BLACKSMITH INSTITUTE

LEAD AND MATERNAL CHILD HEALTH IN THE GLOBAL SOUTH

NOTE: This document borrows heavily from the Toxicological Profile for Lead, published by the Agency for Toxic Substances and Disease Registry, 2007. Except where noted, the reader can assume that this is the source of any data or facts noted.

Summary prepared by Sandra Page-Cook, MPH

1. Executive Summary

Widespread exposure to lead can have devastating consequences for communities. The health, cognitive and behavioral effects of elevated blood lead levels can be serious, and cause suffering, excess health costs and loss of productivity, particularly challenging when coupled with the poverty prevalent in the Global South.

Lead mostly enters the body by ingestion, inhalation, or by mother-to-child transmission in-utero or via breast milk. Health effects of lead exposure include cognitive and neurobehavioral deficits, hyperactivity or attention deficit hyperactivity disorder in children, elevated blood pressure, neurobehavioral and neuropsychological effects in adults and encephalopathy, coma and death.

Children exhibit toxicity to lead at lower exposures than adults, and young children are documented to absorb lead more efficiently than adults. Special opportunities for lead exposure during childhood include:

Lead, Pregnancy and Birth: in addition to any active environmental exposure, blood lead levels increase approximately 20% during pregnancy in all women. This is the release of bone lead, stored over years of exposure, into the blood. Maternal blood lead freely crosses into the placenta, and infant blood lead levels are on average 19% higher than that of their mother at the time of birth. Health effects include the complications of maternal hypertension for mother and fetus, increased risk of miscarriage, preterm birth and low birth weight adjusted for gestational age.

Lead and Birth through Adolescence: infants and young children can be exposed to lead via breast milk or formula prepared with lead contaminated drinking water; crawling and playing on the floor, followed by hand-to-mouth activity; mouthing of objects, and indiscriminate eating of food dropped or found on the floor. Health effects include impaired neurobehavioral and cognitive development and slow growth.

While naturally present in the earth's crust, human use of lead over the past 300 - 400 years has resulted in harmful amounts coming into contact with humans. In 2009, significant sources of excess environmental lead include mining and smelting operations, gun and ammunition factories, and flaking lead based paint. In the Global South, additional sources of exposure include the production of leaded ceramic and pottery glazes and car battery recycling, the biggest use by far.

Blood lead levels are consistently higher in the Global South compared with the Global North, mostly because there are markedly more opportunities for exposure in the Global South, in particular, unsafe car battery recycling. Consisting of 70% lead, deteriorated car batteries can be smelted back into

usable lead and metal. Formally, businesses buy batteries in bulk to reclaim the lead and other metals. Informally, high unemployment rates along with increased car ownership have lead to the proliferation of small-scale recyclers. In many cases, informal battery melting is a subsistence activity, conducted in homes using archaic melting operations to recover and sell the secondary lead to larger processors. There are many opportunities for exposure during the informal process. Despite efforts by government agencies and the industry to bring safer and more efficient practices into the informal recycling process, ignorance of the risks of lead contamination combined with a lack of viable economic alternatives has led to the systemic poisoning of many poor populations throughout the world. Informal car battery recycling operations are found throughout the Global South, most typically on the outskirts of major urban centers.

While a blood lead level of 10ug/dL remains the CDC's official level of concern (above which health intervention is recommended), it is becoming more apparent blood lead in any amount can impact cognition and behavior. Decreasing IQ across a population has a dramatic effect. Lowering the average as well as the IQ of the least and most intelligent increases the number of people that fall into the category of mildly mentally retarded, hence requiring assistance, as well as decreases the number of high IQ people who generally become the leaders and innovators of society, thus magnifying challenges to alleviating poverty and addressing the myriad health and other concerns that face the poor populations of the world.

The confluence of the large number of lead contaminated homes, and the special susceptibility of children, born and unborn represent a disaster for children of the Global South.

Apart from alleviating suffering caused by lead poisoning, there are additional two key reasons for eliminating known sources of lead exposure in the Global South:

a. It is mostly a discrete problem. That is, fixable with a single infusion of resources and effort. Organizations and governments can then move on to address other issues.

b. Chronic lead exposure contributes to many other health and development challenges.

Addressing exposure to lead in the Global South can yield fundamental and sustained improvements to future health and educational status of the world's most vulnerable communities.

2. About Lead

Lead is a heavy metal that forms in the earth's crust and is released naturally into the environment through events such as volcanic emissions and geochemical weathering. Useful properties of lead include corrosion resistance, low melting point, and ease in molding and shaping. Lead has been used as a pigment in paints, dyes and ceramic glazes; in caulk; in pesticides; as a gasoline additive to increase octane rating; and combined with other metals (alloys) to produce ammunition, fishing sinkers, pipes, car batteries, weights, cable covers and sheets to protect humans from radiation.

Human use of lead has resulted in dangerous amounts coming into contact with humans. Environmental lead levels increased more than 1000 fold over the past 300 years, with the greatest increase occurring between 1950 and 2000 reflecting worldwide use of leaded gasoline, along with the proliferation of motorized vehicles. Lead use has reduced in recent years in response to greater awareness of its harmful effects. Today, lead is used in ammunition and in gasoline for airplanes and off-road vehicles throughout the world. Lead is also still used in car batteries – the biggest use by far. About 6 million tons of lead is used annually, of which roughly three quarters goes into the production of car, or lead acid batteries.

Lead that is released into the air is removed by rain or by particles falling to land or surface water. Lead sticks strongly to soil, tending to remain in the upper layer and over time migrating into drinking water.

In 2009, significant sources of excess environmental lead include:
In the Global North:

- Mining and smelting operations
- Gun and ammunition factories
- Old flaking lead based paint from buildings, bridges and other structures

In the Global South, significant sources in addition to the above include:

- Car battery recycling
- Production of leaded ceramic and pottery glazes (and use when the glazed items are used for food)

3. How Lead Enters the Human Body

Human exposure to lead occurs via:

Ingestion of lead contaminated soil, water or food. This is the way most lead enters the body. Typical ingestion routes include swallowing lead clinging to hands (either from soil or direct contact) during eating, drinking, smoking, applying cosmetics or other hand to mouth activity; drinking water from lead polluted rivers or via corroded lead pipes; consuming leafy fresh vegetables

grown in lead containing soils (via dust clinging to the leaves), foods from cans containing lead solder, foods from pottery or ceramic cooking or storage containers with lead containing glaze, or Illegal whiskey made using stills that contain lead-soldered parts (such as truck radiators). Inhaled lead particles that are too large to get into the lungs can be coughed up and swallowed.

Iron, calcium and/or zinc deficiencies can increase lead absorption from the gut, and hence the risk of lead toxicity. Additionally the absence of food in the stomach increases lead absorption. For example, children generally absorb 40-50% of ingested lead, adults absorb around 10-15%, however absorption rates of up to 70% have been seen when people have no food in their stomachs.[1]

Inhalation of lead dust and particles. Lead is commonly found in soil near roadways, around old orchards, older houses (with peeling lead based paint), incinerators, hazardous waste sites, landfills and certain factories. Lead containing soil can become air borne in dry and windy conditions. Inhalation is the primary route for occupational exposure, for example, people who work in the production or recycling of lead containing products, especially car battery recycling and construction workers demolishing or renovating old homes containing lead. Family members can be exposed when workers bring lead dust home on their work clothes.

Mother-to-child transmission in-utero or via breast milk (see *Lead and Maternal Child Health*)

Absorption through the skin. This is not a major route of exposure, however more lead passes through damaged (e.g. scratched or wounded) skin.

Once lead enters the body, it transfers from the blood to the soft tissues and organs (liver, kidneys, lungs, brain, spleen, muscles and heart). After several weeks it moves into the bones and teeth. Lead can be stored in bone for up to 30 years, however some is released back into the blood (to be re-circulated to the organs) under certain circumstances (pregnancy, lactation, after a bone is broken, with advancing age and during chelation therapy).

Analysis of lead in whole blood is the most common and accurate method of measuring recent lead exposure. Bone lead measurements are an indicator of cumulative lead exposure. Lead in tooth enamel is thought to reflect exposure in-utero and during early infancy during which time tooth enamel and dentine is completed.

[1] Agency for Toxic Substances and Disease Registry (ATSDR). *Toxicological profile for lead.* Atlanta; 2007 Aug. http://www.atsdr.cdc.gov/toxprofiles/tp13.pdf

4. Health Effects of Excess Lead Exposure

The health effects of lead are the same no matter how it enters the body. The main target for lead toxicity is the nervous system, both in adults and children. Baseline human blood-lead levels in the United States are 1.9 ug/dL[2] in children 1-5 years and 1.5 ug/dL in adults 20-59 years. There is currently no minimal risk level (MRL) for lead. The CDC has established blood lead levels of 10 ug/dL or greater as the "level of concern", above which public health intervention is recommended. Recent studies have suggested that adverse health effects exist in children at levels less than this, however the level of concern has not been reduced for multiple reasons, including the inaccuracy inherent in laboratory testing (that is, levels less than 10ug/dL cannot be accurately measured on a population level).[3] Symptoms of lead toxicity may be subtle and go unnoticed until blood lead levels reach 40 ug/dL or higher.

Health effects of lead exposure, and associated estimated blood lead levels include:

- Cognitive and neurobehavioral deficits (less than 10 ug/dL in children)
- Early signs of hyperactivity or attention deficit hyperactivity disorder (less than 10 ug/dL in children)
- Mild fatigue and lethargy (10 ug/dL)
- Elevated blood pressure (less than 10 ug/dL)
- Neurobehavioral and neuropsychological effects in adults (40-80 ug/dL)
- Peripheral neuropathy (pain and numbness in hands and feet)(40 ug/dL)
- Colic in children (60-100 ug/dL)
- Encephalopathy, coma and death (70-100 ug/dL in children; 100-120 ug/dL in adults)[4]

5. Lead and Maternal Child Health

Children are not small adults. Children's behavior and physiology influence their exposure and susceptibility to hazardous chemicals, especially very young children, including unborn children. Additionally, children have a longer remaining lifetime to express damage from toxins.

Children exhibit toxicity to lead at lower exposures than adults. For example, encephalopathy resulting from acute lead poisoning is estimated to occur at blood lead levels of between 100-120 ug/dL in adults, and between 70-100 ug/dL in children. The mechanism for this is not completely understood. Young children (less than 5 years) are also documented to absorb lead via the

---

[2] Micrograms of lead per deciliter of whole blood

[3] http://www.cdc.gov/nceh/lead/policy/changeBLL.htm

[4] Cleveland et al, Lead Hazards for Pregnant Women and Children: Part 1. AJN, Oct 2008, Vol 108, No 10

gastrointestinal tract more efficiently than adults, with 40-50% and 10-15% absorption rates relatively.[5] Additionally, children frequently have a greater prevalence of iron, calcium and zinc deficiencies, previously noted to increase lead absorption.

Children also store lead for longer than adults. That is, about 99% of the lead taken into the body of an adult will leave in the waste within a couple of weeks, but only about 32% of the lead taken into the body of a child will leave in the waste in the same timeframe. Under conditions of repeated exposure, lead will eventually accumulate in bone.

The following is a summary of the major special lead considerations for early life. Note that the routes of exposure described are in addition to exposures in the general population.

Lead, Pregnancy and Birth

Routes of Exposure:
As previously stated, bone lead levels are an indicator of cumulative exposure. Bone lead is released into the blood stream when bone metabolism increases, such as during pregnancy and lactation. Blood lead levels increase approximately 20% during pregnancy in all women, with even a small rise associated with pregnancy-induced hypertension. The rise is greatest during the first pregnancy (as bone lead levels may already be depleted during subsequent pregnancies).

Less commonly, pica is "the eating of one or more non-nutritive substances on a persistent basis for a period of at least one month."[6] While the prevalence is not known, pica is most common among very young children and pregnant women. Ingested substances can include lead if it is present in the environment.

Maternal blood lead freely crosses into the placenta. Infant blood lead levels are on average 19% higher than that of their mother at the time of birth. Therefore, childhood lead exposure can result in elevated blood lead levels in a baby born many (up to 30) years later.

Health Effects Include:

- Increased risk of hypertension in pregnant women. Maternal complications of hypertension include seizures, intracerebral hemorrhage, pulmonary edema and acute renal failure. Fetal complications include growth restriction, premature delivery and death.

---

[5] Agency for Toxic Substances and Disease Registry (ATSDR). *Toxicological profile for lead.* Atlanta; 2007 Aug. http://www.atsdr.cdc.gov/toxprofiles/tp13.pdf

[6] American Psychiatric Association. Pica. In *Diagnostic and Statistical Manual of Mental Disorders.* 4th, text revision ed. Washington DC: The Association; 2000. P. 103 (5)

- Increased risk of miscarriage, preterm birth and low birth weight adjusted for gestational age.[7] Low birth weight increases the risk of a host of conditions including respiratory distress syndrome, bleeding in the brain and susceptibility to sepsis, pneumonia and diarrhea in the neonatal period. Sepsis, pneumonia and diarrhea account for about 60% of neonatal deaths. Evidence now shows that adults born with low birth weight also face an increased risk of chronic diseases including high blood pressure, non-insulin dependent diabetes mellitus, coronary heart disease and stroke in adulthood.[8]

Elevated lead levels in men can lower sperm production, and some studies suggest that paternal exposure may also be associated with low birth weight.[9]

Lead and Birth through Adolescence

Routes of Exposure
After birth, infants can be exposed to a toxic amount of lead via their all-milk or formula diet. Lead is mobilized from bone stores to breast milk during the lactation period, and there appears to be a linear relationship between maternal blood and breast milk lead levels.[10] Lead can also be ingested with home prepared reconstituted formula when there is lead present in the drinking water.

After a few months of age, typical childhood behavior that leads to higher rates of ingestion of lead include crawling and playing on the floor, followed by hand-to-mouth activity; mouthing of objects, and indiscriminate eating of food dropped or found on the floor. As children approach adolescence, child specific routes of exposure decrease (e.g. hand to mouth behavior and poor hand washing after touching lead contaminated objects and before eating), while exposures such as via cosmetics, and occupational exposure may become more significant.

Less typical childhood behavior that can lead to increased rates of lead ingestion includes pica.

Health Effects Include:
- Impaired neurobehavioral and cognitive development, ultimately leading to deficits in academic and adaptive life skills, and increased risk of antisocial and delinquent behavior in older children.[11] Because of the incomplete

[7] Gonzalez-Cossio et al, *Decrease in Birth Weight in Relation to Maternal Bone Lead Burden*, Pediatrics. 1997 Vol 100, No 5, 856-862
[8] Qadir M, and Bhutta Z, *Small for Gestational Age. Causes and Consequences.* Pediatric Adolescent Medicine. Basel, Karger, 2009, vol 13.
[9] Min, Yi et al, *Parental Occupational Lead Exposure and Low Birth Weight*, Am J Ind Med. 1996 Nov;30(5): 569-78
[10] Gulson et al. *Relationships of Lead in Breast Milk to Lead in Blood, Urine, and Diet of the Infant and Mother*. Environmental Health Perspectives Vol 106, No 10, Oct 1998
[11] Needleman, H.L. et al *Bone Lead Levels and Delinquent Behavior JAMA*. 1996;275(5)

blood brain barrier, the effect of lead on the central nervous system is greatest during gestation and the first 36 months of life.

- Slow growth. Blood lead levels have been found to be inversely associated with weight gain in neonates, with an estimated decline of 15.1 grams per ug/dL of blood lead. Blood lead continues to be related to decreased stature throughout childhood, with a number of studies finding an effect on growth at levels as low as 2.8 ug/dL. It does appear that only blood levels affect growth; therefore a child must be continually exposed to lead throughout childhood for growth to be inhibited.

6. Lead Exposure in the Global North versus the Global South

Blood lead levels are consistently higher in the Global South when compared with the Global North. While it is generally agreed that further population level research needs to be conducted, in 1994 a meta analysis of existing research found that in children *with no identified industrial or occupational source*, 100% of 0-2 year olds, and 82% of 3-5 year olds had average blood lead levels above the 10ug/dL CDC level of concern in countries in the Global South compared with 78% and 28% respectively in similar populations in the Global North. Levels are higher for populations living, working or attending school near known sources of lead. The same study found that population (children and adults) average blood lead levels were 62 ug/dL in the Global South and 50 ug/dL in the Global North.[12]

Elevated blood lead levels in the Global South as compared with the Global North may be partially explainable by the fact that iron and/or calcium deficiencies, and the absence of food in the stomach, conditions common in poorer countries, increase the absorption of lead. The major reason for the difference is that there are markedly more opportunities for exposure in the Global South.

Sources of lead exposure unique to the Global South include:

Car Battery Recycling
Lead acid batteries are rechargeable batteries made of lead plates – car batteries. The lead plates eventually deteriorate, causing the battery to lose ability to hold a charge. It is now deemed a used lead acid battery (ULAB) and classified as hazardous waste by the Basel Convention. Car batteries can however, be smelted back into usable lead and metal, and the market for reclaiming secondary lead is growing, creating business opportunities in the Global South.

Formally, businesses buy the used car batteries in bulk to reclaim the lead and other metals. These recycling operations are often located in densely populated

[12] "*The Global Dimensions of Lead Poisoning",* The Alliance to End Childhood Lead Poisoning and the Environmental Defense Fund, 1994

urban areas with few pollution controls. In many cases the operations are not managed in an environmentally sound manner and release waste into surrounding soil and water sources in critical quantities.

Informally, high unemployment rates along with increased car ownership has led to the proliferation of small-scale recyclers. These are often marginalized members of society, needing an additional source of income, but with little understanding of the risks. In many cases, informal recycling is a subsistence activity, and undertaken in homes (even in the kitchen), using archaic melting operations to recover and sell the secondary lead to the larger processors. There are many opportunities for exposure during the informal process: the battery acid, containing lead particulates is often dumped on the ground or into the nearest water body, and/or as the lead plates are melted, lead ash is inhaled, collects on clothing or falls into the surrounds. Despite efforts by government agencies and the industry to bring safer and more efficient practices into the informal recycling process, ignorance of the risks of lead contamination combined with a lack of viable economic alternatives has led to the systemic poisoning of many poor populations throughout the world.

About 6 million tons of lead is used annually, of which roughly three-quarters goes into the production of car batteries. Much of this existing demand for lead is met from lead recovered from recycling used car batteries. This high level of recycling is very effective in reducing the volumes of lead dumped in the environment and in minimizing the need for mining more ores, however unhygienic and dangerous conditions often result in serious lead poisoning of the recyclers and the neighboring communities.

Informal ULAB recycling operations are found throughout the Global South, most typically on the outskirts of major urban centers.

Production of leaded ceramic and pottery glazes (and use when the glazed items are used for food)
It is estimated that 30% of Mexico's population use traditional lead-based glazed ceramics for cooking and food storage. Acidic foods common in the Mexican diet like chili peppers, tomatoes and lemons facilitate the transmission of lead from the glaze to the food. As a result, blood lead concentrations are elevated in families that use glazed ceramics, as well as the artisanal communities that produce glazed pottery.

Low heat traditional kilns are commonly used within the homes of the indigenous pottery producers, meaning that women and children are particularly at risk. While lead-free, boron-based glazes are available, higher temperatures are needed to attain the luster produced by lead based glazes. Hundreds of years of lead based pottery glazing in these communities have left high concentrations of lead in local soil.

The confluence of the number of lead contaminated homes in the Global South (from informal industries performed at or near home such as car battery recycling and pottery glazing), and the special susceptibility of children, born and unborn, represent a disaster for children of the Global South.

7. Societal Impacts of Widespread Childhood Lead Exposure

Widespread lead exposure has devastating consequences for communities. In addition to the suffering, excess health costs and loss of productivity from the maternal and infant health effects (complications from maternal hypertension, premature and small for gestational age newborns), as well as the health effects in the general population (elevated blood pressure, peripheral neuropathy, colic in children, encephalopathy and coma), the cognitive and behavioral effects of excess lead exposure can be serious.

While a blood lead level of 10ug/dL remains the CDC's official level of concern (above which health intervention is recommended), it is becoming more apparent blood lead in any amount can impact cognition and behavior. There have been many studies attempting to quantify the relationship between lead levels and lowered IQ. There seems to be the greatest decrease in the lowest ranges of exposure. For example, in one robust study increases in blood lead from 2.4 to 10 ug/dL was found to decrease IQ by 3.9 points, and increases from 10 to 30 ug/dL was found to decrease IQ by an additional 3 points.[13] In another, more recent study, increases in average blood lead levels throughout childhood from 5 to 9.9 ug/dL was found to lower IQ scores by 4.9%.[14]

These decreases in IQ may not seem significant in an individual, but across a population it has a devastating effect. Lowering the average as well as the IQs of the least and most intelligent *increases* the number of people that fall into the category of mildly mentally retarded, and hence require assistance (for example, with caring for a child and preventing and coping with disease), as well as *decreases* the number of people who could be called gifted and who generally become the leaders and innovators of society. This magnifies challenges to alleviating poverty and addressing the myriad health and other concerns that face many populations of the world.

[13] Lanphear, B.P. et al. *Low Level Environmental Lead Exposure and Children's Intellectual Function: An International Pooled Analysis.* Environmental Health Perspectives. Vol 113, No 7, July 2005.
[14] Jusko T.A. et al, *Blood Lead Concentrations <10ug/dL and Child Intelligence at 6 Years of Age.* Environmental Health Perspectives. Vol 116, No 2, Feb 2008.

8. The Value of Addressing Lead Exposure in the Global South

Apart from the obvious benefits to alleviating the suffering caused by lead poisoning, there are two additional key reasons for eliminating known sources of lead exposure in the Global South:

a. They are mostly discrete problems. That is, fixable with a single infusion of resources and effort. For example, the poisoning of communities around unsafe car battery recycling sites can be stopped by a combination of education, treatment of the most poisoned, remediation of contaminated soil and water, enforcement of regulations and establishing alternative work practices. Aid organizations and governments can then move on to address other issues.

b. Chronic lead exposure contributes to many other health and development challenges. For example, the excess low birth weight caused by lead exposure increases susceptibility to sepsis, pneumonia and diarrhea in the neonatal period.[15] Population wide lowered IQ levels decreases the potential of communities to benefit from educational opportunities.

Addressing exposure to lead in the Global South can yield fundamental and sustained improvements to future health and educational status of the world's most vulnerable communities.

[15] Qadir M, and Bhutta Z*, Small for Gestational Age. Causes and Consequences.* Pediatr Adolesc Med. Basel, Karger, 2009, vol 13.