Lead in Museum Collections and Heritage Buildings

Introduction

Lead is seldom used in modern applications because of its toxicity. However, it was widely used in the past and can be found in many objects in museums and other cultural heritage institutions (see Table 1). Anyone who works with or around lead-containing artifacts in museum collections or heritage buildings (e.g. collection researchers, conservators, curators, interpreters, restorers, and the general public) is at risk of lead exposure. This Note provides information about minimizing occupational exposure and also includes resources for locating guidelines and legislation relevant to working with or disposing of lead. For more detailed information on this subject, see Selwyn (2005).

Table 1. Uses of lead and lead compounds

Metallic lead and lead alloys	
Architecture	roofing, flashing, gutters, downspouts, spacers and grout in masonry
Batteries	rechargeable lead-acid batteries
Objects	water cisterns, caskets, urns, mortuary vases, weight standards, weapons, ship anchors, seals, lead shot, lead weights, tokens, medals, vases, stabilizing cores, lining for wooden ship hulls, pewter utensils (e.g. plates, bowls, cups, jugs, spoons), electrodes, connectors, cable sheathing, radiation shields, belt buckles, trophies, casket trim, miniature figures and toys, children's jewellery, hollow-ware, leaded seams on vintage cars, fuses, sprinkler systems alloys, foundry pattern moulds
Sculptures	lead statues, garden urns, borders, planters, basins, component in bronze sculptures
Solder	lead-tin solder
Stained glass	lead cames
Weights	in looms, diving gear, fishing lines, and base of curtains
Lead compounds	
Paint	lead-based paint (on polychrome sculptures, wood surfaces, metal surfaces), putty on window glass
Modern pigments	white: white lead reds and oranges: red lead, chrome orange, chrome red yellow: yellow lead, chrome yellow, Naples yellow blue, brown, black: blue lead
Glazes and enamels	pigments and fluxes in ceramic glazes applied to clay and in enamels applied to metal
Leaded crystal	wine glasses, decanters
Plastics	heat and light stabilizers in plastic toys, vinyl purses, decals, coloured insulation on electrical or telephone wires
Textiles	pigments to colour fabric, compounds to weight silk
Medicine	salves, medications
Cosmetics	face paint, theatrical makeup, eye cosmetics, hair dyes
Organic lead	leaded gasoline

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Lead Toxicity

Lead is one of the most hazardous metals. It accumulates in the human body, and its toxic effects are numerous and severe. Virtually no part of the body is immune from the effects of lead. Furthermore, lead and lead compounds were declared to be "reasonably anticipated to be human carcinogens" by the United States National Toxicology Program in January 2005.

Prolonged absorption of lead or its compounds results in lead poisoning. Acute exposure (i.e. high-level exposure over a short time) can cause colic, coma, convulsions, and death. Chronic exposure (i.e. low-level exposure over a long time) can cause anaemia as well as damage to the brain, digestive system, kidneys, and nervous system. Lead can also interfere with both male and female reproductive systems. Children and the developing fetus are even more seriously affected by lead than adults.

Lead and lead compounds can enter the body by ingestion, inhalation, or absorption. The health impact is determined mainly by the amount of lead that enters and is retained in the body. This is determined primarily by the physical form of the lead rather than its chemical form. The physical forms of lead that are most readily absorbed into the body (and hence the most dangerous) are lead-containing dusts, fumes, mists, and liquids and their vapours.

Lead dust forms when solid materials are broken down into small particles. For example, dusts can be created when handling, grinding, sanding, polishing, or cutting lead or lead-containing materials. The dust can vary in size from large particles, which tend to fall to the ground, to fine particles, which can remain airborne for hours.

Lead fumes are extremely fine particles created after heating lead or lead-containing alloys to a temperature high enough to vaporize the lead. The lead then reacts with oxygen and condenses as fine particles of lead oxide. The plume of smoke generated during soldering with lead-based materials can contain lead fumes and a variety of decomposition products, which can cause eye and respiratory irritation.

