Educational course

Mercury and human health
Educational course

Mercury and human health
Abstract

Mercury is toxic for humans and has potential to cause multiple adverse health effects. The adoption and entry into force of the Minamata Convention on Mercury have opened new opportunities for facilitating actions aimed at minimizing and preventing the negative impact of mercury and its compounds on human health. Sharing of knowledge and expertise is needed to assist the health sector in the implementation of the Minamata Convention and the related resolution of the Sixty-seventh World Health Assembly. This educational course was developed to support the training of public health and health-care professionals, medical and other allied students and professionals, and decision-makers in the health and environmental sectors. It compiles information on human exposure to different types of mercury and their health effects, the use of mercury in the health sector, and the policy and technical documents guiding preventive actions at a national level.

KEYWORDS
Mercury – adverse effects, mercury compounds – adverse effects, environmental exposure, occupational exposure, chemical safety


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Infographic and design: Infographic Pro GmbH, Germany

Layout: Daniela Berretta, Italy

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Acknowledgements

The WHO Regional Office for Europe gratefully acknowledges co-authors Stephan Bose-O'Reilly and Paul Schutzmeier of the Institute and Clinic for Occupational, Social and Environmental Medicine, University Hospital, Ludwig Maximilian University of Munich, Germany, for preparing this publication.

The Regional Office and the co-authors highly appreciate the final revision of the educational course provided by:

- Ellen Rosskam, Chemical Safety and Health Unit, Department of Environment, Climate Change and Health, WHO;
- Benoit Varenne, Department of Noncommunicable Diseases, WHO; and
- Carolyn Vickers, Chemical Safety and Health Unit, Department of Environment, Climate Change and Health, WHO.

This publication was prepared with financial support from the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.
# Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>ACGIH</td>
<td>American Conference of Governmental Industrial Hygienists</td>
</tr>
<tr>
<td>AMAP</td>
<td>Arctic Monitoring and Assessment Programme</td>
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<tr>
<td>ASGM</td>
<td>artisanal small-scale gold mining</td>
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<tr>
<td>BGSU</td>
<td>Bowling Green State University</td>
</tr>
<tr>
<td>BRI</td>
<td>Biodiversity Research Institute</td>
</tr>
<tr>
<td>CNS</td>
<td>central nervous system</td>
</tr>
<tr>
<td>COP</td>
<td>Conference of Parties</td>
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<tr>
<td>DHA</td>
<td>docosahexaenoic acid</td>
</tr>
<tr>
<td>EMEA</td>
<td>European Medicines Agency</td>
</tr>
<tr>
<td>EPA</td>
<td>eicosapentaenoic acid</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
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<tr>
<td>FAO</td>
<td>United Nations Food and Agriculture Organization</td>
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<tr>
<td>GACVS</td>
<td>Global Advisory Committee on Vaccine Safety</td>
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<tr>
<td>GEF</td>
<td>Global Environment Facility</td>
</tr>
<tr>
<td>GI</td>
<td>gastrointestinal</td>
</tr>
<tr>
<td>HCWH</td>
<td>Health Care Without Harm</td>
</tr>
<tr>
<td>HEAL</td>
<td>Health and Environment Alliance</td>
</tr>
<tr>
<td>Hg⁰</td>
<td>elemental (metallic) mercury</td>
</tr>
<tr>
<td>Hg²⁺</td>
<td>inorganic mercury</td>
</tr>
<tr>
<td>IATP</td>
<td>Institute for Agriculture and Trade Policy</td>
</tr>
<tr>
<td>ILO</td>
<td>International Labour Organization</td>
</tr>
<tr>
<td>IPEN</td>
<td>International Pollutants Elimination Network</td>
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<tr>
<td>IQ</td>
<td>intelligence quotient</td>
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<tr>
<td>LCn3PUFAs</td>
<td>long-chain n-3 polyunsaturated fatty acids</td>
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<tr>
<td>MeHg</td>
<td>methylmercury</td>
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<tr>
<td>PPE</td>
<td>personal protective equipment</td>
</tr>
<tr>
<td>ppm</td>
<td>parts per million</td>
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<tr>
<td>PTWI</td>
<td>provisional tolerable weekly intake</td>
</tr>
<tr>
<td>SCCS</td>
<td>Scientific Committee on Consumer Safety</td>
</tr>
<tr>
<td>SCENIHR</td>
<td>Scientific Committee on Emerging and Newly Identified Health Risks</td>
</tr>
<tr>
<td>SCHER</td>
<td>Scientific Committee on Health and Environmental Risks</td>
</tr>
<tr>
<td>SCOEL</td>
<td>Scientific Committee on Occupational Exposure Limits</td>
</tr>
<tr>
<td>STEL</td>
<td>short-term exposure level</td>
</tr>
<tr>
<td>TLV</td>
<td>threshold limit value</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>---------</td>
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<tr>
<td>TWA</td>
<td>time-weighted average</td>
</tr>
<tr>
<td>UNEP</td>
<td>United Nations Environment Programme</td>
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<tr>
<td>USFDA</td>
<td>United States Food and Drug Administration</td>
</tr>
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</table>
Introduction

