CHAPTER 3. SOURCES AND PATHWAYS OF LEAD EXPOSURE

SOURCES AND PATHWAYS OF LEAD EXPOSURE IN CHILDREN INCLUDE:

Lead-based paint.

Soil and dust.

Drinking water.

Parental occupations and hobbies.

Air.

Food.

For some children, other sources and pathways, such as "traditional" medicines, may be critical.

INTRODUCTION

A child's environment is full of lead. Children are exposed to lead from different sources (such as paint, gasoline, and solder) and through different pathways (such as air, food, water, dust, and soil). Although all U.S. children are exposed to some lead from food, air, dust, and soil, some children are exposed to high dose sources of lead. Lead-based paint is the most widespread and dangerous high- dose source of lead exposure for preschool children.

Lead entering the body from different sources and through different pathways presents a combined toxicological threat (ATSDR, 1988). Multiple, low-level inputs of lead can result in significant aggregate exposure. Indeed, for children with lower (but still elevated) blood lead levels (for example, in the range of 10-20 ug/dL) identifying a single, predominant environmental source or pathway is not always possible.

This chapter describes the most important sources and pathways for childhood lead exposure. Information about the levels or concentrations of concern in different pathways is based on information assembled by regulatory agencies and other published data. Nothing in this chapter should be interpreted as suggesting standards for acceptable or unacceptable levels or concentrations of lead in different environmental media.

LEAD-BASED PAINT

LEAD-BASED PAINT IS THE MOST COMMON HIGH-DOSE SOURCE OF LEAD EXPOSURE FOR CHILDREN.

ABOUT 74% OF PRIVATELY OWNED, OCCUPIED HOUSING UNITS IN THE UNITED STATES BUILT BEFORE 1980 CONTAIN LEAD-BASED PAINT.

CHILDREN ARE EXPOSED TO LEAD WHEN THEY INGEST CHIPS OF LEAD-BASED PAINT OR INGEST PAINT-CONTAMINATED DUST AND SOIL.

MANY CASES OF LEAD POISONING RESULT WHEN HOMES CONTAINING LEAD-BASED PAINT ARE REMODELED OR RENOVATED WITHOUT PRECAUTIONS BEING TAKEN.

REMOVING LEAD FROM HOUSING IS IMPORTANT BOTH FOR THE TREATMENT OF POISONED CHILDREN AND FOR THE PRIMARY PREVENTION OF CHILDHOOD LEAD POISONING.

Lead-based paint remains the most common high-dose source of lead exposure for preschool children. Lead-based paint (containing up to 50% lead) was in widespread use through the 1940s. Although the use and manufacture of interior lead-based paint declined during the 1950s and thereafter, exterior lead-based paint and lesser amounts of interior lead-based paint continued to be available until the mid-1970s (CEH/CAPP, 1987). (Lead-based paint produced after the 1940s tended to have much lower lead concentrations than lead-based paint produced earlier.) In 1978, the Consumer Product Safety Commission banned the manufacture of paint containing more than 0.06% lead by weight on interior and exterior residential surfaces, toys, and furniture. Unfortunately, lead-based paint that is still available for industrial, military, and marine usage occasionally ends up being used in homes.

Nationwide, about 3 million tons of lead remain in an estimated 57 million occupied private housing units built before 1980 (representing 74% of all such housing). Of particular concern are the 14 million housing units believed to contain lead paint in unsound condition and the 3.8 million deteriorated units occupied by young children (HUD, 1990).

Pica, the repeated ingestion of nonfood substances, has been implicated in cases of lead poisoning; however, a child does not have to eat paint chips to become poisoned. More commonly, children ingest dust and soil contaminated with lead from paint which flaked or chalked as it aged or which has been disturbed during home maintenance or renovation. This lead-contaminated house dust, ingested via normal repetitive hand-to-mouth activity, is now recognized as a major contributor to the total body burden of lead in children (Bornschein et al., 1986). Because of the critical role of dust as an exposure pathway, children living in sub-standard housing and in homes undergoing renovation are at particular risk for lead poisoning.

