Notes:

• please add details of the date, time, place and sponsorship of the meeting for which you are using this presentation in the space indicated;

• this is a large set of slides from which the presenter should select the most relevant ones to use in a specific presentation. These slides cover many facets of the problem. Present only those slides that apply most directly to the local or regional situation. Where relevant, adapt the information, statistics and photos within each slide to the particular context in which this module is being presented. For instructions on how to use this module visit: https://www.who.int/publications/i/item/WHO-CED-PHE-EPE-19-12-02;

• Lead is one module from a larger training package focused on children’s environmental health. Throughout Lead, a number of different modules are suggested that contain additional relevant information. Consult these other modules where relevant. To see the full package visit: https://www.who.int/teams/environment-climate-change-and-health/settings-populations/children/capacity-building/training-modules;

• the World Health Organization (WHO) reference number for the module Lead: training for health care providers, second edition is WHO/HEP/ECH/CHE/23.04;

• for more information on WHO’s work on children’s environmental health, please visit: https://www.who.int/health-topics/children-environmental-health.
Lead exposure is an important problem affecting children’s health and development worldwide. This presentation will deal with the epidemiology, routes of exposure, clinical manifestations and some basic approaches to prevention and management of lead exposure in children.

The learning objectives for this module are to:

• understand characteristics of lead as a toxicant;
• describe epidemiology of lead poisoning;
• recognize sources of children’s exposure;
• understand children’s vulnerability to lead;
• describe acute and chronic health effects;
• understand diagnosis, treatment and follow-up of lead exposure;
• recognize actions to prevent lead exposure.
Note:
When selecting the slides to include in your presentation, please choose only those of relevance to the region and/or interests of your audience.

This training module includes the following sections:
- magnitude of the problem;
- children’s sources of exposure to lead;
- lead health effects in children – both acute and chronic health effects;
- diagnosis and treatment methods of lead exposure and poisoning;
- interventions to prevent childhood exposure to lead at international, national and local levels;
- case studies on lead poisoning and child health.

Photo:
- © WHO / Diego Rodriguez. Young girls sitting together with a person wearing an elephant mask during celebrations of the Shivaratri Festival in the city of Pushkar, India. This photo depicts young girls in festival attire, including eye makeup. Cosmetics, such as kohl, may contain lead and have led to toxic effects in children.
For the first section of this module, we will start with the magnitude of the problem of lead. This section provides an overview of lead and the epidemiology of lead in children.

Photo:
• © WHO / Diego Rodriguez. Young girls sitting together with a person wearing an elephant mask during celebrations of the Shivaratri Festival in the city of Pushkar, India. This photo depicts young girls in festival attire, including eye makeup. Cosmetics, such as kohl, may contain lead and have led to toxic effects in children.
Lead overview

- Naturally occurring
- Widely used
- Cumulative toxicant
- Affects multiple body systems
- Chemical of major public health concern
- Three forms
  - Inorganic of most concern

No known safe level of lead exposure without harmful effects

Lead is a blue-gray, heavy, soft metallic element that occurs naturally in the earth’s crust. Human activity has caused lead to become widely distributed in the environment, where it persists for long periods of time. Today, most lead in the environment is anthropogenic (due to human activity) in origin. Release of lead has increased with industrialization, mining, smelting, refining and recycling of products containing lead, such as batteries, use of leaded petrol in vehicles and aviation fuel and use of lead in manufacturing, such as ceramics and electronic items (1).

The largest use of lead in 2015, over 80% of its usage worldwide, was in storage batteries for cars and other vehicles. Global consumption of lead is increasing due to growing demand for energy-efficient vehicles. Metals, including lead, are valuable and informal recycling has spread in many regions (2).

Exposure to environmental lead results in accumulation within the human body. Lead is a toxicant that affects multiple systems, including cardiovascular, haematological, renal, gastrointestinal and central nervous systems (1). The World Health Organization (WHO) has identified lead as one of 10 chemicals of major public health concern for which multisectoral action to limit harmful effects are needed (3).

There are three forms of lead (4):
1. elemental, which is naturally occurring in the earth’s crust;
2. organic, previously used in leaded petrol in vehicles, is highly toxic to humans and exposure is now unlikely, except for in certain occupations;
3. inorganic, which is the form of lead used in many items today, including paint and lead-acid batteries, and the form that children are most commonly exposed to.

There is no level of exposure to lead that is known to be without harmful effects to health (5).

Note: for more information on recycling electronic items see the module Electrical/electronic waste and children’s health.

References:


Photo:
- Alchemist-hp. “Lead electrolytic and 1cm3 cube”. https://en.wikipedia.org/wiki/File:Lead_electrolytic_and_1cm3_cube.jpg. This work is available under the Creative Commons Attribution-NonCommercial-NoDerivs 3.0 Unported license (CC BY-NC-ND 3.0; https://creativecommons.org/licenses/by-nc-nd/3.0/).
Children, pregnant women and their unborn babies are especially vulnerable to the adverse health effects of lead exposure. Children who are exposed to lead, especially during early childhood or in utero, may experience permanent and irreversible health impacts, particularly to the development of the brain and central nervous system. Exposure of pregnant women to high levels of lead can cause miscarriage, stillbirth, premature birth and low birth weight (1).

Exposure to lead is preventable and is key to ensuring children’s health, development and futures (2). Recent limitations in the use of lead in petrol, paint, plumbing and solder have resulted in substantial reductions in population-level mean blood lead concentrations. However, significant sources of children’s exposure remain, particularly in low- and middle-income countries (LMICs). Additionally, low-level lead exposure in children remains a global concern. At low levels of exposure that may not cause any obvious symptoms, lead is well recognized to produce a spectrum of injury across multiple body systems, including impaired neurodevelopment in children (1,2).

The next three slides discusses the global magnitude of lead, including lead exposure at low levels, in more detail.

References:

Photo:
• © WHO/ NOOR/ Sebastian Liste. Portrait of Victor, a visually impaired pupil from class 5 at Ober Boy’s Primary Schoo, Kenya.
In 2019, more than 2 million deaths globally were attributed to chemical exposures. Lead exposure was attributed to nearly half of these deaths (1).

The Institute for Health Metrics and Evaluation (IHME) estimated that in 2019, more than 900,000 deaths and 21.7 million disability-adjusted life years (DALYs) worldwide were attributable to lead exposure (2). With respect to specific outcomes, lead exposure accounted for:

- 62.5% of the global burden of idiopathic developmental intellectual disability
- 8.2% of global hypertensive heart disease
- 4.6% of global ischaemic heart disease and
- 4.7% of global stroke (1,2).

Exposure to lead is a significant environmental risk to the health of children around the world. In low- and middle-income countries (LMICs) the risk of lead exposure is particularly high. In 34 LMICs in 2019, 48.5% of children under 15 years of age were estimated to have elevated blood lead levels (3). A review of background blood lead levels completed in 2019 of 1.3 billion children in 34 LMICs found that:

- 632 million children (49%) were estimated to have blood lead levels over 5 micrograms per decilitre (µg/dL); and
- of these, 413 million (32%) were estimated to have blood lead levels over 10 µg/dL (3).

Given that this review included only children in 34 of 137 LMICs, these are likely to be underestimations. These levels and percentages are significantly higher than those seen in high-income countries (HICs). In the United States of America in 2017, less than 2% of children aged 0–5 years had elevated blood lead levels over 5 µg/dL and similar findings have been found in other HICs, including France, Japan and Sweden (3).

**Note:** The 137 countries identified as “low- and middle-income” in this study were defined by the 2018 World Bank income groupings (3).

**References:**

Photo:
• © WHO / Blink Media – Tali Kimelman. A 10-year-old boy has his blood pressure taken as part of treatment for high blood lead levels, Uruguay.
The majority of idiopathic developmental intellectual disability-adjusted life years (DALYs) are attributable to lead exposure, as described on the previous slide (1). Decreases in intelligent quotient (IQ) from even low-level lead exposure are apparent when viewed from a public health perspective. Even low-level lead exposure can have major effects on IQ. These reductions in IQ undermine children’s future potential and diminish their prospects (2). When an entire population experiences a 5-point loss in IQ, declines in creative and economic productivity may be apparent across society (2,3).

The figures on the slide give an example of the effects of a 5-point loss in IQ across an entire population. The normal distribution of IQ scores in a hypothetical population of 100 million people with average IQ of 100, standard deviation of 15, is shown in the figure on the left. This population would be expected to include 2.3 million individuals with IQ greater than 130. On the opposite end, there would be an expected 2.3 million individuals with IQ less than 70. Individuals with IQ less than 70 require significant societal support (4).

