Chapter 9
Lead in Household Products

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Abstract Humans have used lead for various purposes for thousands of years. Despite awareness of the dangers associated with lead, this element continues to appear in a wide range of household products and poses hazards through different exposure pathways. Sources of household lead exposure discussed in this chapter include: paint dust, drinking water, solder, candle wicks, wood finishes and brass fittings, ceramics, shot and bullets, food and spices, toys and jewelry, lead as a stabilizer in vinyl and polyvinyl chloride-based plastics and wiring, cosmetics, electronic equipment and electronic waste, contaminated soil, and lead batteries. Despite awareness of the dangers of lead exposure, lead in consumer products continues to be the reason for recalls, and the majority of those recalled products originate in China. Consumer education on this topic is ongoing, but should be expanded. Targeted audiences should include new parents, medical professionals, teachers, and others. Important messages should stress that any exposure to lead, especially by children, is harmful.

Keywords Lead poisoning · Environmental exposure · Lead in household products · Lead dust · Vinyl products · Polyvinyl chloride · Lead solder · Electronic waste · Toys · Lead shot and bullets · Glass and ceramics · Cosmetics · Batteries · Contaminated soil

9.1 Key Take Home Points

- Lead is present in many types of household products, including leaded paint and dust, solder, wood finishes and brass products, vinyl plastics, toys and

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jewelry, food and beverages stored in leaded ceramic and crystal, and is present in electronic waste and lead batteries.
- Lead can contaminate the soil, drinking water, and the air we breathe.
- Lead-painted surfaces can produce a fine dust that is poisonous, especially to infants and children.
- Dermatological contact with lead from paint dust and certain vinyl products can lead to ingestion through hand-to-mouth contact.
- The current level of concern set by the Centers for Disease Control and Prevention (CDC) is 5 micrograms per deciliter (μg/dL) blood.
- There is no safe level of exposure to lead.

9.2 Introduction

Human beings have used lead for various purposes for at least 7,000 years (Cochran 2006). The Ancient Egyptians, Chinese, Romans, and others used lead for medicinal and cosmetic purposes, roofing, plumbing pipes, goblets, vases, pots, coins, stationery and pottery glazing, among other uses. Although awareness of lead poisoning has existed for over 2,000 years (Chauhan et al. 2010), lead is still present in our environment.

As is illustrated in Fig. 9.1, lead exposure occurs through ingestion, inhalation, and dermatological contact; and lead poisoning can affect nearly every organ in the body (The Lead Group 2013). According to the World Health Organization (2010), lead's adverse health effects include cognitive deficits, attention deficit disorder, behavior problems, dyslexia, hypertension, immunotoxicity, reproductive system damage, convulsions, coma, and death. While children are at higher risk of problems associated with lead poisoning, adults are affected as well. Although the United States's (U.S.'s) CDC has set 5 μg of lead per dL of blood as a reference level for public health actions, research has demonstrated that there is no threshold for health problems associated with lead exposure (American Academy of Pediatrics 2012). In other words, there is no safe level of contact with lead.

In 1909 France, Belgium, and Austria banned the use of white-lead paint (The Lead Group 2013). Lead was banned in the U.S. as an ingredient in residential paint in 1978, and from gasoline in 1986, but there are an estimated 50 million homes and apartments in the U.S. with lead-based paint (Heimlich 1997), and soil throughout the country is contaminated with lead from car exhaust emissions that occurred before the leaded gasoline ban. Beyond these issues, lead continues to be used in products that are used and consumed on a daily basis around the world. Lead exposure also occurs when processing discarded consumer goods. This includes an emerging risk of extensive lead poisoning in China, where crude methods are used to harvest metals from recycled electronic waste (e-waste), resulting in extensive soil and water contamination and elevated blood lead levels in children (Huo et al. 2007). To examine the extent of this issue, a literature