Mists are fine droplets of liquid in the air. When lead mists are generated — for example, during spray painting with products containing lead compounds — lead can be inhaled.

The smaller the dust, fume, or mist particles, the longer they remain airborne before settling in the workspace. Especially dangerous are the fine "respirable" dusts and fumes. These are invisible to the eye and, when inhaled, can penetrate deep into the lungs.

When lead is inhaled, it is absorbed into the bloodstream through the respiratory tract. When swallowed, it is absorbed through the digestive tract. Although certain lead compounds are insoluble in water, they may be soluble in the fluids in the lungs or digestive tract because of the complex nature of these fluids. Therefore, it is wise to consider all compounds containing lead as potentially toxic. Furthermore, both inorganic and organic lead compounds can be absorbed through the skin.

Once absorbed into the bloodstream, lead circulates until it is either stored in the body or excreted from it. The time it takes half of a given amount of lead to be removed from the blood (lead's half-life in blood) is about 27–36 days. About 95% of the lead that is stored in the body resides in the bone, from which it may be released back into the blood during aging, illness, periods of stress, or pregnancy. The rest of the stored lead resides in the brain, kidneys, liver, spleen, and teeth.

Recognizing Lead and Lead-corrosion Products

Lead is a heavy gray metal that is shiny when freshly cut but darkens on exposure to air. Because lead is soft, objects made from lead are easily scratched or bent. Indoors, historic lead objects gradually develop a dark patina. Lead objects that have been buried or exposed outdoors are usually covered with an adherent film of relatively insoluble lead compounds. For more information on the corrosion of lead in various environments, see Selwyn (2004).

Lead metal is susceptible to corrosion indoors when the local environment is contaminated with organic acids, particularly acetic acid. Wood (with oak, Eastern White cedar, and Western Red cedar being the worst), wood products, oil-based paints, some emulsion paints, and certain adhesives are all sources of acetic acid. When lead corrodes in the presence of acetic acid, it becomes covered with white powdery corrosion products. For example, white corrosion products are often observed on lead anchors attached to wooden ship models inside display cases. The loosely adherent white lead corrosion products are a potential source of lead-contaminated dust. For more information on indoor pollutants that affect lead, see Tétreault (2003). Lead formate can also develop on lead in the presence of formic acid; possible sources of this acid are oil-based paints and wood products used in the construction of display cases.

Occupational Health and Safety Legislation

Canada's ten provinces, three territories, and federal government each have their own occupational health and safety legislation. The federal government is responsible for the health and safety of federal employees and workers in certain industries. The remaining workers are covered by provincial or territorial legislation. The current agencies (federal, provincial, and territorial) responsible for occupational health and safety legislation for Canadians can be found on Canada's National Workplace Health and Safety Web site (http://www.canoshweb.org).

The Canada-wide Workplace Hazardous Materials Information System (WHMIS) also gives employers and workers information about hazardous materials in the workplace. The key elements of WHMIS are worker education programs, and mandatory provisions for Material Safety Data Sheets (MSDSs) and safety labelling on containers of controlled products, materials, and substances. An MSDS provides information on the hazards of a product, and precautions for safe use. These forms are provided by the manufacturer of the product. Depending on the form of lead, the minimum concentration for disclosure on an MSDS varies from 0.1% to 1.0% by weight. Each of the agencies responsible for occupational health and safety has established employer WHMIS requirements within their respective jurisdiction. Employers of workplaces where hazardous materials are present are required to train their employees and make product MSDSs available to those who use or could be exposed to potentially hazardous products. MSDSs are also posted on numerous Web sites (see "Where To Find Material Safety Data Sheets On The Internet" at http://www.ilpi.com/msds/index.html).

Everyone working with lead-containing materials should obtain the current occupational health and safety regulations pertinent to lead from the agency responsible for their jurisdiction (http://www.canoshweb.org). These regulations should be revisited periodically, as legislation is amended from time to time. The regulations exist either in a general format that deals with many hazardous materials, or in a stand-alone regulation that deals specifically with lead. There are also some provincial guidelines on lead available online (see Resources, below), and more guidelines may become available in the future (see the "View by Jurisdiction" menu at http://www.canoshweb.org).