A decrease of 5 points in average IQ would shift this hypothetical population distribution to the left, as seen in the figure on the right of the screen. Here, the number of individuals with IQ greater than 130 has been reduced to 990,000, a decrease of more than 50%, while the number of people with IQ less than 70 has increased to 4.8 million (4). This has significant implications for the capacity of a society to provide support to those who need it (2).

Children with blood lead levels equal to or greater than 5 micrograms per decilitre (µg/dL) will experience on average a deficit of 6.1 IQ points. However, most IQ points lost in children occur at even lower blood lead levels as many more children have blood lead levels below the 5 µg/dL threshold. Blood lead levels less than 5 µg/dL are estimated to cause deficits of up to 2.8 IQ points in children, representing 87% of the total IQ points lost due to lead exposure (5-7).

References:


**Figure:**
Lead is a powerful neurotoxicant. Several studies have investigated the effect of lead on lifetime economic productivity lost due to early childhood exposure. These studies consider economic costs as measured in decrements of intelligent quotient (IQ) points due to lead exposure.

A regression model found that in 2011, low- and middle-income countries (LMICs) experienced a loss of 406.2 million IQ-points in children under the age of 5 years due to lead exposure. This led to an annual economic loss of 977 billion international dollars in LMICs, equivalent to 1.2% of global gross domestic product (GDP) in 2011. Some regional breakdowns of these statistics in 2011 include:

- in Africa, annual economic loss of 134.7 billion international dollars with the highest losses in South Africa and Egypt;
- in Asia, 699.9 billion international dollars lost, China and India shouldered about two-thirds of the areas economic loss due to lead; and
- in Latin America, 142.3 billion international dollars lost with the highest loss in Brazil (1).

Several studies of the United States of America and European Union countries have also been made and found that in 2008:

- cognitive impairment attributed to lead contamination was estimated to cost the United States of America’s economy US$ 50.9 billion annually in lost economic productivity (2);
- in the 27 European Union countries the economic costs of childhood lead exposure were equivalent to approximately US$ 57 billion annually (3).

Lead exposure has a profound impact on child health and can lead to long-term economic impacts for both individuals, through lost potential income, as well as for countries.

**Note:** the countries identified as “low- and middle-income” in this study were defined by the 2012 World Bank income groupings (1).

**References:**
The next section of this module outlines the major sources of environmental lead exposure in children.

**Photo:**
* © WHO / Diego Rodriguez. Young girls sitting together with a person wearing an elephant mask during celebrations of the Shivaratri Festival in the city of Pushkar, India. This photo depicts young girls in festival attire, including eye makeup. Cosmetics, such as kohl, may contain lead and have led to toxic effects in children.
Sources of lead exposure: in the home

- Lead-based paint
- Lead in plumbing systems for water for infant formula, drinking
- Household items
- Occupational exposures
  - Take-home
  - Informal recycling
- Improper de-leading or renovation of old houses

There are multiple sources of lead exposure that can be found in the home that pose significant risks to child health.

One of the most significant sources for infants and toddlers is deteriorated lead-based paint. Lead compounds may be added to paint to obtain specific characteristics, for example colour, rapid drying and resistance to corrosion. Even in countries where lead in paint has been banned; old houses, furniture and gardens may still be contaminated. Deteriorating lead paint, including weathered, chipping and peeling paint, is associated with higher amounts of lead contamination in household dust and soil. Paint flakes or resulting lead-contaminated dust may be accessible on floors, walls, windowsills, porches and gardens. Lead-contaminated dust and soil may also be found in playgrounds. Metallic lead is tasteless and odorless, but some of the dispersed oxides and salts of lead taste sweet and appealing to children (1,2). The presence of lead in paints differs from country-to-country, depending on the national legal status of lead-based paints and the implementation of these laws. As of June 2022, 87 countries had legally-binding controls on lead paint (3).

Lead may be present in tap water due to plumbing systems containing lead pipes, solders and fittings. Polyvinyl chloride pipes may contain contamination due to the use of lead during the manufacturing process. Higher concentrations may be found in water that is soft, acidic, or in contact with lead-containing materials for long periods without interruption, such as overnight. Controlling water pH to neutral or mild alkaline range can help to reduce contamination in water from lead in pipes (2,4,5).

As lead is a heavy metal with a low melting point and is resistant to corrosion, it has been used in a wide variety of products that may be present in the household. Additionally, inorganic lead salts are often colourful and can be found in pigments, glazes and paints. Some common household items that have been found to contain lead include (2,6):

- ceramic glazes on tableware
- some traditional or herbal remedies
- some toys
- jewellery
- spices
- food can solder
- wax crayons
- curtain weights
- fishing sinkers
- ammunition.

Lead-containing traditional cosmetics such as surma, kohl and sindoor are used on children and have led to toxic
effects. Food may be contaminated by lead when cooked or served with lead-glazed ceramics, recycled metal pots, or glassware or food tins with lead solder (2).

**Occupations** that involve lead may cause take-home exposure in children. This occurs when lead-contaminated clothes, shoes or materials are brought back from the workplace (2). When the workplace is in the home, children may be constantly exposed to lead (6). Some occupations connected with exposure to lead include: construction workers, plumbers, painters, pottery workers, welders, battery makers or recyclers, glass makers, gunshot makers, jewellers, pipe cutters, lead burners and smelters. As discussed further in the interventions section, work-related exposures may be reduced via the implementation of occupational standards such as personal protective equipment, or separating contaminated items, such as laundry, from the child’s reach at home (2).

Informal storage and recycling of batteries, metals and e-waste may cause severe cases of child lead poisoning. Lead is a valuable metal and trade in informal economies may be found around homes, such as unsound recycling of batteries or other lead-containing materials. Lead fumes are easily formed when lead is heated at temperatures that may be reached in a domestic heater. Informal recycling activities of lead, and items containing lead, have caused significant environmental lead contamination where children live, play and learn. Informal recycling activities are a major source of lead exposure in low-and middle-income countries (LMICs) (7-9).

Finally, **improper de-leading or renovation of old houses** can result in lead exposure. Care must be taken to maintain safe environments when such activities are undertaken (2,6).

**Note:** highlight the most relevant household items that may expose children to lead in your community, area or country.

**Note:** check the legal status of lead-based paints in your country here: https://www.who.int/data/gho/data/themes/topics/indicator-groups/legal-binding-controls-on-lead-paint.

**Note:** for more information see the modules Electrical/electronic waste and children’s health and Occupational risks and children’s health.

**References:**


Photo:
• © Annie Spratt / Unsplash. This photo shows the outside of a house with deteriorating paint, Italy.
Previously, tetraethyl lead (an organic lead compound) was extensively used as a petrol additive (1). This use accounted for a high baseline of lead exposure worldwide. However, during the last few decades, countries have phased out leaded petrol. In 2021, Algeria banned the use of leaded petrol, marking the global elimination of lead in fuel for cars and lorries (2). This preventive measure has been highly effective in reducing children’s blood lead levels. However, lead continues to be used in some aviation fuels. The use of leaded fuel in this industry remains a risk for children living in close proximity to airports (1,3).

Environmental exposure to lead continues to occur due to the use of lead in industrial processes. Significant poisonings and outbreaks of acute-on-chronic exposures have been described in children who live near mining towns, metal processing facilities, battery production and recycling sites, e-waste recycling sites, and near the industrial production of lead-containing chemicals in the African Region (4–7), Region of the Americas (8,9), South-East Asia Region (10) and the Western Pacific Region (11). Many of the most severe lead poisoning cases in children have been linked to small, informal and often family-run businesses.

Additional sources of children’s exposure to lead may also occur due to legacy contamination. Even when industrial lead use has ceased in an area, lead contamination may be a legacy of historical use from former industrial, mining sites and landfills that have been used for industrial waste, including metallic slag, and informal recycling activities (12). The relative importance of each source of lead exposure differs from country-to-country (13).

References:


Photos:
- Top: © Amalia Laborde. This photo shows battery recycling
- Bottom: © Amalia Laborde. This photo shows a sign advertising informal purchasing of lead.
Children have multiple routes of exposure to lead. The next two slides will discuss these different routes. First, we start with the **prenatal** route of exposure.

Pregnant women who are, or have previously been, exposed to lead may also accidentally expose their unborn children to lead. Prenatal lead exposure is determined by maternal body burden. Lead is stored in the bones, where it can remain for years before it is eliminated from the body. From conception onward, lead that has been stored in the mother’s skeleton from years past is released into the circulation under the metabolic stress of pregnancy, especially if the mother is calcium deficient. Throughout pregnancy, lead readily crosses the placenta, and the blood lead concentration of the infant becomes virtually identical to that of the mother\(^1\). Research has found that a newborn’s blood lead level can be between 70 to 100% of that of their mother\(^2\). Once in fetal circulation, lead can readily enter the developing brain through the immature blood-brain barrier\(^1\).

**References:**
Postnatal exposure to lead mainly occurs through two routes: **ingestion** and **inhalation**.

**Ingestion** is children’s primary routes of exposure to lead. This is especially true since lead has been removed from petrol in cars and lorries. Children may be exposed in this way by consumption of lead-contaminated food and water. Children may also ingest lead through non-nutrient ingestion, for example of lead paint chips or flakes and contaminated soils and dust. Children who engage in pica, the compulsive, habitual consumption of non-food items, are at particularly high risk (1). Estimates from the United States of America have found that a child who engages in pica can be exposed to as much as 100 times as much lead through ingestion of contaminated soil as a child who engages in an average amount of hand-to-mouth behaviour (2). Lead can also pass into breast milk (only the plasma fraction), but unless mothers have a very high exposure, breast milk does not contain significant amounts of lead when compared to environmental sources. The benefits of breastfeeding are without a doubt and should continue unless specifically assessed and advised otherwise. The World Health Organization (WHO) and the United Nations Children’s Fund (UNICEF) recommend exclusively breastfeeding for the first 6 months of life with continued breastfeeding along with complementary foods while continuing to breastfeed for up to two years and beyond (3).

**Inhalation** is another childhood route of exposure to lead. Inhalation of airborne lead is no longer a major source of exposure for children and is more common in occupationally-exposed adults. Children can be exposed to fine particles of airborne lead in smoke and dust from industry and activities including open burning of waste containing lead, such as batteries, heat-gun stripping of painted surfaces and welding and torch cutting of lead painted steel or steel alloys containing lead (1,2).

Lead can also be absorbed through the skin. Organic forms of lead (such as tetraethyl lead previously used in petrol) are easily absorbed through the skin (1). However, since the global ban on lead in petrol for cars and lorries, this route of exposure to organic lead is unlikely in children. Inorganic lead, such as in cosmetic products, is poorly absorbed through the skin and is considered to be a minor route of exposure (2,4). However, children’s contact with items that contain lead, such as jewellery and cosmetics, should be carefully monitored (1,2).

**References:**

   [https://apps.who.int/iris/handle/10665/136571], accessed 14 September 2022).

Figure:
The next section of the module discusses children’s special vulnerability and health effects associated with lead exposure.

**Photo:**
- © WHO / Diego Rodriguez. Young girls sitting together with a person wearing an elephant mask during celebrations of the Shivaratri Festival in the city of Pushkar, India. This photo depicts young girls in festival attire, including eye makeup. Cosmetics, such as kohl, may contain lead and have led to toxic effects in children.
Children’s special vulnerabilities mean that they are at the highest risk of lead exposure and its irreversible effects on their health and development outcomes. Their different and unique exposures place them at high risk to ingestion and inhalation of, and dermal contact with, lead. Their dynamic developmental physiology mean that they are going through vulnerable periods of neurological and organ development. If these processes are disrupted by lead, they can cause adverse health effects that can impact a child for the rest of their life.

Children’s have different and unique exposures to lead compared to adults. In utero, the fetus may be exposed to maternal lead as it can readily cross the placenta. Children also have exploratory behaviours and practice frequent hand-to-mouth and object-to-mouth behaviours, increasing their exposure to dust and soil which may be contaminated with lead. Behaviours, such as pica and hand-to-mouth activity, make children more likely to ingest lead from paint chips, dust or polluted soil. Generally, blood lead levels peak at about 2 years of age due to normal hand-to-mouth exploratory behaviours in this age group (1).

Children have a dynamic developmental physiology. Fetuses and children are going through rapid periods of development, including increased cellular division and differentiation. Children’s metabolism is different, and they often absorb nutrients more efficiently. Absorption of lead is increased in children relative to adults. While adults may absorb up to 10% of an ingested dose of lead, children may absorb as much as 50% (2). Additionally, children breathe more air, drink more water and consume more food than adults, relative to the size of their body. If air, water or food items are contaminated with lead, children may receive more lead per kilogram of their body weight when compared with adults (2,3). Iron deficiency with or without associated anaemia can increase absorption of lead. Once absorbed, lead penetrates the central nervous system to a higher degree in young children relative to adults. The blood-brain barrier differs in the developing brain versus the adult brain, so lead readily crosses into the developing central nervous system (3). The developing nervous system is highly sensitive to toxic damage. Exposure to lead during pregnancy and during early childhood can have irreversible and lifelong effects on children’s neurological development (2,3).

Children have a longer life expectancy, so they have longer to manifest a disease with a long latency period. In the long-term, lead is stored in bone with a half-life that can be decades long (3). Because children have many years ahead of them, there is a prolonged period for lead to exert its harmful effects, and longer to live with toxic damage from lead which may manifest in childhood or much later in life (2). For example, lead exposure during childhood is linked to poor cardiovascular outcomes later in life including increased risk of cardiovascular disease and ischaemic heart disease (4). Finally, children are dependent upon adults. Children are unable to remove items or themselves from an environment that is contaminated with lead or assess situations for dangerous, potential lead exposures (1).
Note: for more information on children’s vulnerability to environmental hazards see the modules \textit{Children are not little adults} and \textit{Why children}.

References:

Photo:
* © WHO / Pallava Bagla. Children nap on the floor at a daycare centre, India.
Lead is toxic. There is no safe level of lead exposure for humans. Even low-level exposure can result in blood lead concentrations that are associated with harmful health effects. Lead is harmful to everyone and can damage the:

- brain
- kidneys,
- liver,
- cardiovascular and circulatory systems
- reproductive system.

In adults, lead exposure is linked to increased risk of ischaemic heart disease and stroke.
In pregnant women, lead exposure can damage multiple organs and is linked to negative birth and health outcomes in the developing fetus.

**Young children are the most vulnerable to lead exposure.** Lead exposure during childhood is linked to multiple affects on the central nervous system and can cause intellectual disability, poorer education outcomes and behavioural issues.

The next slides discuss the toxicity of lead and the adverse health effects of lead in children.

**Figure:**
Once absorbed into the body, lead follows a three-compartment model of distribution (1):

- first lead is circulated via the blood stream, 99% of lead circulates in red blood cells, while only 1% is circulated in plasma;
- then it is distributed in soft tissues and organs, including the liver, kidneys and the brain (this will be discussed in more detail in further slides); and
- finally, it is deposited in bones.

The majority of the body burden of lead is distributed to the bones. In children, as much as 73% of the body burden of lead is found in bone. Lead concentrations in bone can increase with age, suggesting a slow elimination process. Lead can remain in bone for as long as 20 years and can serve as a continuous source of lead in blood for many years after exposure has ended. Physiological states, for example pregnancy and lactation, can promote the release of lead from bone, contributing to an increase in blood lead levels (1).

Elimination of lead is mainly through urine (approximately two-thirds) and feces (the remainder). Lead is excreted unchanged by filtration in the kidneys; excretion is likely to differ in children due to lower glomerular filtration rate, as well as decreased tubular secretion and resorption (1,2).

Damage from lead exposure during childhood may be irreversible. The consequence of brain injury from exposure to lead in early life include (3):

- reduced potential for intellectual development
- increased likelihood of behavioural disorders
- shortened attention span

These effects of lead exposure are irreversible and can affect a child across its entire lifespan (3).

**Note:** for more information on toxicokinetics and toxicodynamics of chemicals see the module *Children and chemicals.*

**References:**


Lead is a xenobiotic with no known function in the human body. At the molecular level, general mechanism of toxicity include oxidative stress, inflammation and altered cellular membrane transport of ions (1). Oxidative stress can cause cellular changes, such erythrocyte membrane fragility, inflammation may lead to immunological responses such as increased sensitivity to infections and interference with ion transportation can lead to decreased absorption of iron (2).

Lead has a high affinity to electron donor ligands as sulfhydryl groups; causing impact in numerous enzymes and proteins, particularly heme synthesis. Lead causes anaemia due to increased erythrocyte membrane fragility and decreased haemoglobin synthesis. The lead’s ionic mechanism of action mainly arises from its ability to disturb calcium homeostasis, altering neurological and vasomotor functions. Bone growth and mineralization may be affected by 1,25-dihydroxy vitamin D3 depletion due to lead exposure. Lead has been consistently associated with decreased serum levels of vitamin D in children (2).

Virtually every neurotransmitter system in the brain is affected by lead. In particular, lead likely reduces glutamate release, which interferes with hippocampal long-term potentiation in learning and memory. Lead also has the capacity to activate and inhibit protein kinase C, which plays an important role in synaptic transmission and neurological function. Premature activation of protein kinase C may cause defects in the blood-brain barrier and lead to acute encephalopathy (2).

Lead has shown mutagenic effects in mammal experiments. The International Agency for Research on Cancer (IARC) has classified inorganic lead as a group 2A carcinogen: probably carcinogenic to humans. Though organic lead is designated as group 3: not classifiable as to its carcinogenicity in humans, IARC assumes the toxicities associated with inorganic lead once metabolized in the body to ionized lead (3).

Note on terminology: xenobiotic is any substance that is foreign to the biological system (2).

Note: for more information on toxicokinetics and toxicodynamics of chemicals see the module Children and chemicals.

References:
Adverse impacts of lead are clearly identified at the population level. However, they are not always predictive for individual children. The blue section in this figure represents lead contamination that is a risk factor for chronic, multicausal neurological, cardiovascular and developmental diseases. These effects and their risk factors may not always produce obvious, clinical symptoms. It is important that health care workers are aware of the potential sources of lead and the important but subtle health effects that children may display when exposed to chronic, low-level lead (1,2).

The pink zone illustrates the symptomatic course of acute lead poisoning. The characteristic, severe clinical effects emerge after a sustained increase in blood lead level due to repetitive high exposure. Overt clinical signs and symptoms of lead poisoning may not always be clear when blood lead level is under 40 micrograms per decilitre (µg/dL). Harmful effects may not be evident in a standard clinical examination. Additionally, some effects linked to lead exposure may be mistaken for other health conditions. The subclinical toxic effects can be very damaging, but results may be better assessed from a population perspective. The health sector is involved from one extreme to the other, from building public health interventions to protect children to managing individual cases in practice (1,3).

Reference:
Adverse health effects in utero

A guide to the blood lead levels associated with certain health effects during pregnancy

<table>
<thead>
<tr>
<th>BLOOD LEAD LEVEL</th>
<th>HEALTH EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5 µg/dL</td>
<td>Reduced fetal growth</td>
</tr>
<tr>
<td>&lt;10 µg/dL</td>
<td>Preterm birth; spontaneous abortion (possibly)</td>
</tr>
<tr>
<td>&gt;30 µg/dL</td>
<td>Spontaneous abortion; reduced birth weight</td>
</tr>
</tbody>
</table>

Exposure to lead during pregnancy can impact child cognitive and behavioural development

Lead is toxic to many organs and tissues, and exposure can result in alterations in the function of virtually every body system. Lead poisoning may be subtle, without overt clinical symptoms. Children experience toxic effects at lower levels of exposure than adults, and lead exposure is particularly harmful to children as it may cause permanent neurological damage. Lead can readily cross the placenta, exposing a fetus in utero.

Some examples of the toxic effects of lead during pregnancy and on fetal health are listed below:
- **Prenatal** exposure to lead can cause a variety of adverse birth outcomes, even at low blood concentration. Low level maternal lead exposure is associated with reduced fetal growth (1). Higher levels of maternal lead exposure are linked to multiple adverse birth outcomes including spontaneous abortion, premature birth and reduced birth weight (1,2). Prenatal lead exposure can impact child cognitive and behavioural development (3). No threshold for lead exposure has been identified that does not affect child neurodevelopment, including in utero exposure.

Many other adverse health outcomes in children have been linked to lead exposure, the next slide discusses health effects linked to childhood exposure and the lowest blood lead concentrations at which these have been measured.

**Note:** there is considerable variation in the blood lead concentration at which specific signs of poisoning manifest in individuals. This table is a guide to the blood lead levels with which certain health effects have been associated during pregnancy, according to systematic reviews and large case studies (1).

**References:**

**Figure:**
Some examples of the toxic effects of lead on children’s health are listed below:

- **Central nervous system**: Effects on the developing central nervous system are also evident in children with low blood lead levels. Subtle effects on intelligence quotient (IQ) can be associated with blood lead concentrations below 5 µg/dL and the effects may gradually increase with increasing levels of lead in blood. Effects associated with low blood lead levels include decreased academic and cognitive performance, increased behavioural issues and attention deficit/hyperactivity disorder (1,2). Encephalopathy occurs at blood lead levels greater than 80 micrograms per decilitre (µg/dL) in young children (1). Lead encephalopathy may initiate with behavioral changes and aggression, irritability and intermittent lethargy accompanied by digestive symptoms. Severe cases present with ataxia, intense vomiting, coma, and seizures, with cerebral oedema and increased intracranial pressure (3). After treatment, symptoms in children may improve, but continued neurological and cognitive sequelae can be found. Of note, in children with malaria, severe neurological features appear at levels as low as 50 µg/dL (1).

- **Gastrointestinal**: Abdominal colic or lead colic is a painful episode of abdominal cramps that can be mistaken for other acute abdominal emergencies. Nausea, vomiting, loss of appetite and constipation are common and diarrhoea less frequent (4). These effects most commonly occur in children with blood lead levels greater than 50 µg/dL (1).

- **Haemotological**: Anaemia with or without iron deficiency, is caused primarily by impairment of heme biosynthesis, but an increased rate of red blood cell destruction may also occur. Importantly, young children who are iron deficient are at highest risk of lead-induced clinical anaemia (3). Anaemia in children exposed to lead occurs at blood lead levels less than 10 µg/dL (1).

- **Reproductive**: In adults, both male and female infertility is associated with blood lead levels more than 30 µg/dL (1). In adolescents, puberty may be delayed (1).

Many other adverse health outcomes in children have been linked to lead exposure including renal function impairment, skeletal effects that may reduce growth and impaired hearing function (1,5). Exposure during childhood can lead to increased risk of health effects later in life, for example hypertension, ischaemic heart disease and stroke (2). The level of exposure, duration, frequency and timing linked to cardiovascular effects is currently unknown (1). Exposure to very high levels of lead can lead to death (1).

**Note**: there is considerable variation in the blood lead concentration at which specific signs of poisoning manifest in individuals. This table is a guide to the blood lead levels with which certain health effects have been associated in children according to systematic reviews and large case studies (1).

### Adverse health effects in children

**A guide to the blood lead levels associated with certain health effects during childhood**

<table>
<thead>
<tr>
<th>BLOOD LEAD LEVEL</th>
<th>HEALTH EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5 µg/dL</td>
<td>Decreased IQ, cognitive performance, academic achievement; increased behavioural problems; increased diagnosis of attention deficit/hyperactivity disorder</td>
</tr>
<tr>
<td>&lt;10 µg/dL</td>
<td>Decreased cognitive function; altered mood and behaviour; delayed puberty; anaemia</td>
</tr>
<tr>
<td>&gt;30 µg/dL</td>
<td>Reduced fertility (in adults)</td>
</tr>
<tr>
<td>&gt;50 µg/dL</td>
<td>Abdominal colic; severe neurological features in children with malaria; altered neuromotor and neurosensory function</td>
</tr>
<tr>
<td>&gt;80 µg/dL</td>
<td>Encephalopathy</td>
</tr>
<tr>
<td>&gt;105 µg/dL</td>
<td>Severe neurological features</td>
</tr>
</tbody>
</table>

Note: there is considerable variation in the blood lead concentration at which specific signs of poisoning manifest in individuals. This table is a guide to the blood lead levels with which certain health effects have been associated in children according to systematic reviews and large case studies (1).
References:
5. Pearce JMS. Burton's line in lead poisoning. Eur Neurol. 2007;57(2):118-9

Figure:
It is well recognized that lead can result in irreversible damage to the developing brain, even at relatively low exposure levels. Studies also suggest that there may be no threshold blood lead concentration for neurotoxic effects in children (1).

Current knowledge has established that childhood blood lead levels below 5 micrograms per decilitre (µg/dL) are a causal risk factor for (1):

- decreased cognitive performance, including reduction in intellectual, academic abilities and decreased educational attainment and some evidence of impaired reading ability and changes to visual-motor and reasoning skills (2);
- lower intelligence quotient (IQ) scores;
- increased diagnosis of attention disorders, including attention deficient/hyperactivity disorder (ADHD); and
- increased rates of behavioural problems, such as antisocial and aggressive behaviours.

Blood lead levels below 10 µg/dL in children, a level that was previously considered to be the level that should prompt interventions, are a causal risk factor for all the effects listed above in addition to (1-3):

- delays in puberty, such as delayed sexual maturity in boys and girls;
- reduced growth in infants and older children, including reduced head circumference and height;
- altered mood and behaviours, including evidence of symptoms of anxiety and withdrawal; and
- anaemia.

In 1991, many countries defined the blood lead level that should prompt public health actions as equal to or greater than 10 µg/dL. Over the past 30 years the understanding of low-level lead exposure, previously thought to be relatively harmless, has expanded. Low-level lead exposure is now understood to cause irreversible damage to children’s developing brains, potentially affecting them for the rest of their lives. In response to these findings, some countries have gradually reduced the childhood national reference value. Some examples include (1):

- France has a reference value of 5 µg/dL for children under the age of 7 years based on the 98th percentile;
- United States of America adopted a national reference value of 3.5 µg/dL in 2021 for children aged 1–5 years based on the 97.5th percentile (4);
- Germany uses reference levels of 3.5 µg/dL for children aged 3–14 years, 7 µg/dL for women and 9 µg/dL for men based on the 95th percentile.

For many low- and middle-income countries (LMICs) the resources necessary to establish national blood lead levels may not be available. In these circumstances, the World Health Organization (WHO) suggests that a blood lead level of 5 µg/dL is a practical value at which to initiate clinical interventions (1).
References:
The next section of the module discusses diagnosis and treatment of children exposed to lead.

Photo:
- © WHO / Diego Rodriguez. Young girls sitting together with a person wearing an elephant mask during celebrations of the Shivaratri Festival in the city of Pushkar, India. This photo depicts young girls in festival attire, including eye makeup. Cosmetics, such as kohl, may contain lead and have led to toxic effects in children.
Due to the long period of subclinical exposure and high blood lead level often required to cause an overt clinical case, diagnosis of lead exposure may often depend on clinical suspicion and observation and measurement of blood lead concentration.

Identifying children at increased risk of lead exposure is critical. The first step in determining if a child has been exposed to lead requires that healthcare workers identify any suspected sources of exposure. Steps in this process should include:

- a careful evaluation of the child’s clinical history;
- the use specific questionnaires to identify lead exposure. The ability of lead screening questionnaires to assess a child’s lead poisoning risk may have limited sensitivity and specificity. Thus, it is necessary to locally customize lead questionnaires to detect possible sources of lead in the home, hobbies, toys and parental or care-taker employment (1);
- visual inspections of the home and living environment can aid in the identification of different sources according to a checklist based on those sources described earlier in this module (see slides 10 and 11 for examples of sources);
- local geographic information systems and environmental monitoring programs may also contribute to identifying children living in high-risk areas.

In addition to evaluating possible sources of lead exposure, a child who is suspected to have been exposed to lead must be confirmed with a screening test to assess their blood lead concentration. Blood lead level has been demonstrated as the best biomarker of lead exposure. There is adequate evidence that capillary blood testing accurately identifies children and pregnant women with elevated blood lead levels (2). Blood lead level can be sampled using two different methods (2):

- capillary finger or heel prick screening tests are low cost and small sample point-of-care tests that do not require skilled laboratory training;
- venous blood draw samples are highly accurate and require sophisticated equipment and highly specialized technicians. Venous samples are needed to confirm high levels and to determine a course of treatment for an individual.

Analysis of blood samples to determine lead concentration can be done via two different methods:

- portable anodic stripping voltammetry (ASV) is a low-cost, point-of-care method that requires only finger or heel prick samples and does not require skilled laboratory personnel. It is suited for screening activities, such as at child health clinics or outbreak response sites distant to laboratories. High risk of sample contamination makes careful cleansing of the sample site very important. An elevated result should be confirmed with a laboratory test.
electrothermal atomic absorption spectrometry (ETAAS) and inductively coupled plasma mass spectrometry (ICP-MS) are very precise laboratory methods that require trained laboratory personnel. They can detect blood lead levels down to 0.065 µg/dL and 0.015 µg/dL respectively. These are the methods recommended for exposure assessment and diagnosis of lead poisoning that can further inform clinical management. ICP-MS can also be used to identify the environmental source of a lead sample (2).

A child who is suspected of being exposed to lead should have a complete blood assessment including:

- complete blood count
- iron status

Children with elevated blood lead levels may also have iron insufficiency or iron deficiency anemia. Iron deficiency increases lead absorption.

Other tests were previously used for lead exposure screening, such as radiographs of long bones to assess for “lead lines”, but these are no longer commonplace (3).

Note: for some examples of how to take an environmental history to identify sources of lead exposure visit: https://www.atsdr.cdc.gov/csem/exposure-history/contents.html or view pages 52-3 of reference (4).

Note: if possible, highlight methods of identifying children at risk and available sampling methods in your context or country.

References:
Surveillance programs are crucial to finding the most vulnerable populations and guiding public health decisions. When there is no clinical suspicion, diagnosis of blood lead level relies on laboratory screening. There are no universal guidelines to define lead exposure screening. However, some general criteria may be applied to assess individuals who should be further tested for lead exposure:

- **Age criteria**: children 12–24 months of age are a priority for blood lead testing. In lead-contaminated environments children’s blood lead levels generally peak 18–36 months of age. Screening is less efficient after 36 months of age unless specific high-risk factors are identified (1).
- **Suspected sources of exposure criteria**: these will vary significantly from location-to-location. Some significant sources of lead exposure that should be considered include (2):
  - age of housing, including use of lead paint on both indoor and outdoor areas. For example, in the United States of America, the American Association of Pediatrics (AAP) suggests universal screening of blood lead level for children 12–24 months old living in communities with more than 25% of housing built before 1960 (1);
  - proximity to known sources of lead pollution in water, soil, air or waste;
  - occupation of parents, pregnant women, family members or children themselves. Industries of particular concern include lead mining and smelting, battery manufacturing and recycling, paint manufacturing, ship building, ammunition production, plastic manufacturing and waste recycling.
- **Epidemiological criteria**: includes communities with other children or pregnant women with known elevated blood lead levels (2). For example, in the United States of America the AAP suggests screening all children 12–24 months of age if prevalence of blood lead level equal to or greater than 5 μg/dL exceed 5% in a community (1).
- **Vulnerable populations**: will differ from country-to-country, depending upon the context. However, some examples of vulnerable populations include (1–4):
  - recent migrants who arrive from countries where lead pollution or contamination controls are less stringent;
  - children and pregnant women from low-income backgrounds, who may be more likely to live in old housing or live in close proximity to industrial pollution;
  - child labourers and pregnant women working in the informal sector may be exposed to high levels of lead, for example through informal e-waste or battery recycling; and
  - poor nutritional status, especially calcium and iron deficiencies, can place children and pregnant women at high risk of toxic effects from lead exposure due to increased rate of absorption.

It is important to note that the criteria for screening children and pregnant women for lead exposure will differ significantly from context-to-context and from country-to-country. It is important that primary health care workers...
consider and investigate the possible sources of lead exposure in their community.

**Note:** if possible, adapt the criteria on this slide with screening suggestions from your local centre for disease control, poison centre or governmental health department. Adapt this slide to highlight the most relevant lead exposure criteria in your context.

**Note:** for some examples of screening questions that can be used to identify sources of lead exposure visit: [https://www.atsdr.cdc.gov/csem/exposure-history/contents.html](https://www.atsdr.cdc.gov/csem/exposure-history/contents.html) or view pages 52-3 of reference (2).

**References:**
Acute lead poisoning is rare and is more commonly associated with acute-on-chronic exposure. Acute lead poisoning is commonly associated with ingestion of lead or leaded objects. Blood lead level can rise rapidly and may continue to rise as the ingested lead moves through the digestive tract. Acute lead poisoning may be suspected when children present with unexplained symptoms, such as (1-4):

- Skin pallor, associated with severe anaemia
- Neurological symptoms
- Digestive symptoms
- Renal damage
- Hepatic damage
- Hypertension

Children with acute lead exposure may present with malaise, drowsiness, or encephalopathy that can progress to convulsions and even death. Gastrointestinal symptoms such as anorexia, nausea, vomiting and abdominal pain may also be seen (2,3).

Acute effects with overt symptoms may be associated with recent ingestions of lead particles, metallic objects, or food contamination. Abdominal radiography should be considered for children who have a history of pica or excessive mouthing behaviors. Lead particles are evident as radiopacities, as seen in the image here of an X-ray of a child with soil pica. Gastric decontamination may be considered if leaded foreign bodies are visualized on radiography (5).

**Note:** “acute-on-chronic” is a single exposure against a background of chronic exposure to the same agent (6).

**Reference:**

Image:

The World Health Organization (WHO) recommends that blood lead levels equal to or greater than 5 micrograms per decilitre (µg/dL) should initiate clinical interventions. While no safe level of lead exposure has been identified, this level was selected as a pragmatic value that can be detected without advanced resources and that is actionable.

When a child is found to have lead exposure, the most important aspect of management is to **eliminate the exposure at its source as quickly as possible**. All other aspects of treatment will be of little use if exposure continues. Terminating exposure can reduce blood lead levels resulting in clinical improvement.

Nutritional supplementation should meet age-appropriate recommended daily allowance for calcium, and according to WHO guidelines or standard clinical practice for iron. Iron supplementation should be continued until iron deficiency is resolved, or if not readily assessed, for three months.

Clinical follow-up is essential for children who have been exposed to lead. The follow-up interval for re-evaluation of a patient depends on the severity of poisoning and the initial blood lead concentration. The WHO guidelines suggest the following re-evaluation intervals for children and adolescent patients:

- blood lead level over 30 µmicrometers per decilitre (µg/dL): after 2 to 4 weeks
- blood lead level of 5–29 µg/dL: after 1 to 3 months
- blood lead level under 5 µg/dL: after 6 to 12 months if there is continuing concern about possible lead exposure.

For lead foreign bodies found to be within the gastrointestinal tract, especially in the stomach and for long durations, there is risk of severe and possibly fatal poisoning. WHO recommends to take measures to remove solid lead objects, such as bullets, lead pellets, jewellery, fishing or curtain weights, that are known to be in the stomach.

**Note**: pregnant women who are exposed to lead pose a particular challenge for health care providers. Removing sources of lead exposure is essential. Additionally, ensuring adequate nutrition during pregnancy, especially calcium and iron intake, can help to protect against increased blood lead concentration. For specific recommendations on exposure to lead during pregnancy and management and nutritional recommendations, visit references.

**References:**


The guidance for chelation listed here is a broad overview of the World Health Organization’s (WHO) recommendations for children. For the full guidance please refer to the WHO guideline for the clinical management of exposure to lead (1).

Chelation is a life-saving treatment for cases of severe lead poisoning. This treatment relies on chemical agents that attach to heavy metals and pull them from the bloodstream so they can be excreted in urine. Chelation can be effective at reducing the total lead body burden and is a critical therapy in managing acute toxicity (1). The purpose of chelation is to resolve clinical symptoms of lead poisoning and to reduce blood lead levels. **Chelation must be done in combination with efforts to reduce and ultimately eliminate the source of lead exposure.**

**Chelation is strongly recommended for (1):**
- children under the age of 10 years who have blood lead levels equal to or greater than 45 micrograms per decilitre (µg/dL). Oral or parenteral chelation therapy is recommended;
- children under the age of 10 years with lead encephalopathy. Urgent hospital admission and parenteral chelation therapy are recommended;
- adolescents 11–18 years of age with blood lead levels of 70–100 µg/dL AND who are displaying significant neurological features of lead toxicity or lead encephalopathy. Urgent parental chelation therapy is recommended.

WHO makes a number of other suggestions regarding chelation therapy in children with elevated blood lead levels. See some of these suggestions below (1).

Chelation is also **suggested** for:
- adolescents with blood lead levels of 45–70 µg/dL with mild-moderate clinical features of lead poisoning (such as abdominal pain, constipation, arthralgia, headache, and lethargy);
- adolescents with blood lead levels of 70–100 µg/dL without significant neurological features of toxicity. These patients may suddenly deteriorate and should be closely monitored.

Chelation should be **considered** for children 10 years of age and under with blood lead levels of 40–44 µg/dL if:
- there is doubt about the accuracy of the measurement;
- blood lead level is persistently elevated despite measures to stop exposure; or
- there are significant clinical features of lead poisoning.

Chelation should be **considered** for adolescent girls with blood lead levels of 45–70 µg/dL without clinical features of
lead poisoning.

Chelation is generally **not** suggested for:
- individuals with blood lead levels under 45 µg/dL
- male patients 11 years of age or older with blood lead levels of 45–70 µg/dL who do not show clinical features of lead poisoning; however, these patients should be re-evaluated after 2–4 weeks to ensure that blood lead concentration is decreasing and they remain healthy.

**Note:** the guidelines summarized here refer to non-pregnant patients. Please see the *WHO guideline for the clinical management of exposure to lead* for additional guidance, including management of pregnant patients (1).

**Note:** examples of significant neurological features of lead toxicity include irritability, drowsiness, ataxia, convulsions, and coma.

**Reference:**
WHO guidelines for management of lead exposure

**Chelation**

- **Chelating agents**
  - Mild or moderate poisoning:
    - Succimer (oral)
    - Penicillamine (oral)
  - Severe poisoning:
    - Sodium calcium edetate (parenteral), alone or in combination with succimer or dimercaprol (parenteral)

- **Follow-up:**
  - Re-assess blood lead levels within 2 to 4 weeks

- **Goal:**
  - Resolution of clinical symptoms
  - Sustained blood lead level reduction

The guidance for chelation listed here is a broad overview of the World Health Organization’s (WHO) recommendations for children. For the full guidance please refer to the **WHO guideline for the clinical management of exposure to lead** (1). WHO recommends the use of four different chelating agents. Selection of a chelating agent can depend upon local availability, cost, blood lead concentration, age and other factors such as pregnancy.

The four chelating agents are (1):

- **succimer** - delivered orally and can be used for mild to moderate lead poisoning;
- **penicillamine** - also delivered orally for mild to moderate lead poisoning;
- **sodium calcium edetate** - parenteral delivery and used in severe poisoning cases. It can be used alone OR in combination with **succimer** or **dimercaprol**;
- **dimercaprol** - is delivered parenterally, usually in combination with sodium calcium edetate, in severe poisoning cases.

The four chelating agents listed here are included on WHO Model List of Essential Medicines (2), treatments for which specialized diagnostic or monitoring facilities, and/or specialist medical care, and/or specialist training are needed (1). Penicillamine, sodium calcium edetate and dimercaprol are also on the WHO Model List of Essential Medicines for Children (3).

**Follow-up** to assess the success of chelation is essential. The interval before re-evaluation of a patient depends on the severity of poisoning, initial blood lead concentration and vulnerability of the patient. The following intervals are suggested by WHO for all children and adolescents who have undergone chelation (1):

- **blood lead level should be re-assessed 2–4 weeks** after chelation treatment ends. Higher initial blood lead levels should be re-assessed within a shorter period of time.

**Note:** the guidance on chelating agents summarized here refer to **non-pregnant** patients. Please see WHO guideline for the clinical management of exposure to lead for additional guidance on the use of chelation in pregnant patients (1).

**References:**
The next section of the module discusses interventions to reduce and prevent children’s exposure to lead.

**Photo:** © WHO / Diego Rodriguez. Young girls sitting together with a person wearing an elephant mask during celebrations of the Shivaratri Festival in the city of Pushkar, India. This photo depicts young girls in festival attire, including eye makeup. Cosmetics, such as kohl, may contain lead and have led to toxic effects in children.
Health professionals should have a high index of suspicion for lead exposure in children given its variable and potentially asymptomatic effects. From a clinical perspective, it is important to include lead as an environmental etiology in differential diagnoses. For example, unexplained anemia, abdominal colic or behavioral changes (1). When examining a child with unexplained symptoms health care professionals can ask themselves and their patients:

• are there any potential sources of lead exposure?
• are the signs and symptoms possibly linked to lead exposure?

Health professionals, particularly primary care practitioners, must be knowledgeable of the most up-to-date and available lead screening tests, diagnostics and management recommendations for lead poisoning. Health professionals have the opportunity to educate their patients, families, communities, colleagues and students on the local sources and hazards of lead exposure. They can also liaise with relevant national or local departments to assess lead in homes and control lead sources (2).

As seen throughout this module, lead exposure involves many varied determinants. One critical role of health professionals is to advocate for regulations that protect children from lead in different avenues, such as housing, paint, consumer products and battery recycling (3). The health sector is essential to all levels of lead prevention through family counseling, treatment and management, motivating action and monitoring results of interventions.

References:

Photo:
• © WHO/ Blink Media – Tali Kimelman. This photo was taken at the Unidad Pediátrica Ambiental (UPA) in Montevideo, Uruguay. Dr Maria Moll is examining a 10-year-old child who has elevated blood lead levels from playing with metals, especially by putting them in his mouth, from his family’s metal recycling business.
Preventing childhood exposure to lead is **essential** as the neurotoxic effects are irreversible. Eliminating exposure depends upon the source, but will always involve (1):

- parental/family/caregiver education
- some form of abatement
- long-term follow-up.

Some examples of actions that can be taken in your practice include:

- providing information on the local sources of lead to patients, families, communities and health authorities and encouraging patients to avoid relevant products and activities (2);
- providing guidance on testing for lead contamination in homes and in public areas and on monitoring children’s exposure (2);
- taking a paediatric environmental history at every visit and including lead-specific questions relevant to the individual patient and their context (see slide 32 for some examples questions) (3);
- promoting evidence-based cleaning, renovation, removal or remediation for reducing lead exposure. Importantly, ensure that families are aware that de-leading activities may create a temporarily more contaminated environment, so special care must be taken to ensure that children remain in a non-contaminated environment during this window (1,2); and
- emphasizing adequate nutrition, especially in young children and pregnant patients (1).

**Note:** for more detail, refer to the module *The paediatric environmental history.*

**References:**


**Figure:**

- © WHO / Blink Media - Amanda Mustard. A mother and her son consult with Dr Trakulsrichai at the Ramathibodi Poison Center in Bangkok. The teenager was admitted to the centre seven years prior to this photo for lead
poisoning after accidentally being shot in the leg.
Example key questions:
That health professionals can ask

- Is there any work done with lead in or around the home?
- Has anyone in the household ever been diagnosed with lead poisoning?
- Is there evidence of chewed or peeling paint on woodwork, furniture or toys?
- Does the child exhibit pica?
- Does the family use homemade or hand-crafted glazed ceramic items?
- Is there any information available or suspected local sources or uses of lead?
- Do outdoor play areas contain bare soil that may be contaminated?
- Where does the drinking water come from?

Health professionals can ask their patients and families key questions that can help in detecting sources of lead exposure and identifying at-risk children. Key questions can help to build a paediatric environmental history and assess whether a child or children should be further screened for lead exposure or poisoning. These questions must be context specific to each patient.

Examples of questions that can be asked include (1):

- Is there any work done with lead – for example car battery recycling, radiator repairs or metal recuperation – in or around the home?
- Has anyone in the household ever been diagnosed with lead poisoning?
- Is there evidence of chewed or peeling paint on woodwork, furniture or toys?
- Does the child exhibit pica?
- Does the family use homemade or hand-crafted glazed ceramic items?
- Is there any information available or suspected local sources or uses of lead?
- Do outdoor play areas contain bare soil that may be contaminated?
- Where does your drinking water come from? Tap water, bottled water or well water? Are you aware of any water contamination or are you aware if your water supply has been tested for lead?

There are many questions that can be asked to investigate the source or sources of a child’s lead exposure. More example questions can be found in references (1) and (2).

Note: if you have examples of questions that have been useful in your context or region they can be used here.

References:
Lead prevention policies at the national level are essential to reducing children’s exposure to lead and preventing irreversible neurological damage and disease. This graph shows the declining trend in blood lead levels in children aged 1–11 years in the United States of America over the period 1976–2016, following the implementation of lead poisoning prevention policies (1). These measures included restricting lead in:

- paint
- gasoline for cars and lorries
- plumbing and solder.

The bars represent prevalence of children with blood lead levels greater than 5 micrograms per decilitre (µg/dL) (shown in dark grey on the graph) and greater than 10 µg/dL (light grey); the lines represent population mean blood lead levels in children aged 1–3 years (solid line) and 6–11 years (dotted line).

In European countries, the earlier introduction of unleaded gasoline also tracked with the earlier reduction of children’s blood lead levels. The rapid and intense decrease in blood lead levels highlights the major impact that lead policy interventions can achieve (2).

**Note on the graph:** estimated prevalence (y-axis) is plotted on the log-10 scale. NHANES (x-axis) stands for the National Health and Nutrition Examination Survey, the data source for these values which estimate lead exposure in the United States of America population via blood lead level measurements (1).

**Note:** if you have an example of a lead policy intervention that has been used to reduce blood lead levels in children it can be used here.

**References:**

**Figure:**
Lead prevention policies at the national level are essential to reducing children’s exposure to lead and preventing irreversible neurological damage and disease. Below are some of the key policy ideas that countries can develop to reduce childhood lead exposure.

Every country has now eliminated lead in gasoline, although it continues to be used in some aviation fuel. Lead paint is now one of the primary sources of children’s exposure in the home. Banning lead in paint is an important national policy goal (more information on efforts to ban lead from paint are on slide 37)(1).

Eliminating lead in consumer products is an important policy goal. Products used by children, such as toys, are of particular concern. Children are also exposed to products such as packaging for foods and beverages with lead solder, pottery for cooking and eating with lead glazing, and cosmetics. Lead in traditional medicines should likewise be identified and eliminated (1).

Controlling lead in water can be achieved through a variety of ways. Removal of plumbing and fittings that contain lead is ideal. However, removal can be costly and corrosion control and minimization of solubilization of lead in water distribution systems can also be pursued (1).

Industrial lead use should be managed by measures that protect workers and communities from environmental hazards. Occupational standards that prevent exposure and monitor blood lead concentrations maintain the health of workers; the International Labour Organization (ILO) has promoted such standards since 1919. Industrial hygiene measures, especially in electrical and electronic waste (e-waste) and lead-acid battery processing, are necessary in production, management, disposal and recycling of lead-containing materials. Informal recycling should be discouraged. Past industrial sites must be identified and decontaminated (2).

In some areas of the world, informal recycling of e-waste and batteries is a major source of environmental lead contamination and childhood lead exposure. Policies must address both child labour in this industry and enhance lead pollution controls to prevent outbreaks of childhood lead poisoning associated with unmanaged recycling activities (3,4).

International Lead Poisoning Prevention Week (ILPPW), which occurs annually in October, is a week of action to raise awareness of the unacceptable risks of lead exposure and the need for action. The goals of ILPPW include raising awareness about lead poisoning, highlighting efforts to reduce lead exposure in different countries and among groups, and urging further regulatory action on lead. All partners, from governments to health organizations, are encouraged to organize campaigns during ILPPW (5).
Note: for more information on e-waste see the module *Electrical/ electronic waste and children’s health*.

References:

Photo:
• © WHO.
The Global Alliance to Eliminate Lead Paint (the Lead Paint Alliance) is a collaborative initiative focused on phasing out lead in paint. It is led by the World Health Organization (WHO) and the United Nations Environment Programme (UNEP). It includes diverse stakeholders from governments and intergovernmental organizations to regional bodies, philanthropic organizations, academia and media. Its mission was affirmed at the Second Session of the International Conference on Chemicals Management (ICCM2) in 2009 and the Fourth Session of the International Conference on Chemicals Management. The Lead Paint Alliance was launched in 2011 with demands from the World Summit on Sustainable Development (1–3).

Many people are unaware of the dangers and continued use of lead in paint. The Lead Paint Alliance promotes international actions to prevent and eliminate lead in paints. These measures protect future generations from one of the most important sources of lead exposure. Safer alternatives exist to lead for pigment and driers in paint at no increase in cost. Governments need to take action by restricting the use of lead in paint and requiring paint in public buildings, notably schools, to be lead-free. The goal of the Lead Paint Alliance is to ensure that all countries have legally-binding controls ensuring that lead concentration in paint is no more than 90 parts per million (ppm). This is the lowest and technically feasible regulatory limit that has been set in countries due to lead contamination of ingredients used by paint manufacturers (1,4). Lead in paint can persist for many decades. It is critically important that lead is phased out of paint to prevent continued harm.

As of September 2022, 87 countries, or 45% of all countries, had legally-binding controls on lead in place. In addition, the Lead Paint Alliance has been actively assisting over 60 countries to develop lead paint laws (5). It is also important to note that despite existing lead in paint laws, legacy contamination in housing and schools can still be an issue. For example, houses built in the United States of America prior to 1978 are likely to have some lead-based paint that may expose children as it peels, cracks and deteriorates (6).

**Note:** visit [https://www.who.int/data/gho/data/indicators/indicator-details/GHO/legally-binding-lead-controls](https://www.who.int/data/gho/data/indicators/indicator-details/GHO/legally-binding-lead-controls) to check the status of lead paint in your country. Check local or national guidance to see if lead paint was used in houses or schools in your country, and when it was phased out.

**Reference:**


Figure:
• © WHO.
The final section of this module highlights two case studies involving lead poisoning in children, including methods that were used to identify sources and treatment.

If you have appropriate regional or local case studies that display lead interventions, you can use them here.

Photo:
• © WHO / Diego Rodriguez. Young girls sitting together with a person wearing an elephant mask during celebrations of the Shivaratri Festival in the city of Pushkar, India. This photo depicts young girls in festival attire, including eye makeup. Cosmetics, such as kohl, may contain lead and have led to toxic effects in children.
A 17-month-old boy was admitted to hospital with:
• lethargy
• vomiting
• encephalopathy.

The boy also had a very high blood lead level of 130 micrograms per decilitre (µg/dL). Upon investigation, the child had a history of known lead poisoning. The child had also gone through one outpatient treatment of chelation due to persistently high blood lead levels.

Additionally, the child and his family were living in a house which had undergone de-leading of old paint only three days prior to the admission into hospital. The family was advised that they must find elsewhere to stay during the procedure. However, lack of alternate shelter forced this family to remain in the home while it was de-leaded over a period of four days (1).

Reference:
Over the following months, the child was readmitted to hospital for chelation therapy twice and also underwent outpatient chelation therapy twice, as is shown in the figure.

In this case, an existing chronic exposure to lead became acute poisoning during the process of source mitigation (de-leading). The process of de-leading can cause extreme increases in lead levels as particles are released into dust. As seen in this figure of the child’s blood lead level over time, de-leading precipitated the most acute elevation in the patient’s blood lead level (130 micrograms per decilitre (µg/dL)). Additionally, improper de-leading can leave dust in carpets, furniture and surroundings, resulting in continued exposure.

In this case, the child continued to experience exposure to lead which resulted in a blood lead level that persistently remained 40–50 µg/dL. Eliminating the source of lead exposure is vital in the treatment of lead poisoning.

**Note on the figure:** time in months is displayed in month/year format.

**Reference:**


**Figure:**

A 5-year-old boy presents with clinical symptoms of hyperactivity and abdominal colic. The boy’s mother mentions that until recently she worked in an automobile repair workshop, where the boy often came to play after school (1).

On physical examination the boy now shows (1):
• impaired growth, with height and weight in the 10th percentile
• hearing acuity below the normal range
• short attention span
• delayed speech development
• poor social skills.

The child’s clinical history from one-year prior describe an active child who had met some developmental milestones but note that his language and speech abilities were delayed. Additionally, one-year prior laboratory tests show (1):
• hematocrit was diminished at 30%
• hemoglobin at 10 g/dL
• low ferritin
• peripheral blood smear: hypochromia, microcytosis.

The child was also diagnosed with mild iron deficiency anaemia and completed a 3-month course of iron supplements (1).

Based on the prior clinical history of the boy, his mother’s working history and the symptoms that he is currently presenting you decide to investigate the child for lead exposure. This decision is based upon your knowledge that:
• the impairment in growth and neurodevelopment suggest possible lead exposure;
• the previously diagnosed mild iron deficiency anaemia may have been associated with lead exposure (1,2).

Note: please note this is a case study based on examples from references (1) and (2). Any similarities with real people, events or locations is purely coincidental. If you have a local case study examining lead exposure in children and how it was diagnosed and managed, you can use it here.

References:
2. Case studies in environmental medicine: lead toxicity. Atlanta: Agency for Toxic Substances and Disease Registry,

Photo:
• © WHO/ Aphaluck Bhatiasei. Cars on a road in Monrovia, Liberia.
Laboratory test are ordered to assess the blood lead level of the boy.

The laboratory test finds that:

- the boy had a blood lead level of 50 micrograms per decilitre (µg/dL).

Based upon the blood lead level of the child, what diagnosis, treatment, management and follow-up do you suggest for this boy?

- Due to the age of the child and his blood lead level, he can be diagnosed with lead poisoning.
- Chelation therapy is recommended due to the boy’s age and his blood lead level. Either oral or parenteral chelation therapy is recommended and may be determined by local availability. If possible, ensure that chelation is administered by or in consultation with an experienced practitioner.
- Counsel the family on eliminating the lead exposure. This may include:
  - alerting the local appropriate environmental or health authority who may be able to undertake cleaning of the boy’s house;
  - informing the family that they need ensure their house is cleaned and directing them towards appropriate services;
  - educating the boy and his family on good hygiene practices;
  - educating the boy and his family on possible sources of lead in the environment and how to avoid it;
  - educating the boy and his family on staying away from the automobile workshop where his mother used to work;
  - ensuring that the family understand that without eliminating the source of lead, treatment methods will be of little use.
- Assess the nutritional status of the child, including both iron and calcium deficiency. Iron deficiency can lead to greater absorption of lead. Treating a child for any nutritional deficiency should be done according to locally available guidance and resources.
- Follow-up with the boy should be done within 2–4 weeks following chelation therapy, including re-evaluating his blood lead level.
- Inform the appropriate local authority of the case.

Note: please note this is a case study based on examples from references (1) and (2). Any similarities with real people, events or locations is purely coincidental. If you have a local case study examining lead exposure in children and how it was diagnosed and managed, you can use it here.
Note: use the animation ideas in this slide to engage the learners to discuss diagnosis, treatment, management and follow-up options based upon what has been learned throughout this module.

References:
The World Health Organization (WHO) has developed and collaborated with multiple agencies to create a range of tools and resources to guide the management of childhood lead poisoning and exposure, and to develop legislation and regulation that is protective of child health:

- **WHO guidelines for clinical management of exposure to lead** assists physicians in making decisions about the diagnosis and treatment of lead exposure for individual patients and in mass poisoning incidents (1).
- **Brief guide to analytical methods for measuring lead in blood** provides an overview of commonly used analytical methods for measuring the concentration of lead in blood (2).
- **The paediatric environmental history** allows health care providers to incorporate into the clinical records a description of environmental conditions, behaviours and risk factors relevant to a child’s health (3).
- **Guidelines for drinking-water quality** is an authoritative basis for the setting of national regulations and standards for water safety in support of public health (4).
- **Global elimination of lead paint** is for officials in government who have a role in regulating lead paint, to provide them with concise technical information on the rationale and steps required to phase out lead in paint (5).

**References:**

More information and recommended reading

For more information on children and lead see the additional training modules:

- Air pollution package
- Children and chemicals
- Children and neurodevelopmental behavioural intellectual disorders (NDBID)
- Children are not little adults
- Electrical/ electronic waste and children’s health
- The paediatric environmental health
- Water

Recommended reading on lead and child health:

- Childhood lead poisoning
- Preventing disease through healthy environments: exposure to lead: a major public health concern
- Recycling used lead-acid batteries: health considerations
- Toxic truth: children’s exposure to lead pollution undermines a generation of future potential

For more information on children and lead, see the additional modules within the World Health Organization (WHO) training package on children’s environmental health for the health care sector (1). The following modules may be of particular interest:

- Air pollution package – this includes Ambient air pollution, Childhood respiratory diseases linked to the environment, Household air pollution, Indoor air pollution and Second-hand smoke
- Children and chemicals
- Children and neurodevelopmental behavioural intellectual disorders (NDBID)
- Children are not little adults
- Electrical/ electronic waste and children’s health
- The paediatric environmental health
- Water.

To read more on lead and children see the below suggested references:

- Childhood lead poisoning (2)
- Preventing disease through healthy environments: exposure to lead: a major public health concern, second edition (3)
- Recycling used lead-acid batteries: health considerations (4)
- Toxic truth: children’s exposure to lead pollution undermines a generation of future potential (5).

References:

Acknowledgements for current version

Initial edits by: Yona Amitai (Israel) and Carolina Juanena (Uruguay).

Second draft prepared by: Gloria Chen (WHO Consultant) and Julia F. Gorman (WHO consultant).

Working group for current version: Marie-Noël Bruné Drisse (WHO), Gloria Chen (USA), Julia F. Gorman (WHO consultant), Amalia Laborde (Uruguay), Katherine M. Shea (USA).

Reviewers: Maria Brown (UNICEF), David Carpenter (USA), Elena Jarden (WHO), Patrick Hicks (Canada), Lesley Onyon (WHO).

Final review, technical and copy-editing: Julia F. Gorman (WHO consultant).

WHO CEH training project coordinator: Marie-Noël Bruné Drisse (WHO)

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First draft prepared by Yona Amitai (Israel).

With the advice of the Working Group Members on the Training Package for the Health Sector: Cristina Alonzo (Uruguay); Stephan Boese-O’Reilly (Germany); Stephania Borgo (ISDE, Italy); Irena Buka (Canada); Ernesto Burgio (ISDE, Italy); Lilian Corra (Argentina); Ruth A. Etzel (WHO); Ligia Fruchtengarten (Brazil); Amalia Laborde (Uruguay); Leda Nemer (WHO/EURO); Jenny Pronczuk (WHO); Roberto Romizzi (ISDE, Italy); Christian Schweizer (WHO/EURO); Katherine M. Shea (USA).

Reviewers: D. Beltramino (Argentina), Stephan Boese O’Reilly (Germany), Irena Buka (Canada), Ruth A. Etzel (USA), Amalia Laborde (Uruguay), Jenny Pronczuk (WHO), Katherine M. Shea (USA).

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Editing assistance: Kathy Prout (WHO).

WHO CEH Training Project Coordination Ruth A. Etzel and Marie-Noël Bruné Drisse