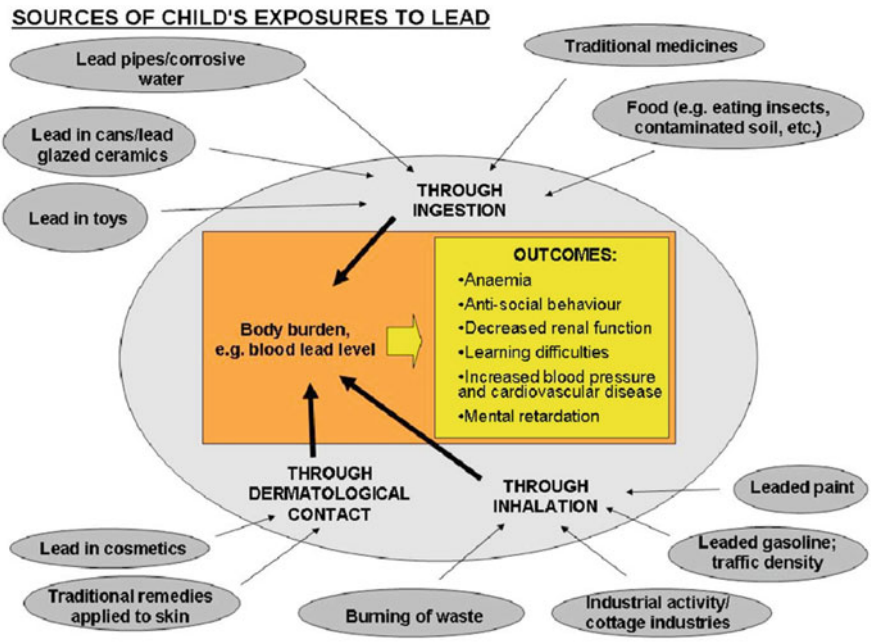

Fig. 9.1 Lead exposure sources. Credit: Permission granted to reproduce this figure by the World Health Organization (WHO) from Childhood Lead Poisoning (ISBN 978 92 4 150033 3), Fig. 1, pg. 19, Copyright 2010, http://www.who.int/ceh/publications/childhoodpoisoning/en/, Accessed 16 April 2013

search was conducted of academic journals, health-related websites, and other sources. Findings are organized through the exposure pathways (oral, inhalation and dermatological) with a separate section on drinking water in the oral exposure section.

9.3 Oral Exposure

9.3.1 Drinking Water

Drinking water can become contaminated with lead in numerous ways. Lead emissions from coal-fired power plants can contaminate water supply sources (Fischetti 2013). Lead-tin solder was used in water supply pipes until 1986. This solder was used to seal joints in copper pipes. In homes that have these pipes that were installed before 1986, lead levels can build up in water when it is not flushed from faucets. For example, when water is stationary in pipes overnight, the first draw of water in the morning may have detectable lead levels. Public health

officials recommend that the first use of water from these systems be done carefully. Water should be run during the first draw until it becomes as cold as it can get. At that point, residual lead will have been flushed from the system. Hot water from lead-soldered pipes should never be used for consumption, as more lead leaches into hot water than cold.

Under certain conditions such as nitrification, lead can leach from polyvinyl chloride (PVC) pipe. Nitrification is:

> …a microbial process by which reduced nitrogen compounds (primarily ammonia) are sequentially oxidized to nitrite and nitrate. Ammonia is present in drinking water through either naturally-occurring processes or through ammonia addition during secondary disinfection to form chloramines (USEPA 2002).

Zhang et al. (2009) observed that nitrification increased lead levels in potable water by reducing pH. They further observed that 45 % more lead was released from leaded brass fixtures connected to PVC pipes as compared with copper pipes. Residents of homes in which PVC piping is used in the supply lines of the plumbing system should be advised to flush their water line in the same manner that is prescribed for copper systems with tin-lead solder.

Rabin (2008) relates how old municipal water systems used lead pipes to deliver water to homes. This was recognized as a public health threat in the 1800s, and in the early part of the twentieth century municipalities began to prohibit lead service lines. This movement was countered by the Lead Industry Association (LIA), which began a public campaign to commend the benefits of using lead pipes. Problems remain to this day, as the federal *Lead and Copper Rule* (LCR) requires water companies to initiate lead water pipe replacement when lead levels in water exceed 15 parts per billion (ppb). But the LCR allows water utilities to replace only the public portion of lead pipes. The private portion of these pipes, from the main service line to a house, can be left in place. Renner (2007) describes that when partial replacement is undertaken, that disturbance results in a rise in lead levels in water. Millions of homes in the U.S. have lead service lines as part of their water supply systems (McCartney 2010).