To ensure workers are not exposed to unsafe levels of lead via inhalation, occupational health standards specify an Occupational Exposure Limit (OEL) for the amount of lead allowed in the air. Some agencies set their own OEL standards, but most base them on the most-current Threshold Limit Value (TLV) set by the American Conference of Governmental Industrial Hygienists (ACGIH). The ACGIH has set the TLV/TWA (time-weighted average) of elemental lead and most inorganic lead compounds for an 8-hour work day and a 40-hour work week at 0.05 milligrams of lead per cubic metre of air (0.05 mg m^{-3}). Workers should not be adversely affected if exposed to airborne lead up to this TLV/TWA limit during a conventional 8-hour workday and 40-hour workweek.

Blood tests to detect lead levels are a useful way to monitor whether a worker is adequately protected against lead exposure. Lead regulations usually require regular testing of blood-lead levels and often specify a level above which workers must be removed from further exposure.

Controlling Occupational Exposure to Lead

Engineering controls (e.g. isolation or ventilation) are recommended by industrial hygienists as the first line of defense in controlling and minimizing exposure to lead. The next steps are administrative controls (e.g. housekeeping, personal hygiene, and storage and disposal programs), followed by the use of personal protective equipment (e.g. respirators and protective clothing).

Engineering controls

Inside buildings, engineering controls such as local exhaust ventilation, fume hoods, or down-draft benches can be used to draw lead fumes or dust away from where lead-based material is being worked. Note that these systems should not draw contaminated air past a worker's breathing area. Down-draft benches with slot vents are particularly useful when soldering, as these minimize exposure to decomposition products from the soldering process.

When large quantities of lead-contaminated materials are generated, such as when removing lead-based paint from historic houses, the debris must be contained, collected, and disposed of as hazardous waste. Containment of the workspace and its isolation from surrounding areas is achieved by using an enclosure under negative pressure. Engineering controls are used for dust extraction and air handling.

Administrative controls

Another important way to minimize exposure to lead is good personal hygiene. Eating and drinking should not be allowed in the workspace because these activities easily transfer lead contamination from the hands into the mouth. It is especially important to wash hands before eating to reduce the ingestion hazard. After working with lead-based materials and before going home, employees should change out of their work clothes and take a shower. This helps to stop lead dust from being taken home and spread to others, especially children. Children should never be allowed into areas where lead is being worked on or used.

Good housekeeping also plays a key role in the control of lead exposure. Keeping the work area clean is one of the best ways to minimize exposure to lead. Regular use of a vacuum cleaner equipped with a high-efficiency particulate air (HEPA) filter is highly recommended. More information on commercially available HEPA vacuum cleaners is available in Stavroudis and Shtrum (1997) and Guild and MacDonald (2004). After vacuuming, all surfaces in the workspace and nearby areas should be cleaned using wet-cleaning or damp-mopping methods with phosphate-rich detergents such as trisodium phosphate (TSP).

Lead-contaminated waste material should be contained, collected, labelled, and disposed of as hazardous waste. During the collection and removal process, lead dust must not be allowed to become airborne. The local municipal government, the waste management agency in the area, or the provincial/territorial Department or Ministry of Environment should be contacted for instructions on disposing of hazardous lead waste.

Personal protective equipment

When engineering and administrative control measures are not sufficient to achieve acceptable limits of exposure to lead, respiratory protection should be used. There are two kinds of respirators: air-purifying and supplied-air. The National Institute for Occupational Safety and Health (NIOSH) is the only organization in North America to test and certify respirators, and its standards are used by Canadian occupational health and safety agencies. Each respirator has an Assigned Protection Factor (APF). A respirator with an APF of 10, for example, will allow a properly fitted and trained user to work safely in an environment that contains 10 times the TLV.