The toxic effects of mercury on human health have long been known. Exposure to all forms of mercury, including metallic, organic and inorganic mercury, can cause health disorders. Of particular concern is the toxicity of mercury for the developing organism, as the neurodevelopmental effects of exposure to (methyl)mercury in utero and in early life have been well documented (1). It is therefore crucial to create a critical mass of experts developing and implementing effective measures aimed at preventing the adverse effects of mercury.

The adoption of the Minamata Convention on Mercury in 2013 and its entry into force in 2017 marked an important step in controlling anthropogenic releases of mercury throughout its life cycle to better protect human health and the environment (2). Reaffirming the commitment of the health sector to play an important role in the implementation of the Convention, the Sixty-seventh World Health Assembly welcomed the formal adoption of the Convention and agreed on priority actions for ministries of health and WHO (3).

Support for building adequate capacities in the health sector at a national level is particularly needed, given that the health sector both uses mercury and is responsible for diagnosing, treating and preventing the health effects of mercury. The sector’s role in prevention is well recognized, and includes identifying the health effects and sources of exposure to mercury; setting reference levels of mercury in environmental media and food; phasing out mercury-containing devices in the health sector and phasing down the use of dental amalgams; and developing strategies, tools for action and guidance to support decision-making process. All of these aspects are covered by this educational course.

Content and structure of the course

The content of the educational course is based on WHO and United Nations Environment Programme (UNEP) documents and reports, as well as the latest scientific publications. The information is presented in the following four modules.

• Module 1. Mercury in the environment: human exposure to mercury
• Module 2. Health effects of mercury
• Module 3. Minamata Convention on Mercury and the health sector’s role in its implementation
• Module 4. Mercury in the health sector

The course includes 163 slides in PDF format accompanied by explanatory text. The PowerPoint version is available to interested users upon request. Please email euroceeh@who.int for more information.

References:

MERCURY AND HUMAN HEALTH

Educational course

MODULES

1. Mercury in the environment: human exposure to mercury
2. Health effects of mercury
3. The Minamata Convention on Mercury and the health sector’s role in its implementation
4. Mercury in the health sector
KEY FACTS

- Mercury is a naturally occurring element that is found in air, water and soil.
- Exposure to mercury – even small amounts – may cause serious health problems, and is a threat to the development of the child in utero and early in life.
- Mercury may have toxic effects on the nervous, digestive and immune systems, and on lungs, kidneys, skin and eyes.
- People are mainly exposed to methylmercury, an organic compound, when they eat fish and shellfish that contain the compound.
- Ethylmercury is used as a preservative in some vaccines and does not pose a health risk.
- Mercury is considered by WHO to be one of the top 10 chemicals or groups of chemicals of major public health concern.

References:

MERCURY IN THE ENVIRONMENT: HUMAN EXPOSURE TO MERCURY

OUTLINE

FORMS OF MERCURY
- Sources of mercury
- Mercury life cycle and fate in the environment
- Bioaccumulation

HUMAN EXPOSURE TO MERCURY
- Environmental exposure
- Occupational exposure
As a chemical element, mercury has also been called colloidal mercury, liquid silver, quicksilver or hydrargyrum.

It has:
- a molecular weight of 200.59 u
- a melting point of \(-38.87 \, ^\circ C\)
- a boiling point of 356.72 °C
- a density of 13.534 g/cm³ at 25 °C.

- This is the most volatile form of mercury.
- It has a vapour pressure of 0.3 Pa at 25 °C and transforms into the vapour phase at typical room temperatures.
- It is relatively insoluble in water (56 µg/L at 25 °C).
- It is soluble in lipids.

