PEDIATRIC LEAD POISONING OF RESIDENTIAL ORIGIN

Rabinowitz M. B.
Marine Biological Laboratory and Harvard Medical School, USA

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Summary

Lead is a naturally occurring element with many useful properties. For centuries it has been known to be toxic. Drinking water can be a source, if soft or acidic waters come in to contact with lead plumbing. Pre-treating the water decreases the corrosiveness by increasing the pH. Exposure to lead can come from many sources, but lead paint has had the biggest impact on children.

Young children are especially at risk because of greater exposures, uptake rates, and susceptiblity of their developing organs. For poisoning it is not necessary to eat paint chips, since dusts can provide sufficient levels. Lead paint was made by mixing linseed oil and pigment grains of basic lead carbonate or lead sulfate. The paint deteriorates and chalks with the release of lead rich particles.

Lead is a neurotoxin, but it also affects heme, blood pressure, and calcium metabolism. The symptoms are non-specific, so diagnosis principally depends on measuring levels of lead in blood. Due to the current ineffectiveness of treatments in averting all the long term effects of lead, prevention is important.

The use of lead based paint peaked in 1924, but continued until the 1970s. In the United States, an estimated 57 million homes contain lead based paint on exposed surfaces. The problem extends to other areas in Europe, Australasia, and Latin America where lead paints were used.

In recent decades, with the reductions in gasoline lead and food can solder, the population exposures have dropped dramatically. Screening of children has been successful, because cases are identified before blood lead levels rise even higher. Screening for lead paint is much preferred.

Remediation of dwellings can be practical, but requires adequate reductions in dust. Inappropriate de-leading practices can increase the risk. Part of societys response has been innovation, regulation and litigation. This is still a vexing problem.

1. Introduction

1.1. Background

Lead is a naturally occurring chemical element. Although not found in nature in its metallic state, lead metal can be fairly easily smelted by roasting the ore with charcoal. As a metal, its many useful properties including ductility, flexibility, durability, and malleability along with its chemical inertness made it a valued commodity to the ancients. It is easily melted and shaped. It was used as water pipes and gutters, weights, some pewter utensils, and, later, in ammunition, ceramic glazes, batteries, and shielding.

Additionally, several common salts of lead and pigment were used in past centuries as a medicine in Europe and elsewhere. Treatments based on lead salts as astringents and ointments were common until this century. Even today, lead compounds are used as remedies and cosmetics in cultures as diverse as Hispanic, Arabic, and Indian. These many uses brought it in to close daily contact with humans, as a common industrial and household item.

Unfortunately lead is also toxic. This has also been known for many centuries. Pliny, during the first century BC, warned of the dangers of lead, and in the mid-1700s, Benjamin Franklin cautioned his readers about lead contamination of rum and ciders. During the 1800s, white lead dust was recognized as an occupational hazard for women and children. In 1897 in Australia, A.J. Turner and J. Lockart Gibson observed that lead paint used on wooden dwellings in Queensland was responsible for an epidemic of kidney disease. They concluded that the children would lick the water off the painted surfaces of wooden veranda railings of their homes and years later develop kidney disease as a consequence of their lead exposure. Blackfan's 1917 article on childhood lead poisoning informed Americans that lead poisoning from paint was a frequent cause of deaths. Later, for example, the Baltimore City Health Department identified 135 cases of pediatric lead poisoning, as part of their routine investigations, including 49 deaths between 1930 and 1941. Lead poisoning was not uncommon.

1.2. Overview

The use of lead as a gasoline additive in the twentieth century resulted in widespread dispersal of lead-bearing particles from the exhaust. Much of that lead was in respirable-sized particles resulting in direct human exposure. Other portions of the automobile exhaust lead entered the food chain by fallout, with additional human exposure. Although the use of lead additives for gasoline has been greatly reduced, the residues from past usage have accumulated and are still present in soils and dusts.