Drinking water can be contaminated with lead from brass or chrome-plated brass faucets. Most of these faucets that were purchased before 1997 contain up to 8 % lead (Massachusetts Water Resources Authority 2012). Federal legislation enacted in 2010 mandates that all faucets purchased after January 14, 2014 have no more than a weighted average of 0.25 % lead per wetted surface area.

Lead solder was used in electronic equipment, but that practice ended with a European Union ban in 2006. Black (2005) reported that when older electronic devices that were disposed of in landfills break down, lead could leach from those landfills and contaminate drinking water. Electronic waste, or e-waste, consists of unwanted electronic devices or Cathode Ray Tubes (CRT). These devices frequently contain hazardous materials, including lead. To prevent groundwater contamination from e-waste, these materials should be properly recycled. E-waste disposal in landfills is illegal in some states (Jarnot 2013).

Lead exposure can occur during manual harvesting of metals from recycled e-waste. In China, where crude methods are used to harvest precious metals from electronics, housings are dismantled manually (Huo et al. 2007). Older television sets with CRTs contain 8 to 9 pounds of lead, and workers can be exposed dermatologically during the manual demolition of the electronics, with discarded materials potentially leaching lead into soil and waterways. This may result in other routes of exposure including ingestion from contaminated drinking water obtained from polluted streams and river beds.

9.3.2 Ingestion

Lead can also enter the body through ingestion. The case of crawling toddlers was mentioned above as an example of lead ingestion through contaminated hand-to-mouth activity from paint and household dust contaminated with lead. But lead can also be ingested directly through contaminated food and other items. In 1991 U.S. food canners voluntarily stopped using lead/tin solder to seal seams in cans used to preserve food. In 1995 the U.S. Food and Drug Administration (FDA) banned the use of lead to solder the seams of such cans. Not all countries have done this, however. Lead solder has been found in cans of rice pudding, lotus-nut paste, and bamboo shoots from China and in canned ham from Denmark (Knight-Ridder News Service 1997).

Lead has been found in venison harvested with lead shot or bullets. An estimated 10 million hunters and their families, as well as those who obtain venison from food pantries, are considered to be at risk for lead ingestion from this source (Hunt et al. 2009). Lead shot and bullets also affect wildlife populations.

Slow cookers, or crock-pots, are another source of lead in the human diet (Insightful Nana 2008). Lead is used in the glazed ceramic insert that is in direct contact with the food that is being cooked. Glazed ceramic dishes, cups, and other tableware can contain lead. Glazed ceramic pots from Latin American countries, such as Mexican bean pots, are likely to have lead in the glazing (Contra Costa Health Services n.d.). Another way that lead can get into food is by growing it in contaminated soil. A study of this issue found that leafy vegetables grown in such soil had higher concentrations of lead than did beans, fruits, and root vegetables (Karnpanit et al. 2010).

Lead-contaminated soil is of particular concern for urban gardens used for growing food for human consumption. Clark et al. (2008) tested 141 backyard gardens in Roxbury and Dorchester, Massachusetts, and found that 81 % of these plots had levels of lead above the U.S. Environmental Protection Agency (USEPA) hazard level of 400 μg per gram (g). While a recommendation to avoid growing vegetables in contaminated soil is to use raised beds lined with landscaping fabric and filled with compost, these authors found that this practice requires maintenance. They observed that lead levels in raised beds increased from

150 μg/g to an average of 336 μg/g over a 4-year period and theorized that the contamination originated from lead particles that were transported by wind.

Lead is also used in glass making to produce lead crystal, which has traditionally been favored because of its radiance and durability (Barbee and Constantine 1994). Barbee and Constantine (1994) found that lead levels in sherry stored in lead crystal decanters were 50 μg per liter (L) after storage for 2 months in a 20-year old decanter, 163 μg/L in a 10-year old decanter, and 1,410 μg/L in a new decanter. They concluded that lead leaching decreases with the age of a decanter. Other researchers have found that lead levels in 4 % acetic acid, white port, and a synthetic alcoholic beverage stored in lead crystal decanters for 1-, 2-, and 10-day periods at room temperature ranged from 100 to 1,800 μg/L, which are above the level that a warning under California's Proposition 65 is required (Appel et al. 1992). This proposition requires that consumer products with known hazards must carry a warning label about such hazards.

High levels of lead have been found in candy imported from Mexico. Some of the candy ingredients, including chilies and tamarind, are dried in the sun. Lead emissions from gasoline and factories can be deposited on the drying foods that are then used in candy making. Some candies are made in ceramic pots that can leach lead (Center for Environmental Health 2006). Mexican candies can also become contaminated with lead when lead ink is used in the candy wrappers.

Lead has been found in baby food, especially baby food with carrots, peaches, pears, and sweet potatoes (Dearen 2013). This particular issue involves a lawsuit filed by an environmental group that is demanding that contaminated baby food must carry a label for California's Proposition 65. Grape juice and fruit cocktail have also been known to have detectable levels of lead (Bolokhova 2013). The sources of lead appear to be contaminated soil and older processing equipment. Some Indian spices and cultural powders have been found to have lead levels that resulted in elevated blood lead levels in children (Gurgel 2010).

In 1994 the Consumer Product Safety Commission (CPSC) recalled crayons imported from China because of high lead levels (CPSC 1994). There was concern that the children could be exposed to lead by chewing on or eating pieces of the lead-contaminated crayons over an extended period of time.

Ayurveda, a traditional medical practice followed in India and other South Asian countries, is associated with medications that can contain lead. This is also the case with traditional or folk medications used in Middle Eastern, West Asian, and Hispanic cultures. The CDC has tracked specific cases of lead poisoning in the U.S. that involved Americans who consumed folk medications (CDC 2004). Lead is deliberately added to some of these medications because of the mistaken belief that it has curative properties. In some cases the source of lead is contaminated soil or older processing equipment.

9.4 Inhalation

Lead inhalation can occur when particle sizes are below 10 μm (micrometers) in diameter, as is the case with fumes and fine dust (World Health Organization 2010). Lead-polluted air results from lead smelter emissions and car emissions in countries that still use leaded gasoline. Lead fumes are also produced when heat guns are used to remove lead-based paint.

Before it was banned, lead-based paint was the paint of choice for double-hung windows because of its superior adhesive properties (Park and Hicks 1995). But as sashes rub against each other when the lower sash is opened and closed, a fine dust is produced (CDC 2012). This is the source of much lead in dust in older homes (CDC 2012). The dust can be inhaled and ingested by toddlers who accumulate the lead on their hands as they crawl (CDC 2012). Hand-to-mouth activity then results in ingestion (World Health Organization 2010). Dust on floors below windows is covered under the clearance standards set by the U.S. Department of Housing and Urban Development (HUD). After work in a house by a paid contractor that disturbs lead paint, the amount of lead on a floor can be no more than 40 μg per square foot (μg/ft^2); interior windowsills can have no more than 250 μg/ft^2; and window troughs can have no more than 400 μg/ft^2.

Candles represent another source of lead fumes and dust. Some candlewicks contain lead as a stiffening agent. Wasson et al. (2002) observed that burning a single candle in a room can raise the amount of lead in the air of that room above the ambient air lead concentration limit set by the USEPA of 1.5 μg per cubic meter (m^3). This lead is in the air as fine particulates that can settle on furniture and floors. Although the Consumer Product Safety Commission (CPSC) banned the manufacture of lead-containing candle wicks in 2003, imported candles, and those purchased at yard sales and from thrift stores, may contain them.

Lead is also present in varnish, shellac, and wood stains in older homes. Sanding surfaces with these coatings can generate high amounts of lead-containing dust. Precautions to be taken during sanding include isolating the work area from the rest of the house and attaching a high efficiency particulate air (HEPA) vacuum to the sanding machine (Hardwood Floors 2012).

9.5 Dermatological Contact

A third pathway for lead into the human body is through dermatological contact. Note that this pathway can also lead to ingestion if the affected area is touched by a hand and is followed up with hand-to-mouth contact. Children's toys are in this category because of lead paint and lead-contaminated vinyl. Bounce houses are the large, inflatable jump houses and bouncy castles that are made of vinyl. The Center for Environmental Health (2010) began testing for lead in these products in 2010. In nearly every test, high levels of lead were detected. Lead is added to the vinyl to

stabilize colors. Some vinyl mini-blinds can contain lead. The CPSC recommends that these blinds should be removed from homes and replaced with blinds that are labeled "No Lead Added" or "Non-leaded formula" (Contra Costa Health Services n.d.a 2013). Lead has been found in toy and adult jewelry and in Disney® charms (Center for Environmental Health 2013).

Lead in amounts that exceed safety standards for children's toys has been found in pet toys (Dale 2013). No safety standards exist for lead in pet toys. Lead was found in the ink of tennis balls for dogs. In addition to safety concerns for dogs, children can pick up a wet ball after it has been in a dog's mouth and get lead on their hands.

Another plastic household product that can contain lead is the garden hose (Hickman 2012). The study that examined this issue focused on PVC garden hoses and found lead levels in 30 % of those tested to contain lead levels over 100 parts per million (ppm), which is the CPSC maximum level for lead in children's products. Water from one of the tested hoses contained lead at 0.280 mg/L (280 ppm); the USEPA action level for lead in drinking water is 0.015 mg/L (15 ppm). Apart from handling the hoses and potential dermatological contact, watering a garden with PVC hoses can pollute the soil with lead. Of course, drinking water from a PVC garden hose can result in lead exposure from ingestion. These hazards can be avoided by choosing polyurethane or rubber hoses. In addition to lead in PVC, lead is also a component of brass garden hose connectors and has been found in excess of 2,500 ppm (Hickman 2012). Garden gloves with raised PVC dots on the fingers also contain lead in excess of 2,000 ppm (Hickman 2012).

Lead has also been found on the wiring of Christmas lights and appliance cords (Laquatra et al. 2008). Lead is used as a stabilizer in the PVC coating that covers the electrical conductors. Lead can be transferred to hands when lights or cords are handled. An additional concern is degradation of Christmas light strings that are installed outdoors. Exposure to sunlight can result in lead being released from the PVC and then contaminating soil.

Cell phone cases have been found to contain lead (Sauler 2013). Those most likely to contain lead are brightly colored and made from synthetic materials, including PVC. To avoid lead exposure from these cases, consumers should select cases made of fabric or non-PVC cases.

The use of lead as a stabilizer in vinyl has been mentioned as a component in bounce houses. This is also the case for vinyl tile flooring (Main 2013). Lead dust can be released from vinyl tiles over time. Removal of vinyl tiles should be undertaken with lead-safe work practices; or they can be covered with linoleum, cork, or hardwood floors.

Vinyl lunch boxes have been found to contain lead (NRDC 2012). Lead is added to vinyl as a stabilizer. Exposure to sunlight and air breaks the chemical bond between lead and vinyl and causes lead dust to form. Children can get the dust on their hands and then transfer it to food, or food can become directly contaminated with the dust. Safer alternatives for carrying lunch are metal lunch boxes, canvas sacks, or paper bags.

Lead in amounts as high as 500 ppm has been found in faux leather purses and sandals at 700 ppm (Nguyen et al. 2013), and wallets at 58,700 ppm (Main 2013). These exposures can be avoided by choosing real leather, canvas, or cotton products.

The FDA conducted studies of lipstick in 2009 and 2012 and found lead levels of up to 7.19 ppm in this cosmetic (Severns 2013). For average and high use of lipstick, Liu et al. (2013) estimated an acceptable daily intake of lead to be less than 20 %. The Environmental Working Group maintains *Skin Deep,* a website with safety information on cosmetics and personal care products (EWG's Skin Deep 2013).

Lead is also present in brass house and car keys (Lucas 1999). Health officials recommend that children should not be given keys to play with and that people wash their hands after handling keys (Rother 2000).

About half the content of a type of eye makeup known as kohl, kajal, al-kahl, or surma can be comprised of lead (FDA 2011a). Kohl has been used since ancient times in Africa, the Middle East, Iran, Pakistan, and India. Although illegal in the U.S., kohl has been found in Europe and North America, particularly in Asian and Middle Eastern specialty stores, and for sale on websites (FDA 2011a).

Progressive hair dye products contain lead in the form of lead acetate (FDA 2011b). These dyes are applied over a period of time to achieve a gradual hair color change. People using such dyes have been monitored and no increase in blood lead level has been found from such use. However, a warning is required on these products that states they are for external use only, should not be applied in areas where there are scalp abrasions, and the product should not be allowed to get into eyes.

Lead is in some types of batteries: automobiles and other vehicles use lead-acid batteries, as do some alarm and emergency lighting systems (Wieman 2013). These batteries do not threaten human health when they are used. Problems occur when they are disposed of improperly. If they are landfilled or incinerated, lead can be released into the environment. Recycling is the best option for disposal of lead-acid batteries.

Table 9.1 provides a summary of lead-contaminated items commonly found in household settings and their exposure pathway(s).

9.6 Conclusions and Future Directions

Wherever possible manufacturers should be encouraged or required to use substitutes for lead in their products. Markowitz and Rosner (2013) describe the difficulty of this work and provide a detailed history of the U.S. effort to ban lead as an ingredient in gasoline and paint. They explain the role of the LIA to discredit the science of lead poisoning and the scientists involved in its research. The LIA deliberately misled the public about adverse health effects from lead and enlisted the assistance of politicians to protect their interests. The bans on lead in gasoline

Table 9.1 Lead-contaminated items and exposure pathway(s)

Item(s)	Source(s) of lead	Exposure pathway(s)		
		Inhalation	Ingestion	Dermal contact
Drinking water	Pipes, solder, faucets		✔	
Walls, windows, doors	Paint	✔	✔	
Candles	Wicks	✔		
Wood surfaces	Varnish, shellac, stains	✔		✔
Canned food	Solder		✔	
Game	Shot or bullets		✔	
Slow cookers (crock pots)	Glazing		✔	
Ceramic dishes, cups, tableware	Glazing		✔	
Garden vegetables	Contaminated soil		✔	
Stored beverages	Crystal decanters		✔	
Mexican candy	Sun-dried chilis and tamarind		✔	
Mexican candy	Glazing in pots used for production		✔	
Mexican candy	Ink on wrappers		✔	
Baby food	Soil, processing equipment		✔	
Grape juice, fruit cocktail	Soil, processing equipment		✔	
Indian spices	Soil, processing equipment		✔	
Folk medications	Deliberate ingredient, soil, processing equipment		✔	
Bounce houses, lunch boxes	Vinyl		✔	✔
Toy and adult jewelry, charms	Deliberate ingredient		✔	✔
Art materials	Crayons		✔	✔
Mini-blinds	Vinyl		✔	✔
Garden hoses	PVC, brass connectors		✔	✔
Garden gloves	Raised dots		✔	✔
Purses, sandals, wallets	Faux leather, vinyl			✔
Lipstick	Deliberate ingredient		✔	✔
Tile flooring	Vinyl	✔	✔	✔
House and car keys	Brass		✔	✔
Kohl	Deliberate ingredient			✔
Progressive hair dyes	Lead acetate			✔
Pet toys	Ink		✔	✔
Christmas lights, appliance cords	PVC			✔
Cell phone cases	Synthetic materials, PVC			✔
Electronic equipment	Solder		✔	
Batteries	Lead-acid		✔	

and paint were ultimately successful. In the case of paint, this was only because dedicated scientists, public health professionals, and others persisted in their efforts to convince the CDC and the USEPA of the seriousness of the issue. In the case of gasoline, the USEPA had ordered a reduction in sulfur emissions from car exhaust. In response, General Motors announced that it would install catalytic converters in cars. These converters were fouled by lead and required the use of unleaded gasoline (Markowitz and Rosner 2013).

Despite awareness of the dangers of lead exposure, lead in consumer products continues to be the reason for recalls, and the majority of those recalled products originate in China (Gips 2009–2010). Even if products that contain lead could be kept from entering markets in the U.S., there is no mechanism in place to prevent their sale at thrift shops, yard sales, and eBay auctions. Consumer education on this topic is ongoing, but should be expanded. Targeted audiences should include new parents, medical professionals, teachers, and others. Important messages should stress that any exposure to lead, especially by children, is harmful. Much work is necessary to raise awareness of the dangers posed by exporting e-waste and its resulting manual recycling, especially by children, in China. USEPA (2012) reported that there have been attempts to institute a federal law regarding e-waste recycling, but these have so far been unsuccessful.

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