NIOSH updated and modernized the regulation for certifying air-purifying particulate respirators in June 1995. Nine classes of air-purifying respirators were defined, based on filter efficiency and use limitations. There are three levels of filter efficiency:

- 95%
- 99%
- 99.97% (which is usually shortened to 100% and rated as a HEPA filter)

There are also three categories of resistance to filter efficiency degradation:

- N (not resistant to oil)
- R (resistant to oil)
- P (oil-proof)

The P100 is the only filter assigned a distinctive magenta colour.

When lead is present in relatively low concentrations (i.e. in environments containing up to 10 times the TLV), air-purifying respirators (half-face piece) with an APF of 10 are usually specified. A filter efficiency of 95%, 99%, or 100% may be acceptable, depending on the regulation. However, due to the high toxicity of lead, it is always preferable to use the 100% efficiency filter.

A higher-protection-factor respirator (e.g. supplied-air respirator) is generally specified for higher levels of airborne lead. Many activities can generate high airborne lead levels. These include brazing, removal of lead-based paints using hand scraping or dry sanding, removal of lead-based paints using power tools without effective dust collection, and spray application of lead-containing coatings.

To ensure a proper seal between the face and the face piece, respirators should be fit-tested by a qualified individual. For more information on respirators, see Canadian Standards Association (2002), Colton (2002), Guild and MacDonald (2004), and Rossol (2001).

Re-usable or disposable protective clothing should be worn to prevent the contamination of personal clothing and the transfer of contamination from the work area to lunch and break areas, vehicles, and homes. Protective clothing includes lab coats, gloves, coveralls, and shoe coverings. Disposable clothing that is contaminated with lead should be treated as hazardous waste.

Lead-based paint removal

Lead-based paint becomes a hazard when it is no longer well-adhered to a surface. As lead-based paint deteriorates and starts chipping, flaking, or peeling, it can become detached from the painted surface and form dust or small particles. Lead-laden dust particles can also be generated by activities that wear down the painted surface, such as opening and closing windows. When anyone then vacuums, sweeps, or walks through this lead-contaminated material, the particles can re-enter the air and be spread farther.

Everyone involved with the removal of lead-based paints from historic buildings or historic industrial sites prior to repainting must take special care to protect themselves from exposure to lead. In the past, workers have suffered lead poisoning when removing lead paint because they used removal processes that generated large quantities of airborne dust or fumes, e.g. abrasive methods such as dry sanding, power sanding, grinding, and abrasive blasting that were not contained and heating methods (particularly open flame burning and hot-air guns).

Safer methods for removing lead-based paint include using HEPA-vacuum-contained abrasive methods, wet hand scraping, chemical strippers, or a heat gun operated at temperatures below 500°C. For more information on reducing hazards when dealing with lead-based paints, see Devine (1998), Martone and Park (1990), Park and Hicks (1995), Rossol (2001), and Stavroudis (1998).

Conclusion

Lead and lead compounds can be absorbed through the skin, inhaled, or ingested. They are especially dangerous in the form of fine dust, mist, or fumes, which can easily enter the body and cause lead poisoning. When dealing with lead-containing materials, appropriate safety precautions need to be followed to minimize exposure to lead. This can be accomplished by using a combination of engineering and administrative controls as well as personal protective equipment. Although general guidelines are summarized in this Note, the reader should consult the appropriate government (federal, provincial, or territorial) agency for current regulations on working with lead and disposing of hazardous lead waste.

Resources

Alberta — Human Resources and Employment, Government of Alberta, *Lead at the Work Site*, revised November 2008 (http://www.hre.gov.ab.ca/documents/WHS/WHS-PUB_ch061.pdf).

British Columbia — Workers' Compensation Board of British Columbia, *Lead: Preventing Exposure at Work*, 2006 (http://www.worksafebc.com/publications/health_and_safety/by_topic/assets/pdf/lead.pdf).

Ontario — Ministry of Labour, Ontario, *Lead on Construction Projects*, September 2004 (http://www.labour.gov.on.ca/english/hs/guidelines/lead/index.html).

Quebec — Commission de la santé et de la sécurité du Québec, *L'exposition au plomb*, 2004 (http://www.csst.qc.ca/publications/listepublications.htm) [in French only].

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