References:

There are three forms of mercury: elemental (or metallic) mercury, inorganic mercury and organic mercury. Their use, release, presence in the environment, and physicochemical and toxicological characteristics differ in terms of sources of exposure, health effects and vulnerable populations. This course addresses the different forms of mercury.

References:


### FORMS OF MERCURY AND THEIR CHARACTERISTICS

<table>
<thead>
<tr>
<th>Mercury form</th>
<th>Sources into environment</th>
<th>Exposure pathways</th>
<th>Main excretion pathways</th>
<th>Health endpoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elemental (metallic) mercury</td>
<td>Natural: volcanoes, rock weathering</td>
<td>Inhalation</td>
<td>Urine Faeces</td>
<td>Central and peripheral nervous systems, kidneys, lungs</td>
</tr>
<tr>
<td>Hg⁰</td>
<td>Anthropogenic: mining of mercury, gold and other metal; fuel combustion; industrial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>processes; waste incineration; spills (for example, broken products)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Inorganic mercury Hg²⁺</td>
<td>Natural: can occur naturally in the environment</td>
<td>Ingestion Dermal</td>
<td>Urine</td>
<td>Central nervous system, kidneys, gastrointestinal tract, immune system, skin (acrodynia in children)</td>
</tr>
<tr>
<td></td>
<td>Anthropogenic: some industrial processes and production of other chemicals; cosmetics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(skin-lightening creams); ritual and folk medicine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic mercury MeHg (methylmercury)</td>
<td>Environmental conversion</td>
<td>Ingestion</td>
<td>Parenteral Transplacental</td>
<td>Faeces</td>
</tr>
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<td></td>
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</tbody>
</table>

This table summarizes information about different forms of mercury (inorganic and organic) and their sources into the environment. It also summarizes differences related to exposures to different forms of mercury and their health effects. Because of the complexity of mercury chemistry, it is often easier to discuss each form separately. The following slides discuss sources by form and briefly outline the common routes of human exposure, toxicokinetics and major systems damaged by excess exposure.

Each of mercury's three forms – elemental (or metallic), inorganic (for example, mercuric chloride) and organic (for example, methyl- and ethylmercury) – have different toxicity profiles with different implications for children's health and development.

References:


Mercury is a heavy metal – an element – and therefore cannot be created or destroyed. Natural sources of environmental emissions are volcanic eruptions, rock weathering and natural combustion. As with most metals, mercury can exist in different forms. Once it has entered the environment, it cycles between air, land and water until it is eventually removed from the system through burial in deep ocean sediments or lake sediments, or through entrapment in stable mineral compounds. The image demonstrates natural and anthropogenic emissions and re-emissions.

According to the 2018 Global Mercury Assessment, mercury sources are grouped as follows:

- natural sources released due to the natural mobilization of naturally occurring mercury from the Earth’s crust through, for example, volcanic activity, geothermal activity or rock weathering (mercury deposited in plants can also be re-emitted and remobilized during forest fires);
- current anthropogenic (human activity-related) releases from the mobilization of mercury impurities in raw materials (including fossil fuels – especially coal but also gas and oil);
- current anthropogenic releases from mercury intentionally used in products and processes (releases during manufacturing, leaks, and disposal or incineration of spent products); and
- remobilization of historic anthropogenic releases previously deposited in soils, sediments, waters, landfills or waste piles.

References:

This graph summarizes some of the many ways in which mercury can enter the atmosphere, water and soil. Human activity is the main cause of mercury releases, particularly coal-fired power stations, residential coal burning for heating and cooking, industrial processes, waste incineration, and mining for mercury, gold and other metals.

Once in the environment, bacteria can transform mercury into methylmercury. Methylmercury then bioaccumulates in fish and shellfish. Bioaccumulation occurs when an organism absorbs a substance at a faster rate than the substance is catabolized or excreted, resulting in higher concentrations of the substance in the organism than in its surroundings.

People may be exposed to mercury in any of its forms under different circumstances. The greatest proportion of emissions is produced by artisanal small-scale gold mining (ASGM) (37%), combustion of fossil fuel (24%) and metal production (18%). Altogether, these account for 75% of total anthropogenic emissions.

