A Small Dose of Lead

Or

An Introduction to the Health Effects of Lead

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Dossier

Name: Lead (Pb)
Use: batteries, old paint, stabilizer in PVC, hobbies, solder, toys, X-ray shielding, smelters, and previously in gasoline and pesticides
Source: home, paint, dust, toys, children hands to mouth, workplace, ethnic health remedies
Recommended daily intake: none (not essential)
Absorption: intestine (50% children, 10% adults), inhalation
Sensitive individuals: fetus, children, and women of childbearing age
Toxicity/symptoms: developmental and nervous system, lowered IQ, memory and learning difficulties, behavioral problems
Regulatory facts: air - 0.5 mg/m^3, drinking water 15 μg/L, not allowed in paint or automobile gasoline, 0.15 μg/m^3 air standard
General facts: long history of use, major problem in paint of older housing, areas around old smelters can be contaminated
Environmental: global environmental contaminant
Recommendations: avoid, wash hands, wash kids hands and toys, phase out uses in PVC plastics, child products, remove old lead-based paint

Case Studies

In the 2[nd] century BC, Dioscorides noted, "Lead makes the mind give way". Despite this warning, the seemingly endless uses of lead have repeatedly brought it into daily use and widespread distribution. In modern times, lead was heavily used in paint and as a gasoline additive. The subtle brain damage that even low levels of lead exposure causes in children was recognized and acted upon only in the last 30 years. It is now well documented that even blood levels below 10 μg/dL can harm the developing brain, robbing children of their intellectual potential. As the following case studies demonstrate lead remains a serious concern.

Take home lead - 1998

In 1998 a California (MMWR, 2001) mother requested a blood lead level determination for her 18-month-old child. The result was a blood lead level (BLL) of 26 μg/dL, which was well above the Center for Disease Control's (CDC) recommended criterion for clinical case management. It was subsequently found that the father had a BLL of 46 μg/dL, which was above the Occupational Safety and Health Administration (OSHA) requirement that worker with BLLs great than 40 μg/dL receive additional medical examinations. Further testing found that his 4-month-old daughter had a BLL of 24 μg/dL. This worker was employed in a company that refinished antique furniture, some of which was covered with lead-based paint. Subsequent testing of co-workers found that two refinishers had BLLs of 29 and 54 μg/dL and four carpenters had BLLs of 46, 46, 47, and 56 μg/dL. A child in another family had a BLL of 16 μg/dL. What will be the long-term effects on the intellectually abilities of these children?

Lead contaminated town - 2001

The children and families of Herculaneum, Missouri have a lead problem (N.Y. Times, 2002), a big lead problem. Herculaneum is home to Doe Run Company, one of the largest lead smelters in the United States, producing 160,000 tons of lead per year. A generation ago, over 800 tons of lead was released into the environment as part of the smelting process. This was reduced to 81 tons in 2001 and the target is 34 tons in 2002. There are signs on the main street informing people about the "high-lead levels on streets" and warning children not to play in the streets or on curbs. One-fourth of the children under 6 were found to have lead poisoning. The U.S. EPA is working to reduce childhood exposure to lead and the company has purchased a number of the most affected homes. How has lead affected the children of Herculaneum? Who is responsible for reducing this hazard?

Lead in children's toys, candy, and jewelry – 2006

Lead products meant for children were highlighted by several serious incidents of lead poisoning, including one death, from ingestion of jewelry containing lead (MMWR 2004, 2006). Many of these products contain over 50% lead. These incidents resulted in the recall of hundreds of thousands of items. A report from Los Angeles County estimated that 34% of the children with elevated blood lead levels were exposed to lead-based products brought into the home such as, folk and traditional medications, candy, ceramic dinnerware, and metallic toys and jewelry. More recently lead was discovered in vinyl lunch boxes were it was used to stabilize PVC plastics. Lead was also found in the paint on imported children's toys that exceeded the standard of 0.06% lead by weight (600 ppm). Many consider this to be an excessive amount and have advocated state and federal regulations to lower the amount of lead allowed in paint and require the testing of children's toys for lead. Despite allow of our knowledge about the childhood health effects of lead we continue to needless exposure those most vulnerable.

