Exposure to lead in the world of work:

Impacts for occupational safety and health

Research report
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Acknowledgements

With the strategic oversight and guidance of Manal Azzi (OSH team lead and Senior OSH specialist, ILO), this report was prepared by Natasha Scott (Independent Consultant), Halshka Graczyk (Technical OSH Specialist, ILO) and Lacye Groening (Technical Officer, ILO). The ILO is grateful to Elena Jardan and Lesley Onyon from the World Health Organization (WHO) for their valuable comments and contributions. We would also like to thank a number of ILO colleagues for their insights and guidance.
Executive summary

Lead is a highly toxic heavy metal, whose widespread use in many industries has impacted the health of numerous workers globally. Exposure to this hazardous metal can severely damage body systems and organs, leading to disability, life-long illness and even death.

Workers in many sectors are exposed, including those in used lead-acid battery (ULAB) recycling, construction, painting, mining and smelting. Whilst a global ban in leaded petrol and regulations restricting the use of lead in some products, such as paint and piping, has been positive for lead consumption, there is increased usage in other industries, such as the electronics sector. Additionally new areas of occupational concern are emerging, for example the use of lead as a plastics additive has created a threat for recycling workers.

The ILO has long recognized the dangers of lead, with some of the earliest international labour standards, specifically the Lead Poisoning (Women and Children) Recommendation (No. 4), 1919 and the White lead (Painting) Convention (No. 13), 1921, concerned with protecting workers from hazardous lead exposures. Since then, the ILO has adopted more than 40 legal instruments related to preventing hazardous chemical exposures in the workplace. The inclusion of a ‘safe and healthy working environment’ as an ILO fundamental principle and right at work (FPRW) provides a framework for action to protect workers against hazards in the workplace, including harmful lead exposures, through a systems approach to managing occupational safety and health (OSH).

This report was undertaken in order to provide a sound evidence base for lead as a world of work concern. It aims to provide stakeholders, such as governments, employers and workers, with a tool to identify sectors of concern in their regions and to understand the potential scale of the problem in terms of occupational health impacts. Finally it outlines key priority actions, at both national and workplace level, to better protect workers at risk of hazardous lead exposures.
Main findings

- Lead continues to be mined and used in growing quantities, despite product bans and increasingly stringent environmental regulations in high-income countries (HICs).

- Workers in numerous different sectors are exposed to lead. Those identified as high risk include, but were not limited to: Battery manufacturing and recycling, painting and paint abatement, construction, lead smelting and refining, e-waste, welding, auto repair, plastics manufacturing and recycling, plumbing and lead mining.

- The Global Burden of Disease is >900,000 for environmental lead exposures, however no such data exists for occupational lead exposures. It is likely that the number of impacted workers is sizeable.

- Occupational exposure to lead can occur in all phases of the metal's life cycle, from mining and refining to production and use, and finally recycling and disposal. Workers are at risk of lead exposure when tasks produce lead dust, fumes or vapours.

- Lead-acid batteries account for around 85 per cent of global lead consumption and at present there is no feasible and economically viable alternative to this damaging product. These batteries have many uses, however the largest market is for automotive batteries, with demand growing rapidly (May et al. 2018).

- According to the World Health Organization (WHO), there is no known safe level of lead exposure (WHO 2022a). Even relatively low levels of lead that were previously considered ‘safe’, have now been shown to damage health.

- Chronic exposure to lead, even in small amounts, may adversely impact the nervous, urinary, reproductive and cardiovascular systems (Figure 1). Inorganic lead compounds have been classified as probably carcinogenic to humans by the International Agency for Research on Cancer (IARC). Workers are also at risk of acute poisoning, if exposed to high levels of lead over a short period of time.

- Evidence from many sectors demonstrates that numerous workers in high-risk industries have blood lead levels (BLLs) of far higher than 5μg/dL, the WHO action level for when protective measures should be introduced.

- Lead poisoning is a completely preventable disease.
Figure 1: Main health impacts associated with occupational lead exposures

Key sectors of exposure

- Battery manufacturing and recycling
- Painting and paint abatement
- Construction
- Lead smelting and refining
- E-waste
- Auto repair
- Plastics manufacturing and recycling
- Plumbing
- Ceramics manufacturing
- Lead mining

Environmental exposures for workers living near worksites exposure

Take home exposures

Workers and their families

Main health impacts

- Acute poisoning
- Cancer
- Brain and nervous system damage
- Kidney diseases
- Reproductive disorders
- Cardiovascular diseases
- Haematological conditions
Priority actions

Given that occupational lead exposure is a global concern, prompt action is needed to protect workers. Key actions should be taken at both national and workplace levels. These include:

- Eliminate any unnecessary uses of lead using a ‘toxics use reduction’ approach, that promotes the phase out of lead from remaining sources of exposure. Following elimination, additional preventative measures should be implemented, using the Hierarchy of Controls.

- Promote the ratification and implementation of international labour standards (ILS) on OSH and on chemicals. These contain specific guidance for safeguarding decent work and protecting workers’ safety and health.

- Ensure that policies for the sound management of lead follow an integrated OSH management systems approach, as outlined in the Occupational Safety and Health Convention, 1981 (No. 155), the ILO Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187) and their accompanying Recommendations (No. 164 and No. 197, respectively).

- Establish a preventative safety and health culture at national and workplace levels, with diverse stakeholders engaged at all levels.

- Implement the Globally Harmonized System of Classification and Labelling of Chemicals (GHS).

- Establish risk or sector-specific guidelines, for example, strictly control lead exposure in industries such as the production and recycling of lead acid batteries and establish legal requirements for training and personal protective equipment (PPE) where necessary.

- Improve workplace monitoring systems and labour inspection programmes to ensure compliance with OSH regulations.

- Conduct research on the health impacts of lead exposures in different sectors and the efficacy of different types of protective interventions for all types of workers.

- Develop and promote viable alternatives to common lead products, such as lead-acid batteries.

- Update, implement and enforce national occupational exposure limits (OELs) for lead, in various forms.

- Mainstream gender into OSH policy and practice. Recognize, respect and address gender diversity at work, and develop inclusive and responsive gender-transformative OSH policies and practice.

- Follow a workplace programme approach for the sound management of lead and instigate a workplace strategy involving chemical identification, comprehensive risk assessment and implementation of control measures.

- Develop health surveillance programmes for workers in high exposure industries and train workers effectively to make sure that guidance is followed.

- Promote and participate in social dialogue for transparent and active communication at all levels, particularly between governments and social partners.

Although the health effects of occupational lead exposure are well established, workers in many different industries continue to be exposed to hazardous levels of this toxic heavy metal. Given the projected growth in key industries reliant on lead-based products, such as the transportation sector which uses lead-acid batteries, there is a need to protect the numerous workers exposed worldwide. Effective and evidence-based systems for the sound management of lead should be implemented at both the national and workplace levels as a matter of priority.
<table>
<thead>
<tr>
<th>Acronyms</th>
<th>Definition</th>
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<tbody>
<tr>
<td>BLL</td>
<td>Blood lead level</td>
</tr>
<tr>
<td>DALY</td>
<td>Disability-adjusted life year</td>
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<tr>
<td>DBP</td>
<td>Diastolic blood pressure</td>
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<tr>
<td>EPI</td>
<td>Emerging policy issue</td>
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<tr>
<td>FPRW</td>
<td>Fundamental principles and rights at work</td>
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<tr>
<td>GBD</td>
<td>Global Burden of Disease</td>
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<tr>
<td>GHS</td>
<td>Globally Harmonized System of Classification and Labelling of Chemicals</td>
</tr>
<tr>
<td>HIC</td>
<td>High-income country</td>
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<tr>
<td>ILO</td>
<td>International Labour Organization</td>
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<tr>
<td>LMIC</td>
<td>Low- and middle-income country</td>
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<td>OEL</td>
<td>Occupational exposure limit</td>
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<td>OSH</td>
<td>Occupational safety and health</td>
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<tr>
<td>PPE</td>
<td>Personal protective equipment</td>
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<tr>
<td>PPM</td>
<td>Parts per million</td>
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<tr>
<td>SAICM</td>
<td>Strategic Approach to International Chemicals Management</td>
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<tr>
<td>SDG</td>
<td>Sustainable Development Goal</td>
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<tr>
<td>SBP</td>
<td>Systolic blood pressure</td>
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<tr>
<td>ULAB</td>
<td>Used lead-acid battery</td>
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<td>WHO</td>
<td>World Health Organization</td>
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Background

Lead in the workplace

Global burden of exposure and work-related health impacts

Global burden of exposure of workers to lead: >1,800,000
(EU-OSHA 2014; Canada CAREX 2020)

Global burden of work-related health impacts: Limited data
(>900,000 due to environmental lead exposure (GBD 2019))

Occupational exposures to lead pose a significant risk to the safety and health of workers around the world. Workers in numerous sectors are exposed to this toxic heavy metal, including those in used lead-acid battery (ULAB) recycling, construction and demolition, painting, mining and smelting, plumbing and tank cleaning, among others.

According to the World Health Organization (WHO), there is no known safe level of lead exposure (WHO 2022a; WHO 2021a). Even relatively low levels of lead, that were previously considered ‘safe’, have now been shown to damage health. Aside from acute poisoning episodes, serious chronic conditions have been associated with occupational lead exposure, including cancers, neurological deficits, cardiovascular disease and reproductive concerns. Whilst Global Burden of Disease statistics exist for environmental lead exposures, there is extremely limited data on occupational exposures. However, it is likely that the number of impacted workers is sizeable.

Although the hazards of lead are well known, the metal continues to be mined and used in growing quantities, despite product bans and increasingly stringent environmental regulations in high-income countries (HICs). Given the projected growth in energy storage, transport and ammunition sales, it is unlikely that lead production will decline in coming decades (Gottesfeld 2022). Whilst the effects are felt by workers globally, shifts of the most hazardous processes to low- and middle-income countries (LMICs) will impact those with the least occupational safety and health (OSH) regulations and social protections.