References:


<table>
<thead>
<tr>
<th>Anthroponic Sources of Mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Artisanal and small-scale gold mining (ASGM)</td>
</tr>
<tr>
<td>- Biomass burning (domestic, industrial and power-plant energy production)</td>
</tr>
<tr>
<td>- Cement production (raw materials and fuel, excluding coal)</td>
</tr>
<tr>
<td>- Cremation emissions</td>
</tr>
<tr>
<td>- Chlor-alkali production (mercury process)</td>
</tr>
<tr>
<td>- Large-scale gold production</td>
</tr>
<tr>
<td>- Mercury production</td>
</tr>
<tr>
<td>- Oil refining</td>
</tr>
<tr>
<td>- Non-ferrous metal production (primary aluminium, copper, lead, zinc)</td>
</tr>
<tr>
<td>- Pig iron and steel production (primary)</td>
</tr>
<tr>
<td>- Secondary steel production</td>
</tr>
<tr>
<td>- Stationary combustion of coal, gas and oil (domestic/residential use, transportation, industrial use, power plants)</td>
</tr>
<tr>
<td>- Vinyl chloride monomer (mercury catalyst)</td>
</tr>
<tr>
<td>- Mercury-containing waste</td>
</tr>
<tr>
<td>- Waste incineration (controlled burning, including burning waste for energy, burning medical waste, burning corpses with amalgam)</td>
</tr>
</tbody>
</table>

References:

Most mercury in the modern environment comes from human activities and heavy industry. There is dramatic evidence that the problem of methylmercury contamination of our food is of our own making.

This image depicts the composite ice core record from Wyoming, United States of America, for 1720–2000. It shows the dramatic increase from baseline mercury levels that have occurred due to human activity: 70% of the mercury released in the last 100 years has been anthropogenic. A number of peaks in mercury releases are attributed to mining during the Gold Rush in the middle of the 19th century, the increase of manufacturing during the Second World War, and industrialization since 1900.

References:

In addition to emissions from various sources, mercury can be remobilized and re-emitted into the air. Remobilization occurs when mercury that had been taken out of atmospheric circulation is released again. For example, mercury accumulated in soil or sediment may be remobilized by rain or floods and then enter the aquatic system.

Re-emission occurs when mercury that has been deposited from the air onto surfaces enters the air again. Mercury taken up by vegetation can also be re-emitted to the atmosphere during forest fires or biomass burning. About half of re-emissions can reasonably be considered anthropogenic.

References:

MERCURY IN ENVIRONMENTAL MEDIA

Mercury and its compounds can be found in all environmental media:

- air
- soil
- biota
- surface and ground waters
- sediments

References:

Mercury can be transformed into more toxic methylmercury in waters

- **In waters** (marine and fresh), mercury can be transformed into methylmercury, which is more toxic for humans.

- **Metallic mercury** is heavy and not easily transported through watersheds, but it becomes more mobile following its association with small particles or the formation of organic mercury.

- **Direct spills** into aquatic environments can cause significant local contamination that can lead to elevated population exposures, for example, through the consumption of fish.

- **Releases** into waters are of a greater local concern than contamination solely due to atmospheric mercury emissions.

References:


The pathways and fate of mercury in aquatic environments are important because inorganic mercury is converted into methylmercury in waters, sediments and wetland soils. Methylmercury is toxic and concentrates in animals. The majority of human exposure to mercury and its health risks are from the consumption of marine and freshwaters foods.

The major processes of mercury cycling are generally similar for all aquatic systems. Inorganic mercury in dissolved or particulate form is the dominant mercury form in most marine and fresh waters. Dissolved gaseous elemental mercury accounts for less than 30% of total mercury in water. Methylmercury is often present at trace levels, but in some settings may reach 30% of total mercury.

In freshwater and coastal environments, inorganic mercury is transformed into methylmercury primarily in sediments. In the open ocean, this conversion takes place largely at intermediate depths of 200–1000 m in the water column. Mercury is lost from aquatic systems in two ways:

• when inorganic mercury is reduced to elemental mercury, it can be re-emitted to the atmosphere; and
• when inorganic mercury binds to particulates in water, it can settle out rapidly and be buried in sediments.

Deep burial in ocean sediments is one of the major pathways by which mercury is removed from the biologically active environment.

