 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) ($60 \text{ ng}/\text{m}^3$) which is approximately 50 times less than the annual average concentration measured in the mid-1970s. California is "in attainment" for lead which means that the state ambient air measurements are at or below the federal and state ambient air quality standards (ARB, 1997e). The state air quality standard is $1.5 \mu\text{g}/\text{m}^3$ averaged over 30 days. The federal standard is $1.5 \mu\text{g}/\text{m}^3$ averaged every calendar quarter.

The United States Environmental Protection Agency (U.S. EPA) has also compiled ambient concentration data from several study areas throughout the United States from 1980-91. Information from these data reported an overall range of concentrations for lead of 0.4 to $50.0 \text{ ng}/\text{m}^3$ with an overall mean concentration of $9.0 \text{ ng}/\text{m}^3$ (U.S. EPA, 1993a).

INDOOR SOURCES AND CONCENTRATIONS

Indoor concentrations of airborne lead are typically equal to or lower than outdoor concentrations; indoor air concentrations range from about 30 to 100 percent of the outdoor lead concentrations (ARB, 1997e).

Most of the lead present in the indoor air of non-occupational environments appears to result from the infiltration of lead particles from outdoor air. However, certain activities that disturb lead-based paint, such as remodeling or paint removal, can release large amounts of lead-bearing particles in the air. Lead has been banned for use in residential paint, but may still be used in industrial, military, and marine applications. Other potential sources of lead in indoor air are re-suspension of lead-bearing dusts and certain hobbies that use melted lead or lead glazes (ARB, 1997e).

Results from a survey of residences conducted in southern California show an average indoor airborne particulate matter (PM_{10}) lead concentration of about $0.027 \mu\text{g}/\text{m}^3$ and a maximum (99th percentile value) of about $0.10 \mu\text{g}/\text{m}^3$ (Pellizzari, et al, 1992). Indoor airborne lead concentrations may become highly elevated during lead-based paint abatement work and in indoor environments such as firing ranges (ARB, 1997e).

Personal exposure concentrations can sometimes be higher than either indoor or outdoor air concentrations, suggesting additional exposure could also be from occupational activities.

Relatively high lead concentrations (average of about $0.22 \mu\text{g}/\text{m}^3$, maximum of about $0.45 \mu\text{g}/\text{m}^3$) have been measured in total suspended particulate samples obtained inside vehicles during commute driving in southern California (Shikiya et al., 1989).

ATMOSPHERIC PERSISTENCE

Lead and lead compounds exist in the particle phase in the atmosphere, and hence are subject to wet and dry deposition. The average half-life and lifetime for particles in the atmosphere is estimated to be about 3.5 to 10 days and 5 to 15 days (Balkanski et al., 1993; Atkinson, 1995). After removal from the atmosphere and being deposited on the ground and soil, inorganic lead may be re-entrained in the atmosphere (ARB, 1997e).

AB 2588 RISK ASSESSMENT INFORMATION

The Office of Environmental Health Hazard Assessment (OEHHA) reviews risk assessments submitted under the Air Toxics “Hot Spots” Program (AB 2588). Of the risk assessments reviewed as of April 1996, lead and lead compounds was the major contributor to the overall cancer risk in 2 of the approximately 550 risk assessments reporting a total cancer risk equal to or greater than 1 in 1 million and contributed to the total cancer risk in 165 of these risk assessments. Lead and lead compounds also contributed to the total cancer risk in 54 of the approximately 130 risk assessments reporting a total cancer risk equal to or greater than 10 in 1 million (OEHHA, 1996a).

For non-cancer health effects, lead contributed to the total hazard index in 37 of the approximately 89 risk assessments reporting a total chronic hazard index greater than 1, and presented an individual hazard index greater than 1 in 2 of these risk assessments. Lead also contributed to the total hazard index in 43 of the approximately 107 risk assessments reporting a total acute hazard index greater than 1, and presented an individual hazard index greater than 1 in 12 of these risk assessments (OEHHA, 1996b).

HEALTH EFFECTS

Probable routes of human exposure to lead are inhalation and ingestion.

Non-Cancer: Lead salts (e.g., lead acetate, lead subacetate) are considered to be forms of inorganic lead. Most significant non-workplace, outdoor air exposure to lead in California is expected to be to inorganic lead particulate. 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 (ARB, 1997e).

Lead is only slowly excreted by the body. Exposures to small amounts of lead over a long time can slowly accumulate to reach harmful levels. Harmful effects may therefore develop gradually without warning. Short-term exposure to high levels of lead may also cause harm.