The burden of hazardous lead exposures for workers, and society as a whole, is significant. Action is needed to promote the safer management of lead within the world of work, thereby protecting the many workers exposed daily. This report aims to provide a sound evidence base for lead as a world of work concern and to highlight key priority actions for stakeholders, at both the policy and workplace levels.
Exposure to lead in the world of work: Impacts for occupational safety and health

Research report

The ILO and lead

The ILO has long recognized the dangers of lead exposure for human safety and health, with one of the first International Labour Standards of the ILO being the Lead Poisoning (Women and Children) Recommendation (No. 4) in 1919. Subsequently, the White lead (Painting) Convention (No. 13), adopted in 1921, prohibited the use of white lead in the internal painting of buildings. Since then, the ILO has adopted more than 40 legal instruments on the protection of workers from chemical hazards such as lead, including Chemicals Convention (No. 170) and Recommendation (No. 177), 1990.

In March 2019, the ILO joined the Global Alliance to Eliminate Lead Paint (the Alliance), a voluntary partnership formed by the UN Environment Programme (UNEP) and the WHO to prevent exposure to lead, while promoting the phase-out of lead paints. The ILO is also a key participant in the Strategic Approach to International Chemicals Management (SAICM), which has identified lead in paint as a concern of special relevance or an emerging policy issue (EPI).

A chemical of concern in the world of work

The harms of lead exposure have been well known for at least 5,000 years, with lead poisoning first documented in manual workers and slaves in antiquity (Riva et al. 2012). Early uses of lead included construction materials, pigments for glazing ceramics, and water pipes (USGS n.d.). The Industrial Revolution caused an epidemic of lead intoxication, however it was only during the 20th century when the metal was officially recognized as a health hazard and legislation to protect health was introduced.

In the past, lead was used widely in the form of tetraethyl and tetramethyl lead, as antiknock and lubricating agents in petrol, causing inorganic lead particles to be emitted from vehicles. Since then, a global ban in leaded petrol has resulted in a significant reduction of human exposure and mean blood lead concentrations (UNICEF 2020). Additionally, the use of lead in certain products, such as decorative paint and piping, has also been prohibited in many developed countries.

Although positive steps have been taken in some regions, many countries are yet to impose bans or regulations. For example, only 94 countries have legally binding controls to limit the production, import and sale of lead paints1 (WHO 2023). Furthermore, whilst lead use in some products may have decreased, this has been offset by increased usage in other industries, for example, the electronics sector, where waste is frequently improperly recycled. New areas of risk have also emerged, for example, the use of lead as a plastics additive has created a threat for many recycling workers.

All workers can be adversely impacted by lead exposures, however some specific groups of workers, such as young workers and pregnant women, are particularly vulnerable to negative health outcomes and developmental impacts. LMICs carry the largest burden of exposure to heavy metals such as lead.

There is a need to take action and implement a range of effective measures to prevent harm to workers, their families and wider communities. Following the addition of ‘a safe and healthy working environment’ to the the ILO’s FPRW framework, ILO Member States have the obligation to promote, respect and realize the principles of a safe and healthy working environment. Protecting workers and their communities from the risks of lead will also contribute towards achieving the Sustainable Development Goals (SDGs), in particular Goal 8: “Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all” and Goal 3: “Good health and well-being”.

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1 As of 31 March 2023
Occupational lead exposures

What is lead?

Physical and chemical properties

Lead is a naturally occurring element found in small amounts in the earth's crust, mainly as lead sulphide. Whilst naturally occurring lead concentrations in the environment do not pose significant human health risks, anthropogenic activities, such as lead mining, smelting and refining have resulted in lead being more widely distributed, in increasingly damaging exposure levels. Indeed, lead is now found in all parts of the environment, including air, water, soil and inside homes (USEPA 2022). Most lead emissions remain near the source, although some particulate matter can be transported over long distances (IPCS 1995). Airborne lead can contribute to human exposures by the contamination of food, water and dust, as well as through direct inhalation. Studies have shown that lead levels in modern humans are 500-1,000 times greater than they were in pre-industrial times (Flegal and Smith 1992).
Lead is a soft metal, usually found as lead compounds combined with other elements. It is a chemically stable, toxic, heavy metal that exists in the environment in three different forms:

- **Elemental lead** - The chemical symbol for lead is Pb. It is a bluish-grey metal that tarnishes easily in air to a dark grey. The density of lead is 11.34 g/cm³. It has a low melting point of 327.46 °C or 621.43 °F. Naturally occurring lead ores comprise 0.002 per cent of the earth’s crust.

- **Organic lead** – Organic forms of lead include tetraethyl lead (TEL), which was previously added to “leaded” petrol. These forms of lead are extremely dangerous, as they are absorbed through the skin and are highly toxic to the brain and central nervous system, much more so than inorganic lead. Use of organic lead has now declined, due to the global phase-out of lead in petrol, and exposure is now generally limited to an occupational context.

- **Inorganic lead** - This is the form of lead found in paint, batteries and many other consumer products. Inorganic lead usually causes occupational toxicity following inhalation of dust/fumes, and to a lesser extent following ingestion and gastrointestinal absorption. Today, inorganic lead is the principal source of occupational lead exposure (Allaouat et al. 2020).

Lead has a combination of physical and chemical properties that have made it extremely useful industrially. It is a soft, dense, very malleable and ductile metal, with high stability. It has considerable corrosion resistance, poor electrical conductance, low sound conductance, a low melting point and high opacity to gamma and X-ray energies (IPCS 1995). Due to these properties, and because it is relatively easy to mine and recycle, lead has been used for many purposes for thousands of years. Some examples of products containing lead are shown in Figure 2.

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**Figure 2: Examples of products containing lead**

<table>
<thead>
<tr>
<th>Lead-acid batteries</th>
<th>Construction materials</th>
<th>Cable sheathing</th>
<th>Paints</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Lead-acid batteries" /></td>
<td><img src="image" alt="Construction materials" /></td>
<td><img src="image" alt="Cable sheathing" /></td>
<td><img src="image" alt="Paints" /></td>
</tr>
<tr>
<td>Ceramic glazes on cookware</td>
<td>Fishing weights and ammunition</td>
<td>Plastics</td>
<td>Photovoltaic solar panels</td>
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<td>Candles</td>
<td>Toys</td>
<td>Cosmetics</td>
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<td>Pipes and other plumbing materials</td>
<td>Dyes</td>
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<td><img src="image" alt="Pipes and other plumbing materials" /></td>
<td><img src="image" alt="Dyes" /></td>
</tr>
</tbody>
</table>
Occupational exposure to lead

Occupational exposure to lead can occur in all phases of the metal’s life cycle, from mining and refining to production and use, and finally recycling and disposal. When lead and items containing lead are processed at any of these stages, lead dust, fumes or vapours are created.

Common work situations may be more associated with hazardous lead exposures than others. For example, handling solid lead sheets does not itself pose significant risks, however stripping off old existing sheets, which may be corroded, can produce dangerous lead dust. High-temperature lead work (above 500°C) can produce lead dust, fumes and vapours, with substantial exposures occurring if work is carried out in confined spaces for long periods. Work involving renovation, repair and painting can expose workers to dust from lead-based paints, with those in lead abatement projects at especially high risk. Informal waste workers in LMICs may be exposed to lead from a variety of sources, including e-waste. New hazards are also emerging, for example, as photovoltaic solar panels reach the end of their shelf-life, recycling processes should consider that they contain small quantities of lead.

In many countries occupational lead exposure is entirely unregulated and exposure monitoring does not exist. Consequently, occupational exposure to lead which results in poisoning still occurs in numerous locations. Moreover, a secondary source of lead exposure for workers’ families can take place, if workers bring home lead-contaminated dust on their skin, hair, clothes or shoes.

Workers may face a triple burden of exposure from environmental and take-home exposures, as well as occupational sources. Lead-containing materials can leach or release particulates into the surrounding environment, causing lead to accumulate in the soil, air and water (WHO 2022b). Concentrations of environmental lead can be especially high near the sites of historic or ongoing mining operations or smelters.

When are workers most at risk?

Workers are at risk of lead exposure when tasks produce lead dust, fumes or vapours. These can include:
- Blast removal, stripping and burning of old lead paint
- Hot cutting in demolition and dismantling operations
- Scrap-processing activities, including recovering lead from scrap and waste
- Lead-acid battery manufacture, breaking and recycling
- Painting of buildings and spray-painting of vehicles
- Working with metallic lead and alloys containing lead e.g. soldering
- Lead smelting, refining, alloying and casting
- Manufacturing and physically processing lead compounds
- Manufacturing leaded glass
- Manufacturing and using pigments, colours and ceramic glazes
- Recycling of any materials containing lead e.g. televisions, computer monitors and some plastic cables

Source: HSE 2012
Global lead consumption

Despite its harmful environmental and health impacts, lead continues to be a valuable commodity and the production of lead is increasing worldwide due to its use in lead–acid batteries. There are two major categories of production: primary from mined ores, and secondary, which is lead recycled from scrap. Of the supplies of lead for recycling, ULAB are the most important, with lead piping, sheet and cable sheathing also significant sources (Thornton et al. 2001). Between 2001 and 2016, global lead mine production grew by 56 per cent, and secondary lead produced from recycling grew by 102 per cent (USGS n.d.). Key statistics regarding the global lead trade are shown in Figures 3 and 4.
In 2021, China was the world’s leading producer, with 2 million metric tonnes of lead. Australia was the second that year, with production amounting to an estimated 500,000 metric tonnes.

In 2020, China’s production of refined lead amounted to some 6.4 million metric tonnes or 48 per cent of global production. The United States of America came second and was the only other country to have a production of more than one million.

Batteries accounted for 86 per cent of the global lead consumption volume in 2019, which was a six per cent increase from 2018.
Main health outcomes

Exposure pathways

Lead is a highly poisonous metal affecting almost every organ and system in the human body. Lead absorption into the body depends on a variety of factors, including particulate size, route of exposure, nutritional status, health and age of the individual. The body absorbs lead through:

- **Inhalation**
  Breathing in lead dust, fumes or vapours. Inhalation is the main pathway for lead exposure for workers involved in producing, refining, using or disposing of lead and lead compounds. During an eight-hour job shift, workers can absorb as much as 400 µg of lead (WHO 1995). Most inhaled lead in the lower respiratory tract is absorbed.

- **Ingestion**
  Swallowing lead when eating, drinking or smoking, when hygiene standards are inadequate. Adults typically absorb up to 100 per cent of ingested lead on an empty stomach and up to 20 per cent after a meal (ATSDR 2019).

- **Dermal absorption**
  Only occurs when in contact with organic lead, for example lead alkyls (petrol additive) and lead naphthenate (oil paints and varnishes). Exposures are more likely for lead workers than the general population.
Main health outcomes

Lead exposure in the workplace

Lead dust, fumes or vapours are created from work processes

Inhalation

Most inhaled lead is absorbed into the body.

Ingestion

20-80 per cent absorbed.

Dermal

Organic lead is more likely to be absorbed.

Absorption routes

Lead in the body

Lead enters the blood and is distributed around the body.

half-life: 28-36 days

Lead in soft tissues

Lead can accumulate in soft tissues e.g. liver, kidneys, lungs, brain, spleen, muscles and heart.

half-life: 28-36 days

Lead in mineralizing tissues

Bones and teeth of adults contain about 94 per cent of the total lead body burden. Inert lead can leave bones and re-enter blood and soft tissues during different life stages.

half-life: 27-30 years

Most lead that enters the body is excreted, mainly in urine.
Once in the bloodstream, lead is primarily distributed among three compartments – blood, mineralizing tissues and soft tissues. The bones and teeth of adults contain about 94 per cent of the total lead body burden (Wani et al. 2017). Inert lead can leave the bones during events such as advanced age, broken bones, chronic disease, menopause, pregnancy and kidney disease. This poses a particular risk, as harmful effects from endogenous sources of lead can occur long after exposure has ended. Therefore both past and current elevated exposures to lead increase worker risks for adverse health effects from lead. Excretion from the body is mainly through urine and partly through faeces, sweat, saliva, hair and nails (PHE 2017). Figure 5 provides an overview of lead absorption routes and its pathway through the body.

There are many proposed mechanisms of toxic lead action. It is recognized that lead induces oxidative stress by the generation of reactive oxygen species (ROS) and impairment of antioxidant defenses (Batra et al. 2020). It also inhibits some enzymes, which results in the impairment of effective erythrocyte formation (O'Connor et al. 2018) and affects metabolism of certain minerals, leading to hypocalcaemia and hypophosphatemia (Nilima et al. 2013).

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**Case study: Brass foundry workers’ estimated lead body burden from different exposure routes**

A study by Julander et al. (2020) analysed the possible lead exposure routes in workers operating computer numerical control-machines in a brass foundry. It also sought to understand if lead-containing metal cutting fluids (MCFs) used by the workers could lead to skin absorption of lead. The workers did not work in the foundry areas of the production facility, and hence did not have any air exposure to lead, as confirmed by the regular air monitoring. The study showed that skin exposure while working with MCFs may lead to skin contamination, and absorption of inorganic lead contributed to a systemic dose. Furthermore, up to 10 per cent of the lead content was present in the skin even after 24 hours. Despite good hand hygienic measures, the workers’ skin doses of lead were found to play an important role for their elevated blood lead levels. The study recommended that skin exposure should be monitored routinely in workers at facilities handling lead.

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**Health impacts**

**Key points**

- In 2019, lead exposure accounted for over 902,000 deaths (GBD 2019).
- Today, 92 per cent of all deaths attributable to lead exposures occur in LMICs (UNICEF 2020).
- Lead exposure accounts for 21.7 million years lost to disability and death (disability-adjusted life years, or DALYs) worldwide due to long-term effects on health, including (WHO 2021b):
  - 30 per cent of the global burden of idiopathic intellectual disability.
  - 4.6 per cent of the global burden of cardiovascular disease.
  - 3 per cent of the global burden of chronic kidney diseases.
WHO has identified lead as one of 10 chemicals of major public health concern needing action by Member States to protect the health of workers, children and women of reproductive age (WHO 2020). Lead is toxic to multiple organs and body systems, including the central nervous system and brain, the reproductive system, kidneys, the cardiovascular system and the blood (Figure 6).

Figure 6: Examples of the toxic effects of lead on worker health

- Brain and nervous system damage
- Acute poisoning
- Kidney diseases
- Reproductive disorders
- Cardiovascular diseases
- Cancer
- Haematological conditions

Source: Adapted from WHO 2021c
Blood lead levels (BLLs)

Key point

The WHO Guideline for Clinical Management of Exposure to Lead recommends a blood lead concentration of 5μg/dL as a trigger for a thorough review of the ways in which a person is being exposed to lead, and for action to reduce or end this exposure (WHO 2021a).

The blood lead level (BLL) is the most commonly used and reliable biomarker of exposure to lead (Barbosa et al. 2005). It is important to note however, that these tests do not measure total body burden of lead and tend to be more reflective of recent or ongoing exposures (ATSDR 2019). Biological monitoring using BLLs is a tool used in OSH programmes for assessing uptake of lead. It helps evaluate workplace health risks and contributes to overall risk management by checking if lead exposures are adequately controlled. Medical surveillance will identify an action level, when an worker’s BLL is above regulatory limits, which will indicate that a review of the control measures is required. When BLLs reach the suspension level, the worker should be suspended from further work with lead.

Chronic exposures resulting in BLLs as low as 10 μg/dL in adults are associated with impaired kidney function, hypertension, nervous system and neurobehavioral dysfunction, and cognitive dysfunction later in life (OSHA n.d). While less common today, workers can be exposed to high lead levels resulting in BLL over 60 μg/dL. Figure 7 shows the effect of BLLs on the health of adults and children.
### Main health outcomes

**Blood lead concentration (μg/dL)**

#### Associated health effects

**Adults**
- Reduced fetal growth
  (based on maternal blood lead concentration)
- Reduced synthesis of 5-aminolaevulic acid dehydratase, contributing to anaemia
- Decreased cognitive functions; altered mood and behaviour
- Possible increased cardiovascular-related mortality
- Hypertension
- Possible increased spontaneous abortion
  (based on maternal blood lead concentration)
- Possible increased preterm birth
  (based on maternal blood lead concentration)
- Anaemia
- Reduced fertility
- Spontaneous abortion
  (based on maternal blood lead concentration)
- Reduced birth weight
  (based on maternal blood lead concentration)
- Subclinical peripheral neuropathy
- Neurobehavioural effects
- Abdominal colic
- Non-specific symptoms,
  e.g. headache, fatigue, anorexia
- Altered neuromotor and neurosensory functions
  e.g. decreased motor skills
- Encephalopathy

#### Associated health effects

**Children**
- Decreased IQ, cognitive performance
  and academic achievements
- Increased incidence of problem behaviour
- Increased diagnosis of attention deficit hyperactivity disorder
- Reduced synthesis of 5-aminolaevulic acid dehydratase, contributing to anaemia
- Decreased cognitive functions; altered mood and behaviour
- Delayed puberty
- Reduced mental growth
  (based on maternal blood lead concentration)
- Decrease in haemoglobin
- Decrease in red blood cells
- Cardiovascular-related mortality
- Delayed puberty
- Altered neuromotor and neurosensory function,
  e.g. decreased motor skills
- Severe neurological features
  in children with malaria
- Abdominal colic
- Encephalopathy
- Severe neurological features

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*Source: WHO 2021a*
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Case study: BLLs among occupationally exposed workers and its effect on calcium and vitamin D metabolism

Lead has been shown to affect the metabolism of calcium, phosphorous and vitamin D, which can decrease bone mineralization, thereby lowering bone mineral density and increasing the risk of osteoporosis. A case-control study by Batra et al. (2020) of lead exposures in Indian workers was conducted over a period of 18 months. A total of 160 subjects were included in the study, half of which were in a lead-exposed group and the remainder in a control group. The subjects included were construction workers, painters, motor garage workers, denting and painting workers, and lead-acid battery workers involved in the manufacturing, assembling and recycling of batteries. Results found BLLs were significantly higher in the exposed group, whilst serum calcium, phosphorous and vitamin D levels were significantly decreased. The study demonstrated that high BLLs altered vitamin D and calcium metabolism, which could lead to an increased risk of osteoporosis in lead-exposed workers.

Acute effects

Acute lead toxicity can occur if a person is exposed to very high levels of lead over a short period of time. It has been associated with the following adverse health impacts (ILO 2022a):

► **General signs and symptoms:** Pallor (caused by vasoconstriction), malaise and unexplained sense of fatigue, headache, dizziness, loss of memory, anxiety, depression, irritability, sleep disturbances, mildly progressive cognitive impairment, generalized weakness and muscle and joint pain.

► **Eyes:** Irritation and inflammation of the eyes.

► **Respiratory:** Irritation and inflammation of the airways, with cough, bronchitis, pneumonitis and impaired respiratory function.

► **Gastrointestinal symptoms:** Abdominal pain and cramps (colic), constipation, nausea, vomiting, anorexia and weight loss.

► **Neurological symptoms:** Pain, muscle weakness, paraesthesia, and, rarely, symptoms associated with encephalitis. Severe lead poisoning typically causes progressive ulnar nerve paralysis, seizures and hemiparesis.

► **Urinary system:** Inorganic lead exposure sometimes causes acute kidney toxicity, probably from accumulation of lead-protein complex in proximal tubular cells.

Chronic effects

Occupational exposure to lead among workers can cause significant chronic effects on multiple body systems and organs.

**Cancer**

There is some evidence that long-term occupational exposure to lead may contribute to the development of cancer. The International Agency for Research on Cancer (IARC) has classified inorganic lead compounds as probably carcinogenic to humans (Group 2A). This is supported by a study by Steenland et al. (2019) that analysed data from two cohorts of almost 30,000 lead-exposed workers in Finland and Great Britain, using historical BLL data. The study showed positive incidence trends for lung, rectal and brain cancer with increasing BLL, as well as for Hodgkin’s lymphoema.

**Haematological**

Lead can shorten the lifespan of red blood cells and subsequently increase the risk of reticulocytosis and anaemia (Rahimpoor et al. 2020).

**Neurological**

Lead is able to pass through the blood-brain barrier and can therefore cause considerable damage to the brain and nervous system. It degrades the myelin sheaths of neurons, reduces their numbers, interferes with neurotransmission routes, and decreases neuronal growth (Rudolph et al. 2003). Sufficient evidence exists to conclude that there is an association between lead dose and decrements in cognitive function in adults.
Lead-induced brain damage can lead to a variety of neurological disorders, such as mental retardation, behavioural problems, nerve damage, and possibly Alzheimer’s disease, Parkinson’s disease and schizophrenia (Sanders et al. 2009). Peripheral neuropathy is associated with long-term, high-level lead exposure at the workplace, and includes signs and symptoms such as extensor muscle palsy, and wrist and ankle drop (OPAS 2013). Occupational lead exposure has also been associated with an increased risk of Amyotrophic Lateral Sclerosis (Meng et al. 2020). Children are at even greater risk of the neurotoxic effects of lead due to their developing brains, with exposures resulting in reduced intelligence quotient (IQ), behavioural changes, increased antisocial behaviour and reduced educational attainment (WHO 2022a).

Case study: Association of cumulative lead and neurocognitive function in an occupational cohort

Khalil et al. (2009) evaluated the association of lead biomarkers (BLLs and tibia bone lead levels) with cognitive function in a cohort of exposed and non-exposed workers over a 22-year period. Cognitive function was tested using the Pittsburgh Occupational Exposures Test battery, which had previously been administered in 1982. In exposed workers, bone lead level predicted lower current cognitive performance, and cognitive decline over 22 years. For lead-exposed workers over the age of 55, higher levels of bone lead predicted poorer cognitive scores, indicating vulnerability for older workers with higher past lead exposure. There was no association with BLL and recency of exposure, suggesting that cumulative body burden is most likely responsible for the progressive cognitive decline.

Case study: Impact of occupational lead exposure on nerve conduction study data

A study by Aktürk et al. (2022) of 197 lead exposed workers and 90 controls looked at the impact of lead exposure on nerve conduction. Nerve conduction studies on motor (median, ulnar, peroneal and tibial) and sensory (median, ulnar and sural) nerves were performed. The study found that the median BLL was 40 µg/dL and peripheral nerves may be impacted by neurotoxic effects arising from lead exposure.

Urinary

Low to moderate levels of lead exposure have been associated with adverse changes in kidney function (Brown-Williams et al. 2009). Chronic lead toxicity can cause glomerular sclerosis, progressive tubular atrophy and interstitial fibrosis. This can lead to elevated blood pressure, hyperuricaemia (causing saturnine gout) and chronic kidney disease (ILO 2022a).

Reproductive

In women, lead exposure can cause infertility, miscarriage, stillbirth, premature birth and low birth weight (WHO 2021b). In men, exposure to lead may affect libido, semen quality by declining sperm count, motility, viability, integrity, elevation in morphological abnormalities, and sperm DNA integrity (Kumar 2018).

Cardiovascular

Hypertension and cardiovascular disease are important consequences of chronic lead toxicity, with changes in cardiac conduction and rhythm associated with increasing lead body burden (ILO 2022a). Long-term, high-dose exposure to lead has been linked with an increased risk of stroke and ischaemic heart disease (WHO 2021b). A 2006 study carried out in the United States observed that individuals with a BLL of 10 µg/100ml or greater had a 60 per cent higher relative risk of death from heart disease, than those who had blood lead levels less than 5 µg/100ml (Schober et al. 2006). Another study of over 14,000 adults in the United States estimated that environmental exposures to lead were responsible for 256,000 deaths a year from cardiovascular disease and 185,000 deaths a year from ischaemic heart disease (Lanphear et al. 2018).
Case study: A cross-sectional comparative study on cardiopulmonary function in lead-acid battery recycling workers

Yadav et al. (2022) investigated the effect of occupational lead-exposure on cardiopulmonary functions in ULAB recycling workers. Anthropometric measurements, systolic and diastolic blood pressure (SBP and DBP) and pulmonary function tests were performed. Venous blood was collected for BLL, haematological and biochemical analysis. Lead exposure was associated with a significant increase in BLL, SBP, DBP, and small airways obstruction in lung function tests. It also impaired platelet indices, affected renal and liver biochemical measurements, and promoted oxidative stress and DNA damage. Multilinear regression found that BLL impacted SBP and increased small airways obstruction. Higher BLL appeared to be an independent modulator of hypertension and poor pulmonary function upon occupational lead exposure in ULAB recyclers.

Gender versus biological differences

Both genders are subject to occupational exposure to lead, however gender-related variances in work tasks have an impact on the exposure sources and levels. Occupational exposure to lead in paint comes from work in paint factories and automotive repair shops, construction and demolition and any type of work involving painting. These are all generally male-dominated occupations, especially in very traditional societies. In contrast, women of child-bearing age are more likely to be exposed to lead paint through lead contaminated dust generated by deteriorating decorative lead paint. This is typically found in homes, schools and other indoor environments, common for typically female dominated occupations.

Biological sex can lead to important differences in exposure and health effects when it comes to chemicals, including lead. For example, the susceptibility of women to hazardous chemicals can vary based on their reproductive cycles and at different life stages such as pregnancy, lactation and menopause, when their bodies undergo physiological changes that may affect their vulnerability to health damage from chemicals. Concerns also exist regarding BLL in menopausal women, as menopause may result in larger releases of lead from the bone tissue. Post-menopausal women have been found to have higher BLL than pre-menopausal women (Potula and Kaye 2006). Lead exposures in men have been associated with reproductive deficits such as damaged sperm and lower sperm count.

Workers in vulnerable situations

Child labourers

Lead exposure can have serious consequences for the safety and health of children. At high levels of exposure, lead attacks the brain and central nervous system, causing coma, convulsions and even death. The developing nervous systems of young children may be particularly impacted, causing reduced IQ, behavioural changes and poorer educational attainment. For example, children with BLLs above 5 μg/dL can score 3-5 points lower on intelligence tests, than their unexposed counterparts (UNICEF 2020). Children who survive severe lead poisoning may be left with intellectual disability and behavioural disorders. Childhood exposure to lead has been shown to cost a total of US$977 billion annually in LMIC, which equated to 1.2 per cent of world GDP in 2011 (Attina et al. 2016). This is considerably higher than the burden in the United States and Europe, suggesting that the largest burden of lead exposure is now borne by LMIC. Figure 8 depicts why children are more at risk of hazardous lead exposures.

Young workers

Young workers are at relatively high risk, because they have unique windows of susceptibility that leave them more vulnerable to specific toxic exposures, especially those such as lead, that affect neurodevelopment and reproductive health. They also often have minimal safety and health training and may engage in risk-taking behaviours not normally seen among adult workers, because of differences in their perceptions of risk and
Main health outcomes

vulnerability. Various risk factors that are specific to young workers increase the likelihood that they will suffer harm from workplace hazards. These risk factors can be inherent to their age, for example, stage of physical, psychosocial and emotional development, or influenced by their age, for example, relative lack of skills, minimal experience and lower levels of education.

**Pregnant women**

Female workers are at particularly high-risk during child-bearing years and pregnancy, when even low doses of chemicals can elicit dramatic and irreversible effects. Lead can accumulate in the body over time, where it is stored in bones along with calcium. During pregnancy, lead is released from the mother’s bones along with calcium and can pass from the mother, exposing the foetus or the breastfeeding infant to lead. Exposure of pregnant women to high levels of lead can cause miscarriage, stillbirth, premature birth and low birth weight (WHO 2021b).

**Migrant workers**

Migrant workers may not speak the local language or dialect, making it difficult for them to understand chemical labels, safe handling procedures and training materials. They often work in informal workplaces offering limited OSH protections, such as training and personal protective equipment (PPE), making them more at risk of hazardous lead exposures. Additionally, migrant workers in the informal economy may be unable to participate in measures to provide for safe and healthy working conditions, making them more susceptible to unsafe conditions.

**People with disabilities**

People with disabilities have been shown to have generally poorer health outcomes (WHO 2011) and disabled workers may also face unique risks depending on their particular disability, making them more vulnerable to hazardous lead exposures. For example, a disabled worker may be unable to access cleaning facilities, making them more susceptible to hazardous lead exposures due to inadequate hygiene.

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**Figure 8: Why the adverse effects of lead exposure are greater for children than for adults**

- **The intake of lead per unit body weight is higher**
- **Children have more years of life ahead of them and thus a longer time to develop the delayed effects of early lead exposure**
- **More dust may be ingested**
- **Their neurological system is still developing and is vulnerable to the toxic effects of lead**
- **Lead absorption in the gastrointestinal tract is higher**
- **The blood-brain barrier is not yet fully developed**

Source: Adapted from WHO 2021b
High risk sectors

According to NIOSH’s lead monitoring programme of workplaces in the United States, Adult Blood Lead Exposure Surveillance (ABLES), lead exposure is most common in the construction, manufacturing, mining and service industries (NIOSH 2022). Concerningly, BLLs have been found to be several times the WHO Guideline for Clinical Management of Exposure in many subsectors. The industry with the highest cases of lead exposure was manufacturing with just over 39 per cent. Within this category, workers in storage battery manufacturing had by far the highest cases of exposure (Figure 9).

**Figure 9: Where cases occur within manufacturing**

- Alumina and aluminium production and processing
- Non ferrous metal (except copper and aluminium) rolling, drawing, extruding and alloying
- Other basic inorganic chemical manufacturing
- Other manufacturing industries
- Ship and boat building
- Storage battery manufacturing

Source: NIOSH 2023
Battery manufacturing and recycling

One of the most concerning sources of lead exposure is the unsound recycling of ULAB, which account for more than 80 per cent of the global demand for lead. These batteries have many uses, for example, in traditional and electric vehicles, back-up power supplies, critical systems such as hospitals and telecommunications, and for green technologies, such as photovoltaic and wind turbine energy storage (UNICEF 2020). The largest market is for automotive batteries, followed by industrial batteries, with demand growing rapidly (May et al. 2018).

Workers in both battery manufacturing and recycling are at risk of hazardous lead exposures. Both processes involve the use of metallic lead for making grids, bearing and solder, resulting in the release of lead particles and lead oxide (Kshirsagar et al. 2017). Inorganic lead dust, which can be absorbed into the body by inhalation and ingestion, is the most significant health exposure in battery manufacture (OSHA n.d). A review by Olana et al (2022), assessing lead exposure in battery manufacturing, found that workers had a pooled mean BLL of 37.996 μg/dL, which is considerably above the WHO guideline for action (WHO 2021a).

Almost all the lead in ULAB can be recovered during recycling processes, and in the United States and Europe nearly all the lead from ULAB is recycled. However, many LMICs lack appropriate regulations and enforcement capacity for safe recycling of batteries, with work carried out in informal and unregulated settings. It is estimated that in Africa alone more than 1.2 million tonnes of ULAB enter the recycling economy each year and much of that goes to informal operators (Oeko-Institut e.V. 2016). Work is often carried out in backyards, where unprotected workers break open batteries manually to remove the lead plates, which are then smelted in open-air pits (UNICEF 2020). However, risks also exist in formal battery recycling facilities, where workers break batteries with axes or machetes.

Painting and paint abatement

Lead compounds can add durability, opacity and colour to paint. Whilst lead-based paint has been phased out in many places, it is still produced and used in some locations. Exposure to lead from lead paint can occur during manufacture and application, and will remain for many years as the paint deteriorates or is removed during painting and demolition. Exposure usually happens from ingestion from dust or fragments of lead-based paint. Significant lead exposures can also arise from removing paint from surfaces previously coated with lead-based paint, such as bridges, buildings undergoing renovation, and structures being demolished or salvaged (OSHA 2004). Several paint removal methods, particularly power sanding and dry abrasive blasting, generate high concentrations of dust and fumes which may be dissipated widely. Workers in countries with limited restrictions are at risk, as are workers working on in old buildings or on lead paint abatement projects in all regions.

Gottesfeld and Pokhrel (2011) conducted a literature review which looked at exposures from lead-acid battery manufacturing and recycling plants in developing countries. The review included studies from 37 developing countries published from 1993 to 2010. The average worker BLL in developing countries was 47 μg/dL in battery manufacturing plants and 64 μg/dL in recycling facilities. Airborne lead concentrations reported in battery plants in developing countries averaged 367 μg/m³, which is 7-times greater than OSHA's 50 μg/m³ permissible exposure limit (NIOSH 2021). The geometric mean BLL of children residing near battery plants in developing countries was 19 μg/dL, which is about 13-fold greater than the levels observed among children in the United States.
Case study: New Zealand bridge workers poisoned by lead (O’Neill 2009)

Around 50 workers on the Auckland Harbour Bridge in New Zealand were poisoned after inhaling lead-based paint dust during maintenance work in 2008. The work consisted of stripping metal on the underside of the bridge, which produced the contaminated dust. Although the workers had been given full-face masks, they found them uncomfortable and instead wore less effective dust masks. Within a month of commencing work, nearly half of the 50 workers showed marked increases in BLLs during medical monitoring.

Construction and demolition

In construction, lead is frequently used for roofs, cornices, tank lining and electrical conduits. Also, lead-based paint is still used commercially on steel structures, such as bridges, railways and ships. Construction workers may be exposed to dangerously high levels of lead dust. Workers most at risk include those involved in iron work, demolition, painting, plumbing, electrical work, remodelling projects and renovations (OSHA 2004). Given that there are more than 229 million construction workers worldwide, there are potentially huge numbers of workers impacted in this industry (ILO 2022b). According to data from the United States, lead exposures in construction are highest in highway, street and bridge construction, followed by painting and wall covering processes (Figure 10).

Figure 10: Where cases occur within construction industries

Source: NIOSH 2023
“Take-home” exposure is when dangerous contaminants come home on workers’ bodies and clothing, unintentionally exposing their families and causing serious concerns, including child lead poisoning. A study by Ceballos et al. (2021) found that construction workers had twice as much lead dust in their homes as janitorial or autobody workers. Some homes had lead dust at the same levels as those recorded in homes near lead smelters, or Boston homes in the early 1990s, when gasoline still contained lead. Lead levels varied widely, from 20 to 8,300 parts per million (ppm), but construction workers’ homes generally had more than twice the levels of the other workers’ homes, with an average of 775ppm compared to 296ppm.

Lead smelting and refining

The potential for hazardous exposures to lead during lead smelting and refining is well recognized, particularly where molten lead and alloys are poured, resulting in lead vapour. This is the case in both primary new metal and secondary recycling smelters and refineries. Lead dust and smoke can be released during processing and slag contaminated with lead particles may be left over after the smelting process. The most common route of lead exposure caused by lead smelting is through inhalation or ingestion of lead dust, particles or exhaust from the burning process. Workers in smelting factories are particularly at risk, as they can be exposed to prolonged and direct inhalation of gaseous emissions and dust.

Case study: Long-term health impacts of lead exposure in lead smelter workers

A NIOSH study of lead exposure in smelter workers included 1,990 male workers who worked at a lead smelter between 1940 and 1965 (Selevan et al. 1985; Steenland et al. 1992). It focused on workers in high-lead departments, including the sinter plant, materials recovery, charge preparation, refineries, the blast furnace, and the slag fuming furnace. The study found that for smelter workers, the risk of dying from kidney disease was highest for people exposed to lead for more than 20 years. In addition, workers had a slightly higher risk of developing kidney cancer, with those in high-lead departments at most risk. Compared to the general population in the United States, the chance of having a stroke was also slightly increased.

E-waste

Electronic and electrical waste (e-waste) is defined by the European Union (Directive 2012/19/EU) as any end-of-life “equipment which is dependent on electrical currents or electromagnetic fields in order to work properly”. Production and use of electronics is rapidly expanding. As a consequence, the global amount of e-waste is expected to increase to 75 million tonnes by 2030 and 111 million tonnes by 2050 (Parajuly et al. 2019). It has been estimated that solid waste management and recycling provide employment for 19 to 24 million women and men worldwide, of which four million work in the formal waste and recycling sector (ILO 2021). Lead is contained in printed circuit boards, cathode ray tubes, light bulbs, televisions and batteries (Grant et al. 2013). The health of workers and their communities is at risk from direct contact with lead, from inhalation of toxic fumes and particulate matter, hand to mouth transfer, as well as from accumulation of chemicals in soil, water and food.
Case study: Informal e-waste recycling in Uruguay

In Uruguay, primitive recycling procedures are a significant source of lead exposure. A study by Pascale et al. (2016) examined BLLs in low-income children exposed to lead through burning cables. The final sample included 69 children and adolescents, with a mean age of 7.89 years. More than 66 per cent of participants had an additional source of lead exposure, manual gathering of metals, and over 5 per cent were exposed to lead through landfills or paint. Average BLLs at first consultation were 9.19 μg/dL and lower at the second measurement (5.86 μg/dL). Greater BLLs were found for children involved in burning cable activities, than for those exposed to lead-based paint.

Welding

Welding is a process in which two or more metals are bonded through pressure, heat or both. Millions of workers around the world are exposed to welding aerosols daily. Inhalation of lead oxide fumes produced during welding processes may cause lead poisoning. There is a strong correlation between the concentration of lead fumes and BLLs, and an inverse relationship between BLLs and testosterone (Dehghan et al. 2019).

Auto repair

Numerous workers are employed by informal auto repair shops globally. Workers in the industry may be exposed to hazardous lead exposures when performing a variety of tasks, such as repairing radiators, using paints and lubricants, welding and handling storage batteries.

Case study: Occupational lead exposure among automotive garage workers in Ethiopia

In Ethiopia there are numerous small-scale and medium-sized industries which use lead-based raw materials that may pose health risks to workers, however there are no workplace regulations for lead exposure. A cross-sectional study by Adela et al. (2012) on the BLLs of 45 automotive garage workers and 40 non-garage workers was carried out in the town of Jimma, Ethiopia. The mean BLL of the automotive-garage workers was found to be significantly greater than that of the controls. The BLLs of all the lead-exposed individuals were found to be over 10μg/dL, and 53 per cent of them had BLLs ranging 12 – 20μg/dL, with the remaining 47 per cent having over 20μg/dL. The garage workers were found to exhibit significantly higher levels of the non-specific symptoms relative to controls. Symptoms included depression, sleep disturbance, wrist drop, tingling and numbness in fingers and hands, nausea and decreased libido. Moreover, the prevalence of these symptoms was greater in the workers with higher service years than in those with lower service years.

Plastic manufacturers and recycling

Lead softens plastic and makes it more flexible, and is therefore used as a plastics additive in a number of products. It is also still used in some countries as a stabilizer in polyvinyl chloride (PVC), and as a pigment in yellow plastics (Stenmarck et al. 2017). High concentrations of lead are generally found in older items that are still in circulation (e.g. toys, construction plastics, wiring insulation), however lower concentrations are also contained in more recently manufactured items (Turner and Filella 2021). Analysis suggests that as historical material is recycled, lead contained in electronic plastics and pigments is dispersed into a variety of newer products. Lead dust can be formed when plastic is exposed to sunlight, air and detergents that break down the chemical bond between the lead and plastics (CDC 2022). Workers are particularly at risk of hazardous lead exposures in informal recycling facilities.
Jewellery making

Lead is dense and easy to shape and work with, and it allows for welding and soldering. It is used in jewellery due to these properties and to provide colour and weight. Lead vapour is released when it is melted at high temperatures, which then can be inhaled by workers. Vapours can condense on workers’ skin, hair and clothes, as well as food and drinking water. Artisans producing jewellery often work at home or in non-regulated shops, making them at risk of hazardous lead exposures (Behari et al. 1983). Indian silver jewellery makers were found to have a BLL of 121 µg/dL, compared to 27 µg/dL in non-exposed controls (Behari et al. 1983).

Ceramics manufacturing

Leaded glazes provide a lustrous and protective waterproof coating on ceramics and are traditionally used in many cultures. They have been in continuous use in traditional pottery in Mexico and many other countries since the mid-1800s (UNICEF 2020). Informal artisans use scrap metal from products such as waste engine parts, batteries and computer components to make the cookware, incorporating metals, such as lead, in the final product (UNEP 2022). In Cameroon, for example, lead recycled from used lead-acid batteries is used to make cookware. Many of those in ceramics production are women and children working in home-based operations. The use of lead-oxide glaze was found to increase the risk of lead toxicity in a community of ceramic folk art workers in Tunisia (Chaouali and Nouloul 2017).

Lead mining

Lead is almost always contained in sulphide ores as galena, or lead sulphide. Miners in regions that lack OSH standards have limited protections against hazardous lead exposures, with some not wearing gloves or even shoes when handling toxic materials. Miners frequently come into direct contact with ore containing lead and also inhale lead dust during mining and crushing processes. Global mined lead production grew considerably from the year 2000 until 2013, and has remained high since then, with no signs of slowing down (Figure 11).

Figure 11: Global mined lead production (1995-2021)

Source: USDS n.d.

Plumbing and pipe fitting

Lead is highly durable, malleable and stable, and therefore has been used extensively in the plumbing sector for pipes, solder, valves and other fixtures and fittings. These items can be made of lead, lead-containing metal alloys or polyvinyl chloride with lead stabilizers (WHO 2022b). Indeed, the name “plumber” originates from the Latin pluberium or “worker of lead”. Plumbers are at risk of lead exposures when working with older pipes.
Niche exposures

Workers in other niche industries may be at risk of hazardous lead exposures, for example ship builders and breakers, glass manufacturers, locksmiths, artists, printers, firing range staff, cable jointers, archaeologists handling lead coffins, and those involved in manufacturing lead-containing products, such as cosmetics, guns and ammunition, fishing weights and dog combs (O’Neill 2009). Waste pickers are also at risk, when considering that many lead-containing products end up on rubbish dumps. Whilst some of these sectors may employ relatively small numbers of workers individually, the total number when combined could be considerable. Extremely limited research on the health impacts of occupational lead exposures exists for many sectors.

Case study: Exposure to lead of boatyard workers in southern Thailand

Lead oxide is used extensively in the construction and repair of wooden boats in Thailand. A study by Thanapop et al. (2007) looked at lead exposure in fifty boatyard workers in Thailand. Lead exposure of workers was assessed by determining airborne and BLLs. A questionnaire was administered to collect information on work history, suspected exogenous lead sources, personal behaviour and knowledge about lead. Evidence obtained by the study indicated that safety behaviour and personal hygiene were poor, for example, PPE wasn't worn and workers smoked, drank and ate during work. The mean personal airborne lead of caulkers (36.4 µg/m³) was higher than that of carpenters (8.3 µg/m³). 48 per cent of all workers and 67 per cent of caulkers had BLLs exceeding 40 µg/dL. Multiple linear regression indicated that BLLs of workers were significantly related to job type and education level.
Priority actions

Prompt action is needed to protect workers around the world from hazardous lead exposures. The safety and health of workers in numerous sectors will continue to be at risk unless a cohesive plan of action is established, with buy-in from stakeholders at all levels. This review has identified key priority actions, at both policy and workplace levels, to help promote the safer management of lead within the world of work.

Policy level actions

- **Eliminate all unnecessary uses of lead**

  Policies and programmes should follow a ‘toxics use reduction’ approach that promotes the phase out of lead from remaining sources of exposure, such as lead paint.

- **Implement a national OSH system for the sound management of chemicals, including lead**

  A strong national OSH system is critical for the effective implementation of policies and programmes on OSH and the sound management of lead. Policies should follow a systems approach, as outlined in the Occupational Safety and Health Convention, 1981 (No. 155), the Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187) and their respective Recommendations (No. 164 and No. 197).

- **Recognize the fundamental principle and right at work of a safe and healthy work environment**

  In June 2022, the International Labour Conference at its 110th Session adopted the resolution on the inclusion of a ‘safe and healthy working environment’ in the ILO’s framework of fundamental principles and rights at work (FPRW). This also included designating the Occupational Safety and Health Convention, 1981 (No. 155) and the Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187) as fundamental Conventions. It is now an obligation of ILO Member States to promote, respect and realize safe and healthy working conditions in the same manner, and with the same level of commitment, as the other four principles covered by the ILO Declaration on Fundamental Principles and Rights at Work. In line with Convention No. 155 and Convention No. 187, the sound management of hazardous chemicals, such as lead, is essential to achieve a safe and healthy working environment, and is key for any comprehensive workplace OSH strategy.

- **Ratify and implement key ILO instruments**

  In the last 100 years, the ILO has adopted more than 40 legal instruments on the protection of workers on OSH, which include protection from chemical hazards such as lead. ILO Member States have the duty to ensure that the fundamental principles and rights at work and ratified international labour standards protect and are applied to all workers. Key conventions pertaining to the sound management of lead in the world of work are shown in Table 1.
## Table 1: Key ILO international labour standards on chemical safety

### Chemicals conventions

- Chemicals Convention (No. 170) and Recommendation (No. 177), 1990.
- Prevention of Major Industrial Accidents Convention (No. 174) and Recommendation (No. 181), 1993.

### Occupational safety and health conventions

- Promotional Framework for Occupational Safety and Health Convention (No. 187) and Recommendation (No. 197), 2006.
- Occupational Health Services Convention (No. 161) and Recommendation (No. 171), 1985.

### Additional international labour standards related to chemicals

- Occupational Cancer Convention (No. 139) and Recommendation (No. 147), 1974.
- Labour Inspection (Agriculture) Convention (No. 129) and Recommendation (No. 133), 1969.
- Safety and Health in Agriculture Convention (No. 184) and Recommendation (No. 192), 2001.
- Safety and Health in Construction Convention (No. 167) and Recommendation (No. 175), 1988.
- Safety and Health in Mines Convention (No. 176) and Recommendation (No. 183), 1995.

### ILO List of Occupational Diseases (revised 2010) in the annex of ILO Recommendation No.194

The List of Occupational Diseases and the Recording and Notification of Occupational Accidents and Diseases [List of Occupational Diseases Recommendation, 2002], includes diseases caused by lead or its compounds (para.1.1.8). It represents the latest worldwide consensus on diseases which are internationally accepted as caused by work. It was designed to assist stakeholders in the identification and recognition of occupational diseases, including those caused by lead. The recognition of diseases as occupational through legislation is essential, in order to properly identify and treat lead-related diseases, as well as for preventative methods.
Further policy level actions

- Implement the Globally Harmonized System of Classification and Labelling of Chemicals (GHS). The GHS is an internationally agreed upon system to standardize hazard information of chemicals through labels and safety data sheets. Correct classification and labelling helps improve OSH and workplace safety systems, whilst appropriate handling, use and storage of hazardous substances can contribute to preventing hazardous exposures.

- Establish risk or sector-specific guidelines, for example:
  - Strictly control lead exposure in industries such as the production and recycling of lead acid batteries.
  - Establish legal requirements for training and PPE for workers conducting lead paint abatement on legacy paint.
  - Integrate lead training into national OSH programme considerations, specifically when it comes to requirements for training and PPE for workers conducting lead paint abatement on legacy paint.

- Improve workplace monitoring systems and workplace inspection programmes to ensure compliance with OSH regulations.

The ILO emphasizes the value of labour inspector training, in order to develop competences of labour inspectorates and enhance inspection effectiveness. This is necessary for enforcing legal provisions relating to work conditions and the protection of workers.

- Conduct research on the health impacts of lead exposures in different sectors and the efficacy of different types of protective interventions for all types of workers. Whilst there is a large body of evidence concerning the health impacts of environmental lead exposures, limited research exists on occupational exposures. This is true even for industries potentially employing large numbers of workers, such as cosmetics and toy manufacturing. Currently minimal research also exists on the types of protective interventions which may provide preventative benefits to at risk populations.

- Develop and promote viable alternatives to common lead products. For example, there are currently no readily available, economical and environmentally sound large-scale alternatives for lead-acid batteries, particularly for vehicles.

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2 For example, see the following UNEP guidelines: Lead Paint Reformulation Technical Guidelines (2022) and Lead Paint Law Compliance and Enforcement Guidance (2023).
Increase the capacity of employers’ and workers’ organisations to engage on lead exposures as a matter of priority.

Mainstream gender considerations into OSH policy and practice. In order to ensure OSH for all workers, inclusive and responsive gender-transformative OSH policies should be developed. The ILO Maternity Protection Convention (No. 183) and accompanying Recommendation (No.191) set out that pregnant women should not be obliged to carry out work that is a risk to her or her child and provides for specific risk assessment concerning pregnant women, including chemicals such as lead, which represent a reproductive hazard. Furthermore, the ILO has developed Guidelines for Gender Mainstreaming in Occupational Safety and Health to assist policy-makers and practitioners in taking a gender-transformative approach for the development and implementation of OSH policy and practice.

Update, implement and enforce national Occupational Exposure Limits (OELs) for lead. Occupational exposure to lead can be prevented by complying with the recommended occupational exposure limit values. This value is the amount of lead in micrograms per cubic meter of air, based on an eight-hour workday. Recommended OEL values differ between countries and between lead compounds. For example, for inorganic lead, the OEL is 5 µg/m³ in Latvia, 75 µg/m³ in the United States and 150 µg/m³ in Germany. For tetraethyl lead, OELs also vary, with a limit of 50 µg/m³ set in Sweden, Denmark, Poland, and Germany, whilst in Canada differences exist even between provinces, with a limit of 50 µg/m³ in Quebec and 100 µg/m³ in Ontario. Equal protections are needed for both men and women, as the dangers of lead exposure are clear, irrespective of gender.

**Case study: UNEP needs assessment survey on used lead acid batteries (UNEP n.d.)**

UNEP surveyed 102 countries to collect data on lead-acid battery regulations, monitoring, manufacturing, recycling and trade processes, and any specific needs that the countries might have to improve their processes, be more sustainable, and reduce lead pollution. From the 40 responding countries that completed surveys, results showed the following needs:

- Asia and the Pacific region expressed the need for technical and capacity building as most required.
- Latin American region expressed more needs for monitoring system, national strategy, technical and capacity building, legislation and regulation building.
- Africa region expressed needs for monitoring system, public private partnership, technology, and legislation and regulation building.

**Key points on OELs**

- In many countries, regulations for airborne exposure levels and biological monitoring levels in blood are not health protective (Gottesfeld 2022).
- Workers are at risk of hypertension, kidney and brain damage, reproductive harm and cancer even at low levels of exposure.
- Outdated national lead standards should be updated to reflect the best available scientific and medical evidence, which documents harm to multiple organ systems even at low levels of exposure (Shaffer and Gilbert 2018).
Case study: Dose-response relationship between cumulative occupational lead exposure and the associated health damages - A 20-year cohort study of a smelter in China

A retrospective cohort study was conducted by Wu et al. (2016) on 1832 smelting workers from 1988 to 2008 in China. Workers were included if they entered the plant and came into continuous contact with lead at work for longer than 3 months. The dose-response relationship between occupational cumulative lead exposure and lead poisoning, abnormal blood lead, urinary lead and erythrocyte zinc protoporphyrin (ZPP) were analysed and the benchmark dose lower bound confidence limits (BMDLs) were calculated. Statistically significant positive correlations were found between cumulative lead dust and lead fumes exposures and workplace seniority, blood lead, urinary lead and ZPP values. A dose-response relationship was observed between cumulative lead dust or lead fumes exposure and lead poisoning. The BMDLs of the cumulative occupational lead dust and fumes doses were 0.68 mg-year/m³ and 0.30 mg-year/m³ for lead poisoning, respectively. The BMDLs of workplace airborne lead concentrations associated with lead poisoning were 0.02 mg/m³ and 0.01 mg/m³ for occupational exposure to lead dust and lead fumes, respectively. In conclusion, BMDLs for airborne lead were lower than OELs, suggesting that the occupational lead exposure limits need re-examination and adjustment.
Interagency cooperation

Global Alliance to Eliminate Lead Paint

The Global Alliance to Eliminate Lead Paint (Lead Paint Alliance) is a voluntary partnership jointly formed by UNEP and WHO to focus and catalyze efforts to achieve international goals to prevent children’s exposure to lead from paints containing lead, and to minimize occupational exposures to lead paint. Its broad objective is to promote a phase-out of the manufacture and sale of paints containing lead and eventually to eliminate the risks that such paints pose. Lead is one of ten chemicals of major public health concern (WHO 2021b). The ILO is a member of the Alliance and leverages its unique tripartite structure to promote social dialogue towards the phase out of the manufacture and sale of lead paint.

SAICM emerging policy issue (EPI)

SAICM provides a valuable multi-stakeholder forum to discuss and address the many challenges facing the adoption and implementation of national policies to safely manage chemicals. One of SAICM’s functions is to call for appropriate action on emerging policy issues as they arise and to forge consensus on priorities for cooperative action. The abolition of lead in paint has been identified as one of eight EPIs. To support the Lead Paint Alliance’s goal of lead paint elimination, a GEF-funded SAICM project “Lead in Paint component”, enabled the Alliance to provide expert advice to assist countries with establishing lead paint laws.

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal

The overarching objective of the Basel Convention is to protect human health and the environment against the adverse effects of hazardous wastes. It was developed to control the transboundary movement of waste globally and to prevent dumping of hazardous waste in developing countries. In 2003 the Conference of the Parties to the Basel Convention adopted the Technical Guidelines for the Environmentally Sound Management of Waste Lead-acid Batteries.

Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade

The Rotterdam Convention is a multilateral treaty to promote shared responsibilities in relation to importation of hazardous chemicals. The convention promotes open exchange of information and calls on exporters of hazardous chemicals to use proper labelling, include directions on safe handling, and inform purchasers of any known restrictions or bans. Two lead compounds, which are both fuel additives, are covered under the Convention: Tetraethyl lead and tetramethyl lead.

Workplace level actions

Although the phase out of unsafe exposure to lead is a priority, workplace prevention efforts should also be implemented as complementary actions. Targeted strategies are needed at both the national and workplace levels, particularly in LMICs and in the informal economy. Key actions include implementing a workplace programme for the sound management of chemicals and carrying out workplace risks assessments to evaluate risks and apply appropriate control measures.

Implement a workplace programme for the sound management of chemicals

The components shown in Table 2 can be used as a general blueprint for the sound management of chemicals in the workplace. As always, national guidelines should be considered in the first instance.
## Table 2: Components of a workplace programme

<table>
<thead>
<tr>
<th>Elements of the programme</th>
<th>Components included</th>
</tr>
</thead>
<tbody>
<tr>
<td>General obligations, responsibilities and duties</td>
<td>Role of the competent authority</td>
</tr>
<tr>
<td></td>
<td>Responsibilities and duties of employers, workers, and suppliers</td>
</tr>
<tr>
<td></td>
<td>Rights of workers</td>
</tr>
<tr>
<td>Classification and labelling following the GHS</td>
<td>Criteria for classification of hazards</td>
</tr>
<tr>
<td></td>
<td>Methods for classification</td>
</tr>
<tr>
<td></td>
<td>Type of labelling on containers of hazardous chemicals</td>
</tr>
<tr>
<td>Chemical Safety Data Sheets</td>
<td>Provision of information and training</td>
</tr>
<tr>
<td></td>
<td>Content of safety data sheet</td>
</tr>
<tr>
<td>Operational control measures</td>
<td>Assessment of control needs and elimination of hazards</td>
</tr>
<tr>
<td></td>
<td>Control measures for: health hazards; flammable, dangerously reactive or explosive chemicals; disposal and treatment of chemicals</td>
</tr>
<tr>
<td>Design and installation</td>
<td>Enclosed systems where feasible</td>
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<tr>
<td></td>
<td>Separate areas for hazardous processes to limit exposures</td>
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<tr>
<td></td>
<td>Practices and equipment that minimize releases</td>
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<tr>
<td></td>
<td>Local exhaust ventilation and general ventilation</td>
</tr>
<tr>
<td>Work systems and practices</td>
<td>Administrative controls</td>
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<tr>
<td></td>
<td>Cleaning and maintenance of control equipment</td>
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<tr>
<td></td>
<td>Provision of safe storage for hazardous chemicals</td>
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<tr>
<td>Personal protection</td>
<td>Personal protective equipment</td>
</tr>
<tr>
<td></td>
<td>Welfare facilities and personal hygiene</td>
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<tr>
<td></td>
<td>Practices to maintain equipment and clothing as necessary</td>
</tr>
<tr>
<td></td>
<td>Training on personal protection</td>
</tr>
<tr>
<td>Information and training</td>
<td>Workers should be provided information (labels and safety data sheets), and be trained how to handle them safely, what to do in an emergency, and how to obtain additional information</td>
</tr>
<tr>
<td>Maintenance of engineering controls</td>
<td>Practices and procedures to keep engineering controls in good working order</td>
</tr>
<tr>
<td>Exposure monitoring</td>
<td>Measuring methods</td>
</tr>
<tr>
<td></td>
<td>Monitoring strategy</td>
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<tr>
<td></td>
<td>Recordkeeping</td>
</tr>
<tr>
<td></td>
<td>Interpretation and application of data</td>
</tr>
<tr>
<td>Medical and health surveillance</td>
<td>Medical exams as necessary</td>
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<tr>
<td></td>
<td>Recordkeeping</td>
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<tr>
<td></td>
<td>Use of results to evaluate programme</td>
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<td></td>
<td>Paid time off for affected workers, including paid sick leave</td>
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<td></td>
<td>Employment protection for those harmed by chemicals</td>
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<td></td>
<td>Transfer to alternative employment for pregnant/breast feeding workers</td>
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<tr>
<td>Emergency procedures and first aid</td>
<td>Planning should be done to anticipate possible emergencies, and have procedures to deal with them</td>
</tr>
<tr>
<td></td>
<td>First aid should be available on-site</td>
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<tr>
<td>Investigation, recording and reporting of accidents, occupational diseases and other incidents</td>
<td>All incidents should be investigated to determine why they occurred, what failed in the workplace or in the emergency plan</td>
</tr>
<tr>
<td></td>
<td>The accident and dangerous incident book should be reviewed regularly to identify risky jobs and processes</td>
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<tr>
<td></td>
<td>Authorities should be notified as required by national laws</td>
</tr>
</tbody>
</table>
Lead monitoring programmes for workers exposed to lead

The WHO Guideline for Clinical Management of Exposure to Lead recommends a blood lead concentration of 5μg/dL as a trigger for a thorough review of the ways in which a person is being exposed to lead and for action to reduce or end this exposure (WHO 2021a). Regular health surveillance and biomonitoring of workers, together with recognition of OELs, help in the early detection of exposure and related adverse health effects. Challenges exist however with regard to monitoring and surveillance, as many countries do not have the technical and laboratory capacity to establish baseline conditions and conduct subsequent monitoring (WHO 2019). Human biomonitoring, for example measuring BLLs, is seen as an effective approach to identify and monitor vulnerable populations, however many countries may need help to implement such programmes.

The health surveillance programme allows the worker’s health to be protected by (HSA 2014):

- Determining the amount of lead going into the workers body through BLL monitoring.
- Allowing for remedial action to control lead absorption.
- Allowing for education of workers on the health effects of lead.

The amount of lead in the blood lead sample can be used to determine:

- When a worker should be suspended from lead exposure at work.
- When an urgent review of work practices and personal hygiene should be made.
- When further testing should take place.
- When a worker is safe to return to work after excessive lead exposure.

Case study: The Adult Blood Lead Epidemiology and Surveillance (ABLES) programme in Washington, USA

Occupational lead exposure continues to be a problem in the United States. NIOSH’s ABLES programme uses data on BLLs from medical surveillance in different states to examine workplace lead exposure trends and promote interventions (NIOSH n.d.). It provides recommendations to protect workers, including the distribution of prevention materials for impacted workers and targeted prevention plans for high-risk industries. ABLES was found to contribute to a decline in national prevalence rates, with a 59 per cent decrease in the national prevalence rates of BLL greater or equal to 25 μg/dL documented from 1994 to 2012. As of 2022, 37 states collaborate with NIOSH as part of the ABLES program.

Implement an adapted workplace risk assessment

A workplace risk assessment is one of the key tools for protecting OSH conditions for those exposed to lead in the workplace. A risk assessment is carried out to categorize hazards, evaluate risks, and identify and implement appropriate control measures. It should take into account risks along all stages of the lifecycle of lead, including production processes, use, recycling and disposal.

The risk assessment should comprise the following five steps:

1. **Step 1: Lead hazard identification**

The presence of lead within a workplace is usually identified by sampling. Different sampling methods can be used to measure the concentration of lead in the air, within a surface coating (e.g. paint), and in dust, soil and other materials (WorkSafeBC 2017). This information is needed to evaluate impact and determine appropriate preventative measures and controls. The risk assessment should consider the scope and nature of work tasks involving the use or disturbance of lead, including the length of work...
Exposure to lead in the world of work: Impacts for occupational safety and health

Shift, whether any 'hot' work will take place, the potential routes of exposure and any pre-existing air and health monitoring data (WorkSafeBC 2017). Workers may face a range of exposure pathways, including inhalation, ingestion or dermal contact, depending on the specific tasks they are performing.

**Step 2: Identify who might be harmed and how**

Once the sources of potential lead exposure have been identified, the next step is to assess the risks associated with potential exposure to lead fumes, vapours or dust. In addition, the risk assessment should identify which workers are at particular risk of hazardous exposures, and the potential safety and health impacts. Workers in vulnerable situations are potentially at greater risk, including pregnant women, youth workers, migrant workers and workers with a disability. For instance, migrant workers may not speak the local language and therefore would find it difficult to understand chemical labels, safe handling procedures and training manuals.

**Step 3: Evaluate the risk – Identify and decide on the safety and health risk control measures**

Once lead has been identified, classified, communicated, and its risks assessed, the third step is to use this information to design an appropriate preventive and protective programme using the Hierarchy of Controls (Figure 12).

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**Figure 12: The Hierarchy of Controls**

- **Elimination**
  - Physically remove the hazard

- **Substitution**
  - Replace the hazard

- **Engineering controls**
  - Isolate workers from the hazard

- **Administrative controls**
  - Change the way work is performed

- **PPE**
  - Protect the workers with PPE, as the last resort

---

More effective

Less effective
There are five categories in the Hierarchy: Elimination, substitution, engineering controls, administrative controls and personal protective equipment (PPE), with control methods at the top of the Hierarchy potentially more effective than those at the bottom:

- **Elimination or substitution**: The most effective way to prevent exposure to a hazardous material such as lead is through elimination or substitution with viable, less toxic alternatives. For example, replacing the lead-containing paint with lead-free paint. It is important to ensure that the new product does not contain any equally hazardous chemicals.

- **Engineering controls**: These are physical changes to the way tasks are carried out onsite. They aim to eliminate or minimize the amount of lead being released into the air. Common engineering controls include (WorkSafeBC 2017):
  - Enclosing specific tasks or work processes that produce lead contamination.
  - Installing local exhaust ventilation for tasks such as welding and cutting.
  - Installing dust collection systems on machines or equipment.
  - Modifying the process to reduce the amount of lead fumes or dust generated.

- **Administrative controls**: These are changes to the way work is organized or performed. They may include (WorkSafeBC 2017):
  - Work scheduling e.g. to reduce exposure duration.
  - Good housekeeping e.g. cleaning up lead dust and waste regularly.
  - Provision of changing and washing facilities.
  - Clean eating and drinking areas, which are separated from work areas.
  - Worker education and training, so that workers are informed about the health hazards of lead and appropriate safety measures.

- **PPE**: All workers who are exposed to lead during the course of their work should be given appropriate, well-fitting PPE. Workers should also be provided information on its correct use. It is important to consider other safety measures in addition to PPE, which should only be used on its own as a last resort.

An example of the Hierarchy of Controls when applied to lead is shown in Figure 13.

![Figure 13: Example of the Hierarchy of Controls for lead](image-url)
Step 4: Record who is responsible for implementing which control measure, and the timeframe

Once control measures have been decided, action should be taken to ensure they are implemented effectively. The workplace should decide who will be responsible for implementing and overseeing the new measures, as well as an appropriate timeline for their implementation based on what actions have been determined to be a priority. A plan of action may also include worker training and regular checks to ensure the measures are still in place.

Step 5: Record the findings, monitor and review the risk assessment, and update when necessary

Risk assessment findings should be recorded and made available to supervisors, workers and labour inspectors. Arrangements will be needed to monitor the effectiveness of the control measures and one way of doing this is through workplace inspections. The risk assessment should be regularly reviewed and updated, as changes to work practices may impact lead exposure levels and exposure pathways. In addition, the control measures may not adequately address risks and further, more stringent measures may be needed.

Examples of engineering controls in construction (OSHA 2004)

- Exhaust ventilation: Equip power tools used to remove lead-based paint with dust collection shrouds or other attachments so that paint is exhausted through a high-efficiency particulate air (HEPA) vacuum system. For operations such as welding, cutting/burning, or heating, use local exhaust ventilation.

- Enclosure or encapsulation: To reduce the risks posed by lead-based paint, encapsulate it with a material that bonds to the surface, such as acrylic or epoxy coating or flexible wall coverings. Floors coated with lead-based paint can be covered using vinyl tile or linoleum.

- Substitution of processes: Consider surface preparation equipment such as needle guns with multiple reciprocating needles completely enclosed within an adjustable shroud, instead of abrasive blasting under certain conditions. The shroud captures dust and debris at the cutting edge and can be equipped with a HEPA vacuum filtration with a self-drumming feature.

- Component replacement: Replace lead-based painted building components such as windows, doors and trim with new components free of lead-containing paint.

- Process and equipment modification: When applying lead paints or other lead-containing coatings, use a brush or roller rather than a sprayer. Also, use non-silica-containing abrasives such as steel or iron shot/ grit sand instead of sand in abrasive blasting operations when practical. When appropriate for the conditions, choose blasting techniques that are less dusty than open-air abrasive blasting, for example hydro-blasting.

- Isolation: Isolation consists of keeping workers not involved in the blasting operations as far away from the work area as possible, reducing the risk of exposure.
What PPE should be used when working with lead? (HSA 2014)

- The type of PPE used should be based on the written risk assessment.
- It will generally include suitable respiratory protective equipment (RPE), barrier cream, gloves, eye protection, safety footwear and disposable overalls.
- Workers should be properly trained in the use maintenance and storage of PPE.
- Individual evaluations are needed to determine the concentrations of lead a worker may be exposed to and the relevant respiratory protection for a situation.
- If tight fitting respirators are used, the employer should arrange for face-fit testing to ensure it correctly and comfortably fits the worker. The use of powered air respiratory protection can give greater protection to the worker.

Social dialogue

Social dialogue should be promoted at all levels and between all stakeholders. Social dialogue is defined by the ILO to include all types of negotiation, consultation or simply exchange of information between, or among, representatives of governments, employers and workers, on issues of common interest relating to economic and social policy. It can exist as a tripartite process, with the government as an official party to the dialogue or it may consist of bipartite relations only between labour and management (or trade unions and employers’ organizations), with or without indirect government involvement. Social dialogue processes can be informal or institutionalized, and often it is a combination of the two. It can take place at the national, regional or at enterprise level. It can be inter-professional, sectoral or a combination of these.

The main goal of social dialogue itself is to promote consensus building and democratic involvement among social partners in the world of work. Social dialogue structures and processes have the potential to resolve important economic and social issues, encourage good governance, advance social and industrial peace and stability and boost economic progress. Given that lead is used in numerous countries around the world and in many different industries, cooperation and collaboration at global, national and workplace levels will be key to achieving objectives regarding the protection of workers from harmful lead exposures.
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