The image shows how mercury concentration in organisms is magnified along the food chain. Mercury attached to aquatic sediments is subject to microbial conversion to methylmercury. Methylmercury enters the aquatic food chain in algae and microorganisms, reaching its highest concentration in fish-eating fish (for example, tuna and sharks) and fish-eating mammals and birds.

References:

HUMAN EXPOSURE TO MERCURY
All humans are exposed to some level of mercury. Most people are exposed to a low level, often through chronic exposure (continuous or intermittent long-term contact). However, some people are exposed to high levels of mercury, including through acute and/or chronic exposures. An example of an acute exposure would be mercury exposure during an industrial accident. Chronic exposure to high concentrations of methylmercury occurs in population with high fish consumption.

This figure illustrates environmental and occupational exposures to mercury that are associated with effects on human health throughout the body, including the nervous system, lungs, heart, liver, kidneys and skin, and effects on the health of fetuses. Children and infants are more susceptible to central nervous system damage and to the effect of mercury on neurodevelopment, with early lifetime exposure leading to long-term morbidity.

References:


## HUMAN EXPOSURE TO MERCURY AND ITS COMPOUNDS

<table>
<thead>
<tr>
<th>Mercury form</th>
<th>Source of exposure</th>
<th>Pathway of exposure</th>
<th>Absorption rate</th>
<th>Main excretion pathways</th>
<th>Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elemental $\text{Hg}^0$</td>
<td>Dental amalgam, air, accidental spills, worksites, food from contaminated sites</td>
<td>Inhalation</td>
<td>75–85%</td>
<td>Urine, faeces</td>
<td>Acute: lungs, gastrointestinal tract&lt;br&gt;Chronic: central nervous system, kidneys</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ingestion</td>
<td>Almost no absorption</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Dermal</td>
<td></td>
<td></td>
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<tr>
<td>Inorganic $\text{Hg}^{2+}$</td>
<td>Cosmetics, soaps</td>
<td>Ingestion</td>
<td>10–30%</td>
<td>Urine</td>
<td>Acute: gastrointestinal tract (vomiting, bloody diarrhoea), kidneys (nephritis)&lt;br&gt;Chronic: kidneys (kidney damage), central nervous system, skin (acrodynia in children), immune system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dermal</td>
<td>Can be high</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic $\text{MeHg}$</td>
<td>Food, mother during pregnancy</td>
<td>Ingestion</td>
<td>95%</td>
<td>Faeces (half life ($T_{1/2}$) is 45–70 days in adults)</td>
<td>Central nervous system, cardiovascular system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parenteral</td>
<td>100%</td>
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<tr>
<td></td>
<td></td>
<td>Transplacental</td>
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</table>

### References:


EXPOSURE PATHWAYS OF INORGANIC AND ELEMENTAL MERCURY

In this scheme depicts the toxicokinetics of mercury in the human body. Toxicokinetics are highly dependent on the form of mercury to which a person has been exposed.

**Inorganic mercury (Hg^{2+})**: Absorption of inorganic mercury through the digestive tract is comparatively low (up to 20% of the ingested dose); the majority of the ingested dose in humans is excreted in faeces. There is also evidence that inorganic mercury can be absorbed through the skin due to the use of cosmetics and skin-lightening soaps and creams. The absorbed portion remains in the body for a considerable length of time. Ionic mercury is excreted primarily through urine and faeces, and also through breastmilk.

**Elemental mercury (Hg^0)**: Ingested elemental mercury is not significantly absorbed by the human digestive system and is almost completely excreted in the faeces. In contrast, about 80% of inhaled elemental mercury is efficiently and rapidly absorbed through the lungs. Once absorbed, it is readily distributed through the body, crossing both placental and blood–brain barriers.

Elemental mercury is oxidized to inorganic mercury (Hg^{2+}) in most body tissues, and this ionic form of mercury can be retained for several weeks to several months, especially in the brain and kidneys. Elimination of Hg^0 occurs primarily via urine and faeces. Most of the mercury excreted in the urine occurs after the Hg^0 has been oxidized to ionic mercury. However, some of the Hg^0 can be excreted directly via urine and faeces before oxidation. Some Hg^0 is also excreted directly via exhaled air.

References:

EXPOSURE PATHWAYS OF METHYLMERCURY

Methylmercury (MeHg): Following exposure via ingestion, about 95% of methylmercury is rapidly and extensively absorbed through the gastrointestinal tract. This form of mercury is distributed throughout the body and easily penetrates the blood–brain and placental barriers. Part of the absorbed methylmercury is slowly converted to Hg²⁺ in the body. Methylmercury is excreted primarily via faeces and hair, with less than one third of total excretion occurring through urine. Methylmercury is also excreted through breastmilk, but at much lower levels.