Lead can adversely affect the nervous, reproductive, digestive, cardiovascular blood-forming systems, and the kidney. Symptoms of nervous system effects include fatigue and headaches. More serious symptoms include feeling anxious or irritable and difficulty sleeping or concentrating. Severe symptoms include loss of short-term memory, depression, and confusion. More severe exposures can prove fatal. Lead can also injure the peripheral nerves to cause weakness in the extremities. Children are a sensitive population as they absorb lead more readily and the developing nervous system puts them at increased risk for lead-related harm, including learning disabilities. Effects on the gastrointestinal tract include nausea, constipation, and loss of appetite. Recovery from severe effects on the nervous system or kidneys is not always complete. Other ill effects include hypertension and anemia (ARB, 1997e). The toxicological endpoints considered for chronic toxicity are the kidney, cardiovascular or blood system, immune, reproductive, and central or peripheral nervous systems (CAPCOA, 1993).

The U.S. EPA has not established a Reference Concentration (RfC) or an oral Reference Dose (RfD) for lead (U.S. EPA, 1994a). The OEHHA developed in their report, *Proposed Identification of Inorganic Lead as a Toxic Air Contaminant, Part B, Health Assessment*, a range of air lead exposures on blood lead levels and subsequent neurodevelopmental risks to young children. This range of neurodevelopmental risks along with information on the U.S. EPA Integrated Exposure Uptake Biokinetic model can be used as an alternate approach to account for health effects of lead exposure including air, soil, and water (ARB, 1997e).

In men, adverse reproductive effects include reduced sperm count and abnormal sperm. In women, adverse reproductive effects include reduced fertility. Still-birth, miscarriage, low birth weight, and neurobehavioral deficits may be more likely. The State of California has determined under Proposition 65 that lead is a developmental toxicant and a male and female reproductive toxicant (CCR, 1996).

Cancer: There are several inconclusive epidemiological studies of exposed workers which provided limited evidence of cancers of the kidney, stomach, and respiratory tract. Rodent studies have found increased kidney cancers following the oral administration of lead. The U.S. EPA has classified lead in Group B2: Probable human carcinogen (U.S. EPA, 1994a). The International Agency for Research on Cancer has classified lead and inorganic lead compounds in Group 2B: Possibly carcinogenic to humans, and organic lead in Group 3: Not classifiable (IARC, 1987a).

The State of California has determined under Proposition 65 that lead and lead compounds, lead acetate, lead phosphate, and lead subacetate are carcinogens (CCR, 1996). The inhalation potency factor that has been used as a basis for regulatory action in California is $8.0 \times 10^{-5} (\mu\text{g}/\text{m}^3)^{-1}$ for lead acetate and $1.1 \times 10^{-5} (\mu\text{g}/\text{m}^3)^{-1}$ for lead subacetate (OEHHA, 1994). In other words, the potential excess cancer risk for a person exposed over a lifetime to 1 microgram per cubic meter of lead acetate is estimated to be no greater than 80 in 1 million and 11 in 1 million for lead subacetate (OEHHA, 1994). A cancer potency value of 1.2

$\times 10^{-5} (\mu\text{g}/\text{m}^3)^{-1}$ for inorganic lead has been established (ARB, 1996a). The oral potency factor that has been used as a basis for regulatory action in California is 2.8×10^{-1} (milligram per kilogram per day) $^{-1}$ for lead acetate and 3.8×10^{-2} (milligram per kilogram per day) $^{-1}$ for lead subacetate (OEHHA, 1994).

TABLE I - PHYSICAL PROPERTIES OF LEAD COMPOUNDS

Molecular Formula & Substance Name	CAS Registry Number	Synonyms	Color	Molecular Weight	Specific Gravity	Melting Point °C	Water Solubility g/100 ml (0-25 °C)
C ₄ H ₆ O ₄ •Pb lead acetate	301-04-2	sugar of lead	colorless crystals or white granules	325.3	3.25	280	44.3
PbBr ₂ lead bromide	10031-22-8	---	white powder	367	6.66	373	0.8441
Cl ₂ Pb lead chloride	7758-95-4	lead dichloride	white crystals	278.1	5.85	501	0.99
CrO ₄ •Pb lead chromate	7758-97-6	chrome yellow	yellow crystals	323.2	6.12	844	6 x 10 ⁻⁶
O ₂ Pb lead dioxide	1309-60-0	brown, plumbic acid; lead oxide brown	brown crystals	239.2	9.37	290	insoluble
N ₂ O ₆ •Pb lead nitrate	10099-74-8	lead dinitrate	white crystals	331.2	4.53	470	37.65
O ₈ P ₂ •3Pb lead phosphate	7446-27-7	normal lead orthophosphate	white powder	811.5	7	1014	1.4 x 10 ⁻⁵
C ₄ H ₁₀ O ₈ Pb ₃ lead subacetate	1335-32-6	lead monosubacetate	white powder	807.7	information not available	information not available	information not available
O ₄ S•Pb lead sulfate	7446-14-2	lead bottoms	white rhombic crystals	303.3	6.2	1170	0.0042
PbS lead sulfide	1314-87-0	plumbous sulfide	silvery, metallic crystals or black powder	239.2	7.5	1114	insoluble

(ARB, 1997e; Merck, 1989; Sax, 1989)