Numerous studies have established that the risk of lead poisoning is related to the presence of lead-based paint and to the condition of such paint (ATSDR, 1988; EPA, 1986). Children who live in rehabilitated lead-free housing or who return to lead-reduced housing after undergoing medical treatment have significantly lower blood levels than children living in similar, nonrehabilitated housing (Bornschein et al., 1986; Chisolm et al., 1985). Data from several urban lead poisoning prevention programs indicate that deleading the home of a poisoned child can reduce blood lead levels substantially (Rosen et al., in press; Amitai et al., in press; G. Copley, unpublished data). Deleading or lead paint abatement can be an effective method of reducing children's exposure to dangerous levels of lead in paint and house dust if properly done (Farfel and Chisolm, in press), but may actually increase dust lead levels if not done properly (Farfel and Chisolm, 1990).

Lead paint is typically found on kitchen and bathroom walls and throughout pre-1950 homes on doors, windows, and wooden trim. The risks of lead poisoning are greater when lead paint or the underlying surface are in deteriorated condition and when lead paint (even intact paint) is located on surfaces accessible to children (EPA, 1986). Lead paint on interior and exterior window components is particularly of concern because it is abraded into dust by the repeated opening and closing of these windows (Farfel and Chisolm, 1990).

Many cases of childhood lead poisoning that result from renovation or remodeling of homes have been reported (Marino, 1990). Before older homes undergo any renovation that may generate dust, they should be tested for the presence of lead-based paint. If such paint is found, contractors experienced in working with lead-based paint should do the renovations.

There is no uniform standard for safe or allowable amounts of lead in existing painted surfaces. States and the federal government use values ranging from 0.7-1.2 mg/cm2 of wall when lead is measured using a portable x-ray fluorescence analyzer (XRF) or a standard of 0.5% lead by weight when tests are performed using laboratory analysis. These regulatory limits are based mostly on practical, not health, considerations.

Lead paint also continues to be used on the exterior of painted steel structures, such as bridges and expressways. In addition to the obvious risk to workers, increased lead absorption has been reported in children exposed to chips or dust during the deleading or maintenance of such structures (Landrigan et al., 1982).

Deleading, even when performed in the homes of children who have already been poisoned, is an important method of primary lead poisoning prevention because it reduces or removes the lead hazard from that housing unit for all future occupants. Methods for the safe abatement of residential lead paint are detailed in Chapter 8. The Department of Housing and Urban Development has primary responsibility for issues related to lead-based paint in housing.

SOIL AND DUST

Soil and dust act as pathways to children for lead deposited from paint, gasoline, and industrial sources.

The long-term efficacy and cost-effectiveness of different measures to reduce lead levels in soil need to be evaluated.

Reduction of dust lead is important both as part of deleading and as a means of interim risk reduction.

Soil and dust act as pathways to children for lead deposited by primary lead sources such as lead paint, leaded gasoline, and industrial or occupational sources of lead. Since lead does not dissipate, biodegrade, or decay, the lead deposited into dust and soil becomes a long-term source of lead exposure for children. For example, although lead emissions from gasoline have largely been eliminated, an estimated 4-5 million metric tons of lead used in gasoline remain in dust and soil, and children continue to be exposed to it (ATSDR, 1988).

Because lead is immobilized by the organic component of soil, lead deposited from the air is generally retained in the upper 2-5 centimeters of undisturbed soil (EPA, 1986). Urban soils and other soils that are disturbed or turned under may be contaminated down to far greater depths. Soil lead levels within 25 meters of roadways are typically 30-2,000 parts per million (ppm) higher than natural levels, with some roadside soils having concentrations as high as 10,000 ppm. Soils adjacent to houses painted with exterior lead paints may also have lead levels above 10,000 ppm. Measured lead levels in soil adjacent to smelters range as high as 60,000 ppm (EPA, 1986).

As part of normal play and hand-to-mouth exploratory activities, young children may inhale or ingest lead from soil or dust. Ingestion of dust and soil during meals and playtime activity appears to be a more significant pathway than inhalation for young children (EPA, 1986).

Different investigators have found widely varying relationships between levels of lead in soil and dust and children's blood lead levels. Blood lead levels generally rise 3-7 ug/dL for every 1,000-ppm increase in soil or dust lead concentrations (EPA, 1986; Bornschein et al., 1986; ATSDR, 1988). Particle size and the chemical form of lead may affect the bioavailability of lead in soil and dust; access to soil, behavior patterns, presence of ground cover, and a variety of other factors also influence this relationship (Barltop and Meek, 1979).