References:

Human exposures can be assessed through the measurement of mercury concentrations in a number of different biological materials. The most commonly used biomarkers are the concentrations of mercury in hair, urine, blood and cord blood. Their selection can depend on factors such as the potential source of exposure, the mercury form and the exposure life stage. For example, exposure to methylmercury is reflected in the level of mercury in scalp hair. Once incorporated into hair, mercury does not return to the blood, providing a good long-term marker of exposure. Mercury in maternal hair (close to the scalp) is a proxy of fetal mercury exposure.

In contrast to hair, the presence of mercury in blood represents short-term exposure to organic and inorganic mercury, and does not provide information on long-term exposure and its variations. Total mercury concentrations in blood are proportional to methylmercury concentrations in hair. As a biomarker of prenatal exposure, mercury in cord blood is preferable, as it provides information on both the exposure of mothers and the prenatal exposures of their children.

Urine is the matrix of choice for assessing exposure to inorganic and elemental mercury. In the occupationally non-exposed population, the number of dental amalgam surfaces has been found to be associated with urinary mercury. In the general population, urinary mercury can also be elevated due to high fish consumption, demethylation and excretion of inorganic mercury and, partially, the limited excretion of methylmercury.

As a potential biomarker of prenatal exposure – the most vulnerable window for exposure to mercury – mercury in meconium has a weaker association with adverse health outcomes than mercury in cord blood.

Placental and fetal membranes have been confirmed to accumulate both inorganic and methylmercury during the pregnancy, but the significance of placental membranes as an indicator of exposure to either form of mercury is questionable. Recently, mercury levels in fingernails and toenails at parturition have been considered useful biomarkers for prenatal exposure of mothers and fetuses. However, more research is needed to decide on the use of biomarkers other than blood, cord blood, hair and urine.

References:


All people are exposed to mercury as a global pollutant, but levels of exposure differ depending on age, location, eating habits, occupation, etc. Data on background exposure in the general population have been obtained from national biomonitoring studies and from cross-sectional studies. Across the national biomonitoring studies, the majority of participants had blood mercury levels that fell below 5 µg/L, especially when reviewing the median.

In all countries, blood mercury levels in adults were approximately 2.1-fold higher than in children, and this varied across age groups. For example, in the second cycle (2009–2011) of the Canadian Health Measures Survey, median blood mercury levels in Canadians increased with age as follows: 0.21 µg/L for children aged 6–11; 0.19 µg/L for young people aged 12–19; 0.65 µg/L for adults aged 20–39; 1.0 µg/L for adults aged 40–59; and 1.2 µg/L for adults aged 60–79.

References:

There are success stories of reduction of exposure to mercury.

- The approximately two-fold decline in urinary mercury level in the United States of America over the past decade is likely due to improvements in dental materials and practices that reduce contamination from fillings in teeth.
- Similar trends have been observed in German children and among American dental professionals.
- Across the Arctic, mercury exposures remain elevated but have dropped over the past two decades, probably as a result of local dietary advisories and changing consumption patterns.
- In other places, including the Faroe Islands and the Seychelles, mercury exposures have decreased as a result of dietary consumption advisories.

Further efforts will continue to yield beneficial results.

The representative data from national biomonitoring studies can be used to gauge temporal trends, especially when are two or more comparable sampling periods. For blood mercury, combining the data from Canada, Czechia and the United States into a linear regression model showed annual decreases of approximately 0.026 µg/L or 2.25% (over 10 years, this would be a decrease of 0.26 µg/L, ~22.5%), with median blood mercury levels plateauing around 0.75 µg/L.