Exposure to lead can come from many sources. For the usual person, most of their lead comes from their diet. The uses of lead for water pipes can, with certain water qualities, increase their lead exposure to the level necessary for overt toxicity. Gasoline additive resulted in widespread exposure, but usually not in sufficient quantities to result in overt intoxication. Rather, the entire population is subjected to sub-clinical quantifies, which make additional exposures from other sources more perilous. Of all the forms of lead exposure, the one which has had the greatest impact on children has been the use of lead bearing paints.

The manufacture of lead pigment was one of the major uses of lead in the 20th century, and exposure to lead paint was the principle source of pediatric lead intoxication. The bulk of this manuscript is related to lead paint, its composition, manufacture, properties, and fate. The health effects of lead are the same, regardless of the source of exposure. Before discussing paint in detail, the other major residential source, lead in drinking water from plumbing is discussed.

2. Plumbing as a Source of Poisoning

2.1. Lead in Water

Lead is present in trace amounts in natural surface and ground water. Atmospheric inputs of lead by fallout or surface runoff usually form insoluble salts or are absorbed onto particles and enter the sediment. Consequently, most water supplies are quite low in lead, less than 5 μg L^{-1}. However, drinking water can be markedly higher due to contact with lead bearing pipes, solder, and plumbing fixtures in the residence. Waters that are particularly corrosive (plumbosolvent) because of acidity or softness can be troublesome and can result in elevated lead levels in the consumed water, especially in hot, stagnant, or "first draw" water. Faucets and tap fixtures made of brass often have lead present as a contaminant in the alloy, and this can be a source of high lead levels in the first draw. In these circumstances, drinking water can be the overwhelming source of lead, reaching well over 300 μg L^{-1}. Fully flushing typical distribution systems even with corrosive water and fresh lead solder will usually lower water lead levels, usually to below 20 μg L^{-1}. Current American standards for lead in public drinking water are 50 μg L^{-1} but will likely be reduced to 10 or 20 μg L^{-1} as a "no-action" level.

The extent of the problem of lead contamination by the water distribution system is difficult to estimate. It has been estimated that in America 16% of partially flushed water systems exceed 20 μg L^{-1}. The use of lead pipes has long been prohibited, and are being replaced, but they are still used particularly in remote areas and farms. The use of lead solder in residential water supplies has recently been outlawed by the 1986 Amendments to the Safe Drinking Water Act, but existing systems usually contain some lead, estimated to be 10 kg per house.

As lead that is in contact with some waters gradually acquires a partially passivating internal carbonate coating, older houses have less lead in the tap water than newer homes. For example, standing water from homes with copper pipes and lead solder newer than 5 years averaged 31 μg L^{-1}, while homes less than 18 months old averaged 74 μg L^{-1}. In contrast, homes with galvanized pipes averaged less than 6 μg L^{-1}. New, exposed lead solder can raise standing water lead levels to above 100 μg L^{-1} within 40 minutes.

2.2. pH Adjustments of Drinking Water

The contribution of lead pipes, cisterns and plumbing to lead poisoning has been long recognized, particularly when soft or acidic water is conveyed. The addition of lye or lime to the water supply before distribution raises the pH to above 7.5 and lowers its corrosiveness. This approach has been shown to be a useful system-wide remedy. Efforts in Scotland and later in Boston in the 1970s involved treating the water prior to distribution with lime to decrease the corrosiveness and plumbosolvency of the water, by increasing its pH.

This was very successful as an interim measure until the lead mains and tanks were removed. Even tody this is an ongoing effort. In July 1998, the Massachusetts Water Resources Authority issued public notification that the target pH would be raised from 7.8 to 9.0 during the next phase of adjustments. Some communities are expected to have pH targets of 9.2 to 9.8 by mid 2001. The continued existence of lead attic water supply tanks represents a continued hazard, and their removal is required for blood lead levels to reach acceptable levels.

3. Lead Paint

3.1. Paint Ingredients and Properties in General

Paint is a substance composed of a solid coloring material or pigment suspended in a liquid medium. Typically, it is prepared and applied as a liquid which soon dries and hardens into a protective coating. To be desirable, a paint must have certain properties including adhesion, ease of application, and integrity of the coating, including its physical durability and ability to retain its color. It must be strong, but must also be elastic to changes from the expansion and contraction of the substrate. Of course, it must offer protection of the surface against wear and weather.

Paint liquid is composed of as many as four basic components: vehicles, solvents, pigments and additives. The vehicles carry the pigment grains to the surface where they remain after drying. Solvents may be used to improve spreadability of the paint, but evaporate on drying. The pigments give paint its opacity, color, hiding power, and hardness. Pigments also includes inert extenders or fillers which add body to paint at little expense. Additives may be used to improve drying, resist fading, or other special purposes. The ingredients of paint have included a wide range of natural and artificial materials.

3.2. Lead Paint Ingredients and Properties

In the case of lead paint, it is usually just a mixture of linseed oil from the flax plant and very fine white lead pigment grains. The pigments may be basic lead carbonate or lead sulfate, at times mixed with zinc oxide and rutile titanium oxide that are used as extenders to improve its hiding power. Several other lead pigments have been used to a lesser extent, including lead silicate as a wood primer and red lead for corrosion resistance of metal bridges and other structural steel.

Lead based paint, in which the white lead pigment grains were often the only pigment, was made by grounding and mixing a combination of linseed oil and white lead, which was later thinned for application. After brushing onto wood and exposure to air, evaporation and oxidation commence. Also, the lead grains react with the oil compounds to form insoluble lead soaps, which grow and interlock to form a durable film.

With the passage of the years, the surface deteriorates in the form of chalking, caused by the gradual oxidation and the loss of the paint matrix, with the release of insoluble pigment. This continual loss of surface material in the form of chalk-like fine lead powder results in a surface that can be repainted without much additional preparation, which professional painters prefer. It was often the custom to repaint the house frequently, perhaps every few years, and labor expended on surface preparation were thus reduced. Many distinct layers of paint thus accumulate on a house.Lead has also been used as a paint drier, in addition to its use as a pigment. Driers are compounds added to paint to hasten drying. White lead pigment is itself a drier, but smaller amounts of other lead compounds were sometimes added for this purpose. These include lead resinates, linoleates, and naphthenates.

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Biographical Sketch

M. B. Rabinowitz was born in New York in 1947, a forth generation American. He graduated in 1968 from the Massachusetts Institute of Technology with an SB in Physics. He received an MS from the University of California, Los Angeles, in Planetary Sciences and a PhD in 1975 in Geochemistry, where he did a post-doctoral fellowship. His principle advisors were George Wetherill, Joel Kopple and Willard Libby. He married Diane Hoxmeier and has one child.

In Los Angeles, he used isotopic methods to identify smelter or automotive lead in soils and grasses from Missouri and California. At the Wadsworth Veterans Hospital, he performed long-term isotopic tracer study in a metabolic balance ward, constructed a multi-compartment model of lead kinetics, and calculated the relative importance of dietary and respired inputs. Also, whilst there, he performed a clinical trial of various chromium supplements on diabetes.

At Boston Children's Hospital he surveyed over 10,000 umbilical cord blood samples and repeated environmental assessments of 200 homes to examine the role of lead in child development. He measured lead in interior portions of deciduous teeth and related these values to past blood lead. As a Visiting Associate Professor at National Taiwan University, he measured lead in blood and teeth to investigate the relationships among lead exposure, family factors and a child's school performance.

Other activity has included a case-control study of tea drinking and oral cancer, immobilizing soil lead by phosphate treatment, understanding dentin as a biomarker, and writing a history of biokinetic models. Currently, he serves as an Associate Scientist at the Marine Biological Laboratory and a Clinical Instructor in Neurology at Harvard Medical School. He is a member of the American Geophysical Union, the Society for Environmental Geochemistry and Health, the American Public Health Association, and the Explorers Club. He enjoys ocean sailing and tai chi chuan.