Introduction and History

> If we were to judge of the interest excited by any medical subject by the number of writings to which it has given birth, we could not but regard the poisoning by lead as the most important to be known of all those that have been treated of, up to the present time.
> M.P. Orfila, *A General system of Toxicology*, 1817

Lead provides many insightful lessons for a student of toxicology, history and society. During over 8000 years of using lead, we have relearned forgotten and ignored lessons on the health effects of lead. Lead is naturally presence at very low levels in the soil and water prior to the extensive environmental distribution by people but has no beneficial biological effects. Its physical properties of low melting point, easy malleability, corrosion resistance and easy availability make it well suited to applications both ancient and modern. It is found along side gold and silver, making lead both a by-product and a contaminant during the smelting of these precious metals. The earliest recorded lead mine dates from 6500 BC in Turkey.

> **Pb Lead**
>
> Atomic Number: 82
> Atomic Mass 207.20

Significant production of lead began about 3000 BC and lead was first widely used by the Roman Empire. Large mines in Spain and Greece contributed to the global atmospheric redistribution of lead. Easily manipulated, lead was used by the Roman's in plumbing. In fact, the word plumbing is derived from plumbum, Latin for lead, which also gave rise to the chemical symbol for lead, Pb. Lead is slightly sweet to taste, making it a good additive for fine Roman wine that was then shipped all over Europe. Even in these times, there were reports that lead caused severe colic, anemia and gout. Some historians believe that lead poisoning hastened the fall of the Roman Empire. For thousands of years, Greenland ice has faithfully recorded the rise and fall of lead use by civilizations that came and went.

In more modern times, the durability of lead made it an excellent paint additive but the sweetness made it a tempting edible item for young children. Childhood lead poisoning was linked to lead-based paints in 1904. Several European countries banned the use of interior lead-based paints in 1909. At one time baby cribs were painted with lead-based paint, which resulted in infant deaths and other illness. In 1922, the League of Nations banned lead-based paint but the United States declined to adopt this rule. In 1943, a report concluded that children eating lead paint chips could suffer from neurological disorders including behavior, learning and intelligence problems. Finally, in 1971, lead-based house paint was phased out in the United States with the passage of the Lead-Based Paint Poisoning Prevention Act. Homes built prior to 1978 may have lead-based paint either inside or outside and homes, and apartments built prior to 1950 will very likely have lead based paint both inside and outside and should be inspected carefully. This is a particularly serious problem for children living in older housing in large cities. A CDC report found that 35% of African-American children living in the inner cities with more than 1 million people had blood lead levels greater that 10 μg/dL, which is the CDC action level established in 1991. In the 1990s, the EPA required that information on lead be disclosed when a home or apartment was being sold or rented. In addition, specific training is required for workers removing lead from homes or apartments. Lead-based paint continues to remain a serious problem in for many children. The history of the use of lead based paint is summarized in table 8.1.

Table 8.1 - History of Lead-Based Paint

Year	Event
1887	US medical authorities diagnose childhood lead poisoning
1904	Child lead poisoning linked to lead-based paints
1909	France, Belgium and Austria ban white-lead interior paint
1914	Pediatric lead-paint poisoning death from eating crib paint is described
1921	National Lead Company admits lead is a poison
1922	League of Nations bans white-lead interior paint; US declines to adopt

1943	Report concludes eating lead paint chips causes physical and neurological disorders, behavior, learning and intelligence problems in children
1971	Lead-Based Paint Poisoning Prevention Act passed
1978	Lead-based house paint banned

Adapted from Gilbert and Weiss, 2006.

> "Therefore, in contrast to popularized reports, there is no persuasive evidence that low level lead exposure is responsible for any neurobehavioral or intelligence defects. In fact, the bulk of the evidence suggests that there is no adverse impact of low level lead exposure."
> International Lead Zinc Research Organization, October 1982
>
> "Lead Poisoning remains the most common and societal devastating environmental disease of young children."
> Public Health Service - L. Sullivan, 1991

The addition of lead to gasoline is one of the greatest public health failures of the 20th century. It is a fascinating story of the intersection of big business, government and societal interests. Tetraethyl lead (TEL) was discovered in 1854 by a German chemist and in 1921 shown to reduce car engine knock by Thomas Midgley of the United States. This was a period of tremendous competition in the automobile industry and growth in the oil, gas and chemical industries in the United States. A year latter the U.S. Public Health Service issued a warning about the potential hazards associated with lead. In 1923 the Du Pont Corporation began the first large-scale production of TEL and the first workers died from lead exposure. The same year leaded gasoline went on sale in selected regions of the country. During this period Du Pont acquired a 35% ownership of General Motors, and General Motors and Standard Oil formed a joint company, Ethyl Corporation, to produce TEL. In 1924 five workers die from lead poisoning at the Ethyl facility in New Jersey, although the number affected by lead exposure is unknown. In 1925 sales of TEL were suspended while the U.S. Surgeon General reviewed the safety of TEL. The next year, a committee approved the use of TEL in gasoline and sales were immediately resumed. By 1936, 90% of the gasoline sold in the U.S. contained lead, and the Ethyl Corporation was expanding sales in Europe. In the early 1950s the U.S. Justice Department investigated anticompetitive activities associated with Du Pont, General Motors, Standard Oil, and Ethyl Corporation. Environmental concerns were highlighted in a 1965 report documenting that high levels of lead in the environment were caused by human use of lead. In 1972 the U.S. EPA gave notice of an intended phase out of lead in gasoline and was promptly sued by the Ethyl Corporation. Four years later the EPA standards were upheld in court and in 1980 the National Academy of Science reported that leaded gasoline was the greatest source of environmental lead contamination. In 1979, the effects of lead on the intellectual development of children were documented in a seminal paper written by Herbert Needleman and others. The fight over phasing out lead from gasoline was far from over when, in 1981, then Vice President George Bush's task force proposed to relax or eliminate the lead phase-out program. The relationship between leaded gasoline and blood lead levels was demonstrated when the EPA reported that blood lead levels declined by 37% in association with a 50% drop in the use of leaded gasoline between 1976 and 1980. Subsequent studies showed a correlation between the increase in gasoline use during the summer and a rise in blood lead levels. By 1986 the primary phase-out of lead from gasoline was completed but in some areas of the country, such as Washington State, leaded gasoline was available until 1991. The World Bank called for a ban on leaded gasoline in 1996 and the European Union banned leaded gasoline in 2000. We are still living with the decisions made in the 1920s to add lead to gasoline. It is estimated that 7 million tons of lead were released into the atmosphere from gasoline in the United States alone.

Occupational exposure to lead has decreased from the overt cases of death and disability in the 1930s and 1940s, but, as the case studies illustrate, it continues to occur. In the past, painters using lead based paints suffered from health problems such as wrist and foot drop or as Ben Franklin reported, the "dangles". Lead paint removal from bridges and buildings is now regulated. Radiator repair and battery recycling continue to be sources of lead exposure. Battery recycling facilities in less-developed countries are a serious source of worker lead exposure and environmental contamination. Public safety officials that train at shooting ranges using lead ammunition may be exposed to elevated levels of lead. Occupational exposure is a potential hazard not only to the adults but also to their children as the lead may be brought home on clothing.

Home hobbies or business can also be a source of lead exposure. Lead is commonly used in stained glass, jewelry making, glazes on pottery, painting, soldering, making ammunition or fishing sinkers, and exposure can occur from stripping paint from furniture or wood work. Lead-glazed pottery has caused a number lead poisonings, particularly when high-acid foods, which leach lead from the glaze, are consumed from the pottery.

At one time canned foods were a significant source of lead because of poor-quality solder joints in the cans. High-acid goods, such as tomatoes, would leach lead from the cans. Finally, contamination of drinking water with lead occurs primarily from lead solder joints or old fixtures and occasionally lead pipe was used to bring water to a home. As with many metals, lead was used in a number of remedies, some of which are still available and used by some ethnic groups.

Lead continues to show up in a range of products, many destined to be used by children. Because lead is cheap and easy to use it is found in jewelry and other trinkets. These products are used and handled by children resulting additional lead exposure. Lead is used as a stabilizer for PVC plastics and has been found in mini-blinds for windows and in school lunch pails. Cosmetics, such as lipstick were discovered to be contaminated with lead. Recently lead based paint was used on children's toys. Even candy and candy wrappers were found to be contaminated with lead. State and national laws were enacted to ban what seems to obvious, the sale of products meant for children that contain lead.

Biological Properties

The absorption, distribution and subsequent health effects of lead illustrate the basic principles of toxicology. Foremost is the sensitivity of the children to the adverse effects of even low levels of lead exposure and second is dose. There are many reasons why children are more sensitive to lead. Children are much smaller than adults and by weight will receive a much higher dose given the same exposure. Differences in absorption of lead also increase the sensitivity of children. Adults absorb only 5-10% of orally ingested lead while children absorb approximately 50% and can absorbed much more depending on nutrition. Children and pregnant women will absorb more lead because their bodies have a greater demand for calcium and iron, and the intestine responds by favoring their absorption. Lead substitutes for calcium and is thus readily absorbed, particularly if a diet is low in calcium and iron. Children in families of low income are often in older housing that contains lead and with a poor diet are most vulnerable to the developmental effects of lead. The same is true for pregnant women, whose bodies need more calcium.

Lead distributes in several compartments within the body, each with a different half-life. When lead enters the blood stream it attaches to red blood cells and in the blood has a half-life of about 25 days. Lead readily cross the placenta, thus exposing the developing fetus and fetal nervous system to lead. Lead is also stored in the muscle, where it has a longer half-life of about 40 days. Calcium requirements for children are high in part because of rapid bone growth. Lead readily substitutes for calcium and is stored in bone, which was actually visible in x-rays of children with very high lead exposure (fortunately this is very rare now, at least in the United States). In normal circumstances, bone turnover or half-life is very long, so the half-life of lead in the bone is about 20 years. However, if bone turnover is increased, the lead in the bone is mobilized into the blood. This can occur during pregnancy or in older women subject to osteoporosis, which can be caused by decreasing estrogen levels. We accumulate lead over a lifetime, but particularly when we are young, so that as adults our bone and teeth contain approximately 95% of the total lead in the body. As we shall see, the short half-life of lead in the blood made tooth lead levels an important indicator of childhood lead exposure and a vital maker to use in correlating with developmental effects.

Health Effects

> "How long a useful truth may be known and exist, befor it is generally receiv'd and practis'd on"
> Benjamin Franklin - 1763

Lead is one of the most intensively studied hazardous agents of the twentieth century. The more toxicologists and other researchers investigated the health effects of lead, the more they realized that even very low levels of lead exposure were hazardous (Gilbert and Weiss, 2006). The most common biomarker of lead exposure is the blood lead level, usually measured in micrograms (μg) per one tenth of a liter of blood (dL) or μg/dL. For example, many regulatory agencies set 40 μg/dL as a level of concern for adult male workers. Typically, at this level workers would be removed from the environment responsible for the exposure and ideal some determination would be made as to the cause of the exposure. The blood level of concern for children has dropped steadily as shown in the Figure 8.1 and some believe that there is sufficient data on the health effects below 10 μg/dL that the CDC should significantly lower the blood lead action level (Gilbert and Weiss, 2006).

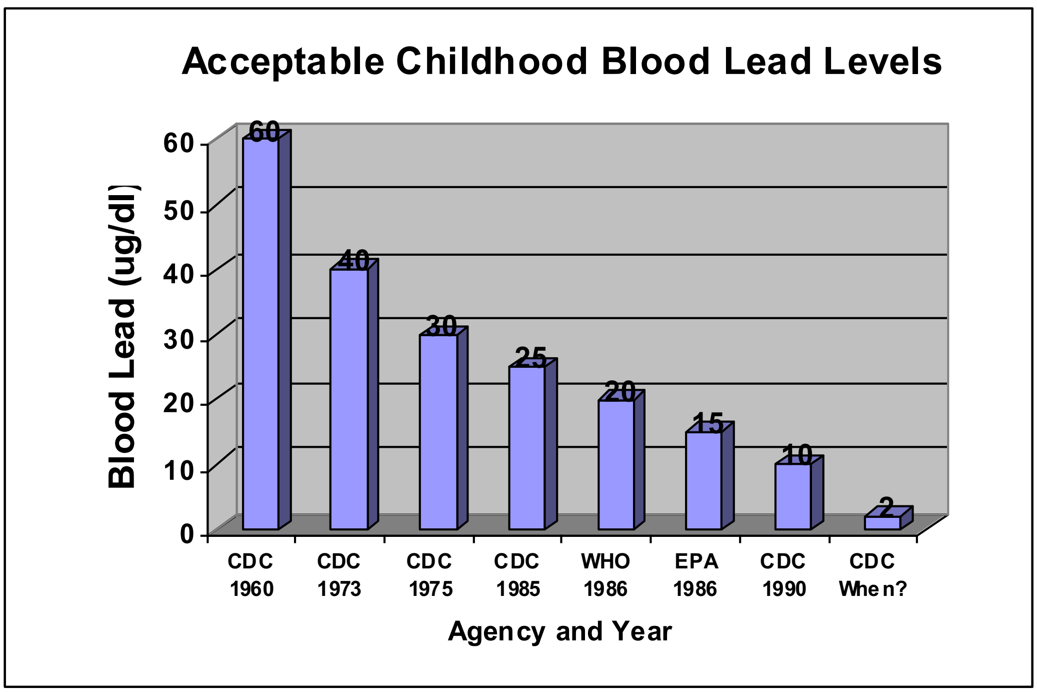


Figure 8.1 Acceptable Childhood Blood Lead Levels

The decline in acceptable childhood blood levels was a function of research and improved control of lead contamination, such as the removal of lead from gasoline. A

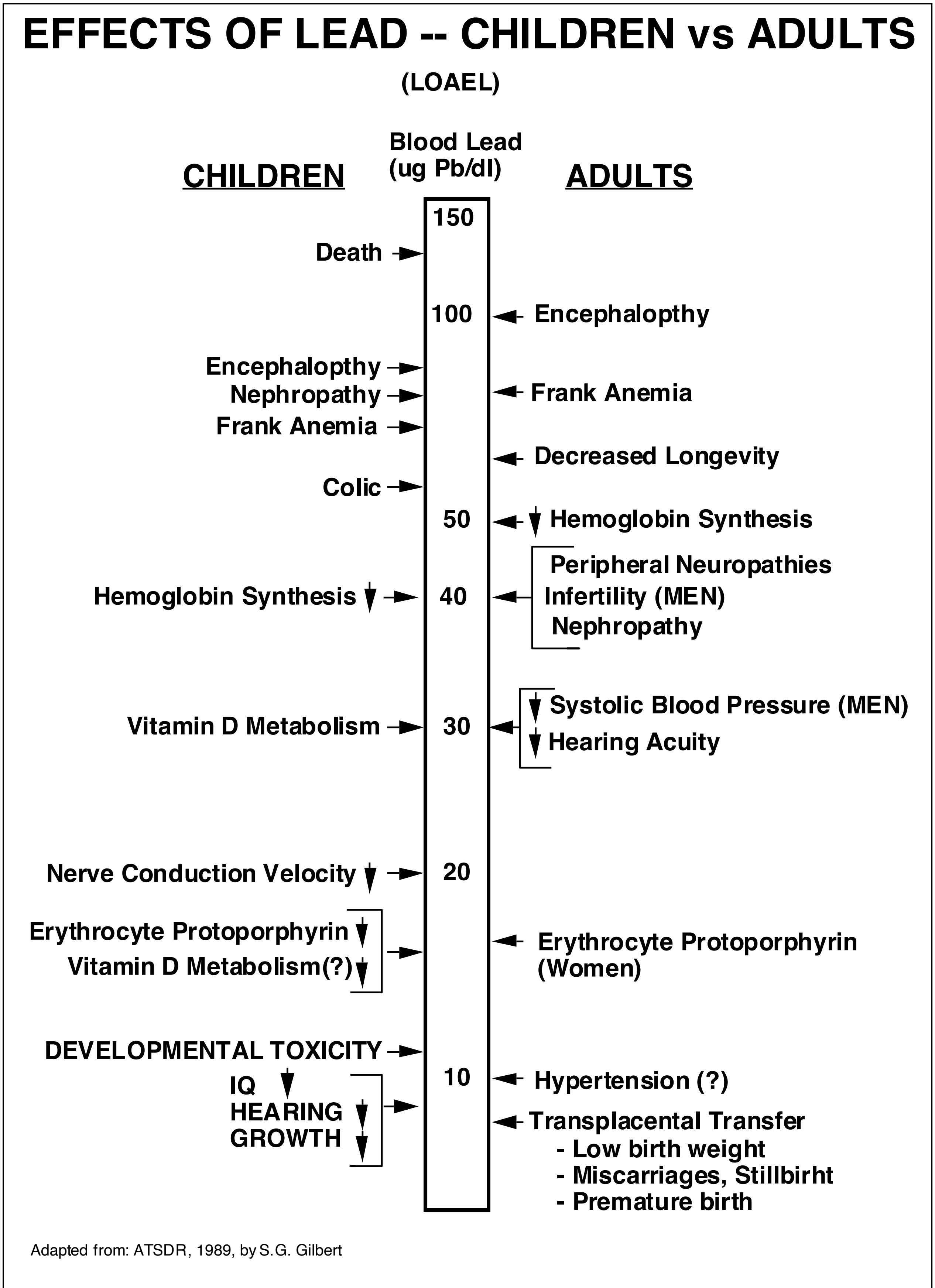
blood lead level of 10 μg/dL does not represent a "safe" level, only one where it is prudent to take action to reduce exposure. But it must be noted that a level of 10 μg/dL is considered an action level and does not provide any margin of safety for a child's developing nervous system. Currently, there appears to be no safe level of lead exposure for the developing child.
The nervous system is the most sensitive target of lead poisoning. Fetuses and young children are especially vulnerable to the neurological effects of lead because their brains and nervous systems are still developing. At high levels of lead exposure, the brain will swell (encephalophathy), possibly resulting in death. At one time it was thought the children that survived high levels of exposure would recover and have no adverse effects. In the 1940s persistent learning and developmental effects were demonstrated in children exposed to high levels of lead. In 1979 a study by Needleman showed that even low levels of lead exposure would reduce the school performance of children. This study was one of the first to use tooth lead as marker of childhood exposure, which correctly classified early childhood exposure even if current blood lead levels were normal. Numerous studies found similar results and it is now generally accepted that every 10 μg/dL increase in blood lead levels there is a 2 to 4 point IQ deficit within the range of 5 to 35 μg/dL. While a few point IQ drop my not seem like much over the entire population it is very serious and even more serious for the individuals affected. Subsequent long-term studies of infants and young children exposed to lead showed that as they became older that was an increased likelihood that they would suffer from decreased attention span, reading and learning disabilities and failure to graduate from high school.

Adult nervous system effects are also apparent following lead exposure. In the past painters using lead-based paint developed damage to the peripheral nervous system, which caused a wrist or foot drop. Nerve damage could be evaluated in the forearm by using an instrument to measure how fast the nerves conduct an electrical signal from one point to the next. But, as was the case with children, when more subtle effects were looked for, they were found. In adults with blood levels greater that 25 μg/dL there is evidence of decreased cognitive performance.

Lead exposure can produce a number of other effects. One of the most common effects is on the red blood cells. The red blood cells become fragile and hemoglobin synthesis is impaired, which results in anemia. Changes in the red blood cells and some enzymatic changes were used as a maker for lead exposure. Similar to other metals, lead adversely effects kidney function, but this is now rare with reductions in occupational exposure. Several studies have demonstrated that elevated lead exposure is related to elevated blood pressure levels, particularly in men. There appears to be a weak association between lead exposure and increased incidence of lung and brain cancer. Lead exposure is a reproductive hazard for both males and females. In males, lead affects sperm count and sperm motility, resulting in decreased offspring.

The fact that children are more sensitive to the effects of lead exposure is illustrated in the Figure 8.2. It is clear that amount of lead it takes to kill someone is not nearly as important as the lifetime effects on the quality of life.

Figure 8.2 Effects of Blood Lead – Children vs. Adults


EFFECTS OF LEAD -- CHILDREN vs ADULTS
(LOAEL)
Blood Lead
(ug Pb/dl)
CHILDREN
ADULTS
150
Death
100
Encephalopthy
Encephalopthy
Nephropathy
Frank Anemia
Frank Anemia
Decreased Longevity
Colic
50
Hemoglobin Synthesis
Peripheral Neuropathies
Infertility (MEN)
Nephropathy
Hemoglobin Synthesis
40
Systolic Blood Pressure (MEN)
Hearing Acuity
Vitamin D Metabolism
30
Nerve Conduction Velocity
20
Erythrocyte Protoporphyrin
Vitamin D Metabolism(?)
Erythrocyte Protoporphyrin
(Women)
DEVELOPMENTAL TOXICITY
IQ
HEARING
GROWTH
10
Hypertension (?)
Transplacental Transfer
- Low birth weight
- Miscarriages, Stillbirht
- Premature birth
Adapted from: ATSDR, 1989, by S.G. Gilbert

Reducing Exposure

While there are standards for lead exposure, at this time there is no level that is considered safe, so the best policy is to avoid lead exposure altogether. This is difficult because as a contaminant in food, water or dust, lead cannot be seen, tasted or smelled. The next best thing is to be aware of potential sources of lead and take appropriate action. For example, if you are moving into an older home with young children or you are planning to start a family, have the paint and soil around the house tested for lead. If the house is old it may contain pipes or solder joints with lead or fixtures with high concentrations of lead. Test kits are available in some stores but these generally only indicate if lead is present, not how much. Home renovation is an important source of lead exposure. Sanding or removing paint may create dust with high concentrations of lead. Young children exhibit hand to mouth behaviors and will ingest significant amounts of lead just from the dust. The EPA has information on safe home renovation.

If you work or come into contact with lead, wash your hands as soon as possible. If you handle lead and then eat, whatever you touch with your hands will contain a small amount of lead. Removing your shoes before coming into the house will reduce tracking in dust that contains lead. This is particularly important if there is indication of soil contamination such as might occur near or down wind from a smelter. Beware of any hobby using lead or products that might contain lead. Reduce or eliminate lead-based products whenever possible. Most states now ban lead pellets for hunting because the lead pellets are a hazard to birds and contaminate the environment with lead. Old cooking utensils, leaded crystal and some pottery glaze may contain lead that will leach into foods, particularly those high in acid. Even some cosmetics contain lead, particularly hair coloring products that gradually hide gray hair. Tobacco contains a small amount of lead, another reason to avoid inhalation of tobacco smoke.

Regulatory Standards

Governmental agencies have set limits on lead in the drinking water and in occupational settings. State laws also exist and may be more stringent than the U.S. Federal government.

OSHA – lead in air – 0.5 mg/m^3 (milligrams per cubic meter) The OSHA standards are under review. See Shaffer & Gilbert review.
EPA maximum level for lead in public drinking water systems is 15 $\mu g/L$; EPA
EPA air lead standard 0.15 $\mu g/m^3$ rolling 3-month average

From CDC (September 7, 2020
"CDC now uses a blood lead reference value of 5 micrograms per deciliter to identify children with blood lead levels that are much higher than most children's levels. This new level is based on the U.S. population of children ages 1-5 years who are in the highest 2.5% of children when tested for lead in their blood.

This reference value is based on the 97.5th percentile of the National Health and Nutrition Examination Survey (NHANES)'s blood lead distribution in children. The current reference value is based on NHANES data from 2007-2008 and 2009-2010."

Recommendation and Conclusions

The developing nervous system of children is by far the most sensitive to lead exposure. Because of a child's small size and greater absorption of lead, even a very low level of exposure results in a high dose of lead. The developing nervous system is exquisitely sensitive to the effects of even small amounts of lead, resulting in life-long learning deficits. Exposure to lead at an early age clearly deprives a child of his or her ability to express their genetic potential. The optimal action is to avoid lead exposure and ensure children and pregnant women have an adequate diet with appropriate calcium and iron. Additional recommendations include washing your hands frequently and taking off your shoes to reduce dust in the home.