References:

### SOURCES OF OCCUPATIONAL EXPOSURE

- Mining
- Chlor-alkali industries
- Gold extraction (ASGM)
- Dentistry (amalgam fillings)
- Manufacturing and recycling of fluorescent lamps and other mercury-containing products
- Management of mercury-containing waste
- Manufacturing of scientific instruments
- Manufacturing of electrical control devices
- Laboratories
- Pharmaceutical industries
- Pesticide production and seed treatment

**References:**

OCCUPATIONAL EXPOSURE LIMITS (I)

Scientific Committee on Occupational Exposure Limits (SCOEL) (European Union):
- 8-hour time-weighted average (TWA): 0.02 mg/m³

American Conference of Governmental Industrial Hygienists (ACGIH):
- Elemental and inorganic forms: TWA: 0.025 mg/m³
- Alkyl compounds: TWA: 0.01 mg/m³; short-term exposure limit: 0.03 mg/m³
- Aryl compounds: TWA: 0.1 mg/m³

The time-weighted average (TWA) is the average exposure within the workplace to any hazardous contaminant or agent using the baseline of an eight-hours-per-day or 40-hours-per-week work schedule. The TWA reflects the maximum average exposure to the hazardous contaminants to which workers may be exposed without experiencing significant adverse health effects over the standardized work period.

The short-term exposure level (STEL) is the acceptable average exposure over a short period of time, usually 15 minutes as long as the TWA is not exceeded. The threshold limit value (TLV) is a level to which it is believed a worker can be exposed day after day for their working lifetime without adverse effects.

The European Union (EU) limits are:
- TLV: 0.025 mg/m³ as TWA (not classifiable as a human carcinogen)
- EU Occupational Exposure Limit: 0.02 mg/m³ as TWA
- MAK (inhalable fraction): 0.02 mg/m³.

According to ILO:
- TLV: 0.025 mg/m³, as TWA; (skin);
- MAK: (inhalable fraction): 0.02 mg/m³

References:

Concentrations of total mercury in air and urine at which effects are observed at a low frequency in workers subjected to long-term exposure to mercury vapour

<table>
<thead>
<tr>
<th>Observed effect</th>
<th>Mercury level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Air $^b$ (µg/m&lt;sup&gt;3&lt;/sup&gt;)</td>
</tr>
<tr>
<td>Objective tremor</td>
<td>30</td>
</tr>
<tr>
<td>Renal tubular effects; changes in plasma enzymes</td>
<td>15 $^c$</td>
</tr>
<tr>
<td>Nonspecific symptoms</td>
<td>10–30</td>
</tr>
</tbody>
</table>

a. These effects occur with low frequency in occupationally exposed groups. Other effects have been reported, but air and urine levels are not available.

b. The air concentrations measured by static air samplers are taken as a TWA, assuming 40 hours per week for long-term exposure (at least five biological half-times, equivalent to 250 days).

c. Calculated from urine concentration, assuming that a mercury concentration in air of 100 µg/m<sup>3</sup> measured by static samplers is equivalent to a mercury concentration of 300 µg/L in the urine.

Urine is the most frequently used indicator medium for assessing body burden following chronic exposure to mercury vapour. The mercury concentration in approximately 98% of all urine samples from people without known exposure to mercury is less than 5 µg/L. Mild proteinuria may occur in the most sensitive adults at urine values of 50–100 µg/L following chronic occupational exposures. Objective tremor and psychomotor disturbances usually appear at urine values of more than 300 µg/L, but no clear threshold has been established. Most effects of mercury vapour usually disappear within a few months after cessation of exposure.

References:


Humans can be exposed to mercury from:

- air, water and soil
- consumer products
- food

References:

EXPOSURE BY AIR
(MERCURY VAPOUR)

- In areas remote from industry, atmospheric levels of mercury are about 2–4 ng/m³. They are about 10 ng/m³ in urban areas.
- The daily average amount absorbed from the atmosphere as a result of respiratory exposure is about 32–64 ng in remote areas, and 160 ng in urban areas.
- This exposure is marginal compared to exposure from dental amalgam: the estimated average daily absorption from dental fillings varies between 3000 ng and 17 000 ng.
- The estimated guideline for mercury concentration in air is 1 µg/m³.

People can be exposed to all forms of mercury in air – metallic, inorganic and methylmercury. However, the level of exposure and risk for the general population is usually quite low.

References:

EXPOSURE BY AIR (INORGANIC MERCURY)

- Cationic forms of inorganic mercury are retained in the lungs about half as efficiently as inhaled mercury vapour.
- The estimated guideline providing adequate protection against renal tubular effects would be two times higher than the guideline for mercury vapour.
- A guideline for inorganic mercury vapour of 1 μg/m³ as an annual average has been established.

References:

EXPOSURE BY AIR
(METHYLMERCURY)

- Inