Lead (Pb)

In a nutshell

Lead is a naturally-occurring heavy metal which is relatively soft and resistant to corrosion. It has been used since antiquity in plumbing but also in cosmetics and wine, and more recently in lead-acid batteries and in organic form as a fuel additive (tetraethyl lead), which led to global environmental contamination. Levels are decreasing in the developed world but are a concern in many parts of the world.

Lead is toxic to multiple body systems, notably the nervous and cardiovascular systems, blood, gut and kidney. Critical low-dose chronic effects are developmental neurotoxicity in children and increased blood pressure in adults. Lead exposure via diet and environmental dust and dirt may in some regions present an unacceptable health risk.

Lead contamination in phosphate (P) mineral fertilizers only occurs in small amounts, and is therefore unlikely to present any significant additional human health risk. Further, use of phosphate fertilizer can immobilize lead in soil, and reduce its transfer to some crops.

What is lead?

Lead (Pb) is a naturally-occurring metal, present at relatively low levels in the earth's crust. It has high density, a low melting point, and is relatively soft and resistant to corrosion. It is or has been widely used use in construction, plumbing, lead-acid batteries, leaded gasoline, white paints, as well as in ammunition, weights, solders, pewters, fusible alloys, and radiation shielding. The most commonly used type is inorganic red lead monoxide. Soluble lead nitrate and lead acetate are used in chemical manufacturing.

Most lead encountered in the environment today is inorganic. Organic lead is almost entirely manufactured; the most prominent example is tetraethyl lead, which was introduced in the 1920s as a fuel additive to improve engine performance and economy; this led to global environmental lead contamination. Initiated by the US 1970 Clean Air Act, leaded petrol was withdrawn in most countries by the end of the 20th century. Organic lead is absorbed by the body better than inorganic lead and is therefore more toxic, but is transformed in the body and environment to inorganic lead.

Contamination from different sources

As lead is an element, once it is released into the environment, it persists. The widespread occurrence of lead in the environment is largely the result of human activity, such as mining, smelting, refining and informal recycling of lead; use of leaded petrol (gasoline); production of lead-acid batteries and paints; home-based industries such as jewellery making, soldering, ceramics and leaded glass manufacture; electronic waste; and use in water pipes and solder.

Other sources of lead in the environment include volcanic activity, geochemical weathering and sea spray emissions, and remobilization of historic sources, such as lead in soil, sediment and water from mining areas.

Typical background concentrations of lead do not exceed 0.1 µg/m3 in the atmosphere; 100 mg/kg in soil; and 5 µg/L in fresh- and seawater.

Human exposure and health effects

Lead has been used in antiquity for medical and cosmetic purposes, and particularly by the Romans in plumbing; it has been claimed that lead was the Roman equivalent of modern plastics. Romans were exposed to high levels of lead, probably related to its use in sweetening poor quality wine (e.g. with lead acetate, also known as “lead sugar”). From the Renaissance on, painters and artists were exposed to high lead levels from lead-based colors including lead carbonate (cerussite, “white lead”); poisoning victims may have included Rembrandt and Goya (unfortunately, white lead-based decorative paints are still sold in a number of countries). The Industrial Revolution caused an epidemic of chronic lead intoxication, resulting in improved occupational hygiene measures in the 20th century. Tetraethyl lead fuel additive introduced in the 1920s led to global environmental lead contamination; towards the end of the 20th century, the identification of low dose neurodevelopmental and cardiovascular effects has greatly modified the concept of chronic lead poisoning.

Recent reductions in the use of lead in fuel, paint, plumbing and food container solder have resulted in substantial reductions in population exposure. As of 2017, most countries have banned lead in fuel, but significant sources of exposure still remain, particularly in developing countries.

For the non-smoking general population, the largest contribution to lead exposure is ingestion of food, dirt and dust. The amount of lead in edible plants depends on soil concentrations and is highest around mines and smelters. Cereals and spices can contain high levels. Smoking tobacco increases lead intake. Lead present in tap water is mainly due to household plumbing systems containing lead pipes, solders and fittings.

In Europe, important sources of dietary lead exposure include bread and rolls (8.5 %), tea (6.2 %), tap water (6.1 %), potatoes and potato products (4.9 %), fermented milk products (4.2%) and beer and beer-like beverages (4.1 %), although this will vary between age groups and regions.

Lead in the body is distributed to the brain, liver, kidney and bones. It is stored in the teeth and bones, where it accumulates over time. Human exposure can be assessed directly through measurement of lead in blood, teeth or bones (bone and tooth lead reflect cumulative exposure).

Lead is a cumulative toxicant that affects multiple body systems, notably the nervous and cardiovascular systems, blood, gut and kidney. Based on effects in animals, inorganic lead compounds are considered by the International Agency for Research on Cancer (IARC) to be probably carcinogenic to humans. Children are particularly vulnerable to the neurotoxic effects of lead, and even relatively low levels of exposure can cause serious and in some cases irreversible neurological damage (reduced IQ). The most sensitive effect in adults is increased blood pressure, which will modestly increase the risk of heart attack and stroke. Based on these effects, lead exposure is estimated to account for 0.6% of the global burden of disease, with the highest burden in developing regions. Current dietary exposure estimates for children are considered a concern. For adults, mean dietary exposure estimates are of some concern, but less than in children.

Because developmental neurotoxicity has been seen in children even at very low exposure levels, no safe level of lead intake is currently defined by the World Health Organization (WHO); a previously

established Provisional Tolerable Weekly Intake PTWI of 25 µg/kg bw was withdrawn in 2011. The WHO guideline maximum content for lead in drinking-water is 10 µg/L.

Lead contamination from organic compost fertilizer (e.g. grass cuttings) may present a problem, but is not normally a significant contaminant in mined phosphate mineral fertilizers. Further, use of phosphate fertilizer can immobilize lead in soil, and thus reduce lead levels in some crops (particularly Brassica vegetables) in contaminated areas.

Bibliography

ATSDR 2008. Lead Toxicity. Case Studies in Environmental Medicine. U.S. Agency for Toxic Substances and Disease Registry, 15 August 2010. http://www.atsdr.cdc.gov/csem/lead/docs/lead.pdf

Bellinger DC, 2011. The protean toxicities of lead: new chapters in a familiar story. Int J Environ Res Public Health. 8(7):2593-628.

EFSA 2012. Lead dietary exposure in the European population. EFSA Journal 2012; 10(7):2831. doi:10.2903/j.efsa.2012.2831.

IARC 2006. Inorganic and organic lead compounds. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 87. Summary of Data Reported and Evaluation, December 2006. http://www.inchem.org/documents/iarc/vol87/volume87.pdf

JECFA 2011. Lead (addendum). Pp. 381-497,533-534 in WHO Food Additives Series 64, Safety evaluation of certain food additives and contaminants in food. http://whqlibdoc.who.int/publications/2011/9789241660648_eng.pdf

Kessler R, 2014. Lead-Based Decorative Paints: Where Are They Still Sold-and Why? Environ Health Perspect. 122(4):A96-A103.

Riva MA et al, 2012. Lead poisoning: historical aspects of a paradigmatic "occupational and environmental disease". Saf Health Work. 3(1):11-6.

UNEP 2017. United Nations Environment Programme, Partnership for Clean Fuels and Vehicles, Lead Campaign. http://www.unep.org/transport/pcfv/lead-campaign, accessed 28-Oct-2017

WHO 2010. Exposure to lead: a major public health concern. http://www.who.int/ipcs/features/lead.pdf

WHO 2011. Lead in Drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality. http://www.who.int/entity/water_sanitation_health/water-quality/guidelines/chemicals/lead.pdf

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