On broader scale we need to reduce the use of lead in a wide range of consumer products. Clearly this starts with products meant for children such as toys, vinyl plastics, jewelry and candy. Large amounts of lead are distributed in the environment from a variety of sources such lead fishing sinkers, car wheel weights, and bullets used in hunting and target practice. Most importantly we must reduce the number of homes contaminated with lead based paint. Many of these changes will require legislative or regulatory changes and acceptance that these changes benefit society. Finally, the CDC must review and lower the blood lead action level to send a clear message that no level of child lead exposure is acceptable.

More Information and References

Slide Presentation

- A Small Dose of Lead presentation material and references online: www.asmalldoseoftoxicology.org
  Web site contains presentation material related to the health effects of lead.

European, Asian, and International Agencies

- International Programme on Chemical Safety (IPCS) - Upcoming International Lead Poisoning Prevention Week. Online: <https://www.who.int/campaigns/international-lead-poisoning-prevention-week> (accessed: 6 September 2020).

"The aim of International Lead Poisoning Prevention Week is to draw attention to the health impacts of lead exposure, highlight efforts by countries and partners to prevent childhood lead exposure, and accelerate efforts to phase out the use of lead in paint."

- Australia – Australian Government Department of the Environment, Water, Heritage and the Arts. Online: <http://www.environment.gov.au/protection/chemicals-management/lead> (accessed: 06 September 2020).
  This site provides educational material about the sources of lead and strategies for living with lead.

North American Agencies

- Health Canada - Lead. Online: < https://www.canada.ca/en/health-canada/services/environmental-workplace-health/environmental-contaminants/lead.html> (accessed: 06 September 2020).
  Health Canada provides information on the health effects of lead and remediation programs.

- U.S. Environmental Protection Agency (EPA) Office of Pollution Prevention and Toxics - Lead Program. Online: <https://www.epa.gov/lead> (accessed: 06 September 2020).
  Site has information on lead health effects and lead abatement.

- U.S. Centers for Disease Control and Prevention (CDC). Online. <https://www.cdc.gov/nceh/lead/> (accessed: 06 September 2020).
  Site has information on CDC Childhood Lead Poisoning Prevention Program.

- U.S. Department of Housing and Urban Development (HUD) - The Office of Lead Hazard Control and Healthy Homes (OLHCHH). Online: < https://www.hud.gov/program_offices/healthy_homes> (accessed: 6 September 2020).
  Site contains information on lead paint in English and Spanish.

- U.S. EPA Safe Drinking Water – Final "lead free" rule - Online: http://www.epa.gov/safewater/lead/index.html. (accessed: 06 September 2020).

- U.S. EPA The Lead Hotline - The National Lead Information Center - Phone: 1-800-424-LEAD (424-5323) - https://www.epa.gov/lead/forms/lead-hotline-national-lead-information-center (accessed: 06 September 2020).

- U.S. Department of Labor Occupational Safety & Health Administration. Online: < http://www.osha.gov/SLTC/lead/index.html> (accessed: 06 September 2020). This site addresses work place lead exposure.

- U.S. Agency for Toxic Substance Disease Registry (ATSDR). Online: < http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=22 > (accessed: 06 September 2020).
  Toxicology Profile Series – Lead - The Lead Poisoning Prevention Outreach Program funded by the Environmental Health Center (EHC).

- Washington State, Department of Ecology – Lead Chemical Action Plan. Online: http://www.ecy.wa.gov/programs/swfa/pbt/lead.html.
- Reviews the source and use of lead in Washington and make recommendation on the reduction of lead exposure. (accessed: 06 September 2020).

Non-Government Organizations

- Washington Swan Working Group - an Affiliate of The Trumpeter Swan Society - Lead Poisoning. Online: <http://www.swansociety.org/> (accessed: 07 September 2020).
  Site has information on the lead poisoning of swans.

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