Even if ongoing deposition of lead into soil and dust is eventually halted, measures will have to be taken to reduce exposures from lead- contaminated soils and dusts. Until data demonstrating the efficacy and cost-effectiveness of permanent soil and dust abatement measures are available, interim risk reduction steps will be needed in some places. Dust control via wet mopping and frequent hand washing has been shown to reduce the blood lead levels of children with high blood lead levels (Charney et al., 1983), but this is not a permanent solution so long as the source of the lead in the dust remains. For urban and smelter communities, where outdoor soil can be a major source of lead in house dust (Diemel et al., 1981; Yankel et al., 1977), indoor dust abatement may not be effective unless abatement of soil lead is also conducted. Soil abatement may consist of either establishing an effective barrier between children and the soil or the removal and replacement of at least the top few centimeters of soil. Grass cover, if properly maintained, may be an effective means of limiting exposure to dusts originating from lead-contaminated soil (Jenkins et al., 1988).

DRINKING WATER

CONTAMINATION OF DRINKING WATER WITH LEAD USUALLY OCCURS IN THE DISTRIBUTION SYSTEM.

SEVERAL PROPERTIES OF WATER AND ITS PATTERN OF USE AFFECT HOW MUCH LEAD CONTAMINATION RESULTS FROM A PARTICULAR WATER DISTRIBUTION SYSTEM.

SOME PRACTICAL MEASURES CAN LOWER THE LEAD CONTENT OF DRINKING WATER.

Lead levels are typically low in ground and surface water, but may increase once the water enters the water distribution system. Contamination of drinking water can occur at five points in or near the residential, school, public, or office plumbing, including: 1) lead connectors (that is, goose necks or pigtails), 2) lead service lines or pipes, 3) lead-soldered joints in copper plumbing throughout the building, 4) lead-containing water fountains and coolers, and 5) lead-containing brass faucets and other fixtures. The 1986 Safe Drinking Water Act Amendments banned the use of lead in public drinking water distribution systems and limited the lead content of brass used for plumbing to 8%.

Several properties of water and its patterns of use affect the extent of lead contamination that results from a particular water delivery system. These factors include: 1) the corrosiveness of water (that is, pH, alkalinity, and mineral content), 2) age of the lead-soldered joints and other lead components (the newer ones often pose a higher risk), 3) quantity and surface area of lead materials, and 4) standing time and temperature of water in contact with leaded surfaces.

Typically, lead pipes are found in residences built before the 1920s, with the oldest cities having the most frequent use of lead pipes. Pipes made of copper and soldered with lead came into general use in the 1950s. Overall, lead leaching from copper pipes with lead- soldered joints represents the major source of water contamination in homes and public facilities such as schools.

In some areas of the United States (for example, Pennsylvania), cisterns are used to store water, especially rain water that may be acidic. Cisterns also can be roof-collection systems, which are common in some island areas (for example, Hawaii, the Florida Keys). When lead solder is used either in the construction of these cisterns or to repair leaks, or the cistern has a lead liner, the potential for lead contamination of the water is substantial. If the water has a relatively low pH, has low concentrations of cations such as Ca^{++} or Mg^{++} (that is, "soft" water), or has an elevated organic content, the water is probably aggressive in dissolving lead from the cistern. Corrosion control may be effective in reducing water lead levels in the case of corrosive water.

Lead in drinking water is probably absorbed more completely than lead in food. Adults absorb 35%-50% of the lead they drink, and the absorption rate for children may be greater than 60% (ATSDR, 1988).

In general, lead in drinking water is not the predominant source for poisoned children. In some circumstances, however, lead exposures from water are unusually high. Some water cooler-fountains have been found to have lead-soldered or lead-lined tanks. Patterns of intermittent water use from these fountains results in the water standing in the tanks longer than in typical residential situations, which can increase the amount of lead that is leached from the tanks. Several babies have been poisoned when hot tap water, which was then boiled (resulting in concentrating the lead), was used to make baby formula (J. Graef, personal communication).

Practical measures to reduce exposure to lead in drinking water include using fully-flushed water for drinking and cooking and always drawing water for ingestion from the cold water tap. The effectiveness of many point-of-use devices (treatment devices that are installed at the tap) in reducing lead in water varies and may be affected by the location of the device in relation to the lead source and by compliance with manufacturer's use and maintenance instructions. Some, like reverse osmosis and distillation units, may be effective. Carbon, sand, and cartridge filters do not remove lead.

The Environmental Protection Agency regulates the permissible lead content of water.

OCCUPATIONS AND HOBBIES

CHILDREN MAY BE EXPOSED TO HIGH LEAD LEVELS WHEN WORKERS TAKE HOME LEAD ON THEIR CLOTHING OR WHEN THEY BRING SCRAP OR WASTE MATERIAL HOME FROM WORK.

HOBBYISTS MAY ALSO INADVERTENTLY EXPOSE THEIR FAMILIES TO LEAD.

THE CURRENT OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION STANDARDS MAY NOT ADEQUATELY PROTECT THE HEALTH OF WORKERS.

A variety of work and hobby environments expose people to lead and may result in lead exposures for their families. Occupations frequently reported to have resulted in adult lead poisoning are shown in Table 3 1. Many potential hazardous activities, like furniture refinishing and making stained glass, may be either hobbies or occupations. Other activities that may be associated with lead exposure include using indoor firing ranges, doing home repairs and remodeling, and making pottery. "Take-home" exposures may result when workers wear their work clothes home or launder them with the family laundry or when they bring scrap or waste material home from work (Grandjean and Bach, 1986).

Strict compliance by industrial operations with the Occupational Safety and Health Administration (OSSA) General Industry Lead Standard governing lead exposures (29 CAR 1910.1026) would greatly reduce both occupational lead exposure and the associated indirect exposures in the homes of these workers. Unfortunately, not all occupational settings are covered by this regulation. Workers in construction including lead abatement workers -- are excluded from coverage under the General Industry Lead Standard; they are covered under a much weaker construction standard. Numerous workers in these work environments have been excessively exposed to lead, with construction workers particularly having a high risk of very high blood lead levels (Maizlish et al., 1990). Compliance with the OSSA comprehensive lead standard is inadequate (Landrigan, 1990; Maizlish, et al., 1990) even by those industries required to be in compliance. Furthermore, the current OSSA standard may not adequately protect the health of workers (Landrigan, 1990). OSSA plans to revise its standard within the next several years.

AIRBORNE LEAD

ALTHOUGH LEAD USE IN GASOLINE HAS BEEN MARKEDLY REDUCED, PREVIOUS USE HAS RESULTED IN WIDESPREAD CONTAMINATION OF SOIL AND DUST.

EXCEPT AROUND POINT SOURCES, AIRBORNE LEAD IS ONLY A MINOR EXPOSURE PATHWAY.

Until recently, the combustion of leaded gasoline by motor vehicles was the predominant source of airborne lead in the United States. However, the Environmental Protection Agency (EPA) ordered the reduction of almost all lead in gasoline during the 1970s and 1980s, and 1990 amendments to the Clean Air Act will completely prohibit the use of lead as a gasoline additive beginning as early as January, 1992 and concluding no later than December 31, 1995. As discussed in the previous section, however, soil and dust contaminated by deposition of lead-containing particles can contain high concentrations of lead.

Except around point sources, like smelters and battery manufacturing plants, inhalation of airborne lead is now a minor exposure pathway for individual children. Other industrial activities may also result in localized exposures to lead, including burning solid waste in incinerators and sandblasting or demolishing bridges and other lead- painted metal structures. These localized activities, however, can be important sources of high-dose exposure.

FOOD

THE QUANTITY OF LEAD IN THE U.S. DIET HAS DECREASED MARKEDLY IN RECENT YEARS.

IMPROPERLY FIRED CERAMIC WARE, LEADED CRYSTAL, AND LEAD-SOLDERED CANS RESULT IN LEAD LEACHING INTO FOODS.

SOME FOOD-HANDLING PRACTICES CAN INCREASE THE LEAD CONTENT OF FOODS.

During the 1980s, the quantity of lead in the U.S. diet decreased markedly. "Market basket" data from the U.S. Food and Drug Administration (FDA), used to estimate typical lead intake, show that the average dietary lead intake for a 2-year-old child was about 30 ug/day in 1982, about 13 ug/day by 1985, and about 5 ug/day in the period 1986- 1988. This reduction was achieved through substantially restricted use of lead-soldered side-seam cans and the phasing out of lead as an additive in gasoline. In 1980, 47% of domestically produced food and soft drink cans were lead-soldered. By 1989 use of lead-soldered cans declined to 1.4% of domestically produced cans. Counter to this trend is the continued use of lead solder in cans of imported foods, because cans manufactured outside the United States typically continue to contain lead solder.

Lead in foods comes from several sources in addition to lead solder: soil in which the plant is grown; air and rain; food processing (including lead leaching from some types of metal cans described above); contact with lead solder or ceramic vessels used to store the food; and contact with lead dusts in the home. If lead contamination is unusually severe, the quantity of lead in the diet will be much higher than the "Market Basket" estimates. Examples include imported food from countries that do not restrict the use of lead solder in cans; storage of foods packaged in lead-soldered cans for over a year or so, even if the can is unopened; storage of acidic foods in ceramic containers made with improperly applied leaded glazes; and food processed with lead- contaminated water.

Under some circumstances, food grown in "urban gardens" may have an elevated lead content if the garden soil is high in lead or if there are high lead concentrations in the air or water used for irrigation. Soil conditions (for example, pH, phosphorus content, buffering capacity, and the amount of organic matter) and the type of plant have a great effect on how much lead is transferred to the plant. The amount transferred is difficult to predict because many factors affect lead uptake. It is recommended that the crops grown on contaminated soil be tested to determine their lead uptake. Such tests may be arranged through the Agriculture Extension Service, state or federal departments of agriculture, or private laboratories.

Occasionally, food supplements can be seriously contaminated with lead. Examples have included various dietary supplements from "natural" sources, such as calcium supplements derived from animal bone sources.

In addition, some food-handling practices in the home can increase the lead content of foods and should be avoided. Foods should not be stored in unopened, lead-soldered cans for over a year or so. Foods should not be stored, even under refrigeration, in opened cans even if the can is subsequently covered. Food should be stored only in containers that do not release lead (for example, glass, stainless steel, or plastic containers). If ceramic food containers are ever used to store food, they should be made with lead-free glazes. Leaded crystal should not be used to store food for prolonged periods of time and should not be used to hold baby formula or juices.

Lead solders should never be used to repair food containers or to construct or repair cooking utensils. High lead levels may be present in hot water prepared in lead-soldered tea pots.

OTHER SOURCES

OTHER SOURCES AND PATHWAYS OF LEAD EXPOSURE

"TRADITIONAL" MEDICINES

COSMETICS

CASTING AMMUNITION, FISHING WEIGHTS, OR TOY SOLDIERS

MAKING STAINED GLASS

MAKING POTTERY

REFINISHING FURNITURE

BURNING LEAD-PAINTED WOOD

Published data, as well as anecdotal evidence from clinicians and others who work with lead-poisoned children, have identified a variety of other sources of concern.

Many "non-Western" medicines (for example, greta and azarcon used to treat diarrhea or gastrointestinal upset) and cosmetics (for example, surma or kohl used around the eye for decorative or medicinal purposes) contain substantial quantities of lead and other metals. Rather than occurring as trace ingredients or trace contaminants, various lead compounds are used as major ingredients of traditional medicines in numerous parts of the world. "Traditional healers," using non- Western pharmacopeias, manufacture these products, which are often brought to recent immigrant groups by friends and relatives. Examples of such exposures have been reported from the Arab cultures, from the Indo-Pakistan subcontinent, from China, and from Latin America.

Many hobbies can result in substantial exposures to lead. For example, molten lead can be used in casting ammunition and making fishing weights or toy soldiers; leaded solder is used in making stained glass; leaded glazes and frits are used in making pottery; and artists' paints may contain lead. Furniture refinishing may also result in lead exposure.

In some areas, the burning of lead-painted wood in home stoves and fireplaces is a source of lead exposure. Lead fumes are generated, ashes contaminate the home, and ashes are often disposed of in the back yard, resulting in contamination of the environment.

FOLK REMEDIES CONTAINING LEAD INCLUDE:

ALARCON
ALKOHL
AZARCON
BALI GOLI
CORAL
GHASARD
GRETA
LIGA
PAY-LOO-AH
RUEDA

SOURCES OF LEAD OUTSIDE THE UNITED STATES

CHILDHOOD LEAD POISONING IS A PROBLEM WORLDWIDE.

Childhood lead poisoning is a problem worldwide. In other parts of the world, however, predominant sources of lead are very different than in the United States. For example, leaded gasoline is still widely used in many countries and contributes to elevated blood lead levels, especially in urban children. Poorly glazed pottery leading to high food lead levels can be the most prominent source of lead in some areas, for example, in parts of Latin America. Point industrial sources may dramatically increase air and soil lead levels in parts of the world where environmental controls have not been effectively implemented, for example, in Eastern Europe. Lead contamination from cottage industries that recycle lead, often in backyards, is a problem in Central America and elsewhere. For children moving to or from the United States, an assessment of potential lead hazards requires specific knowledge of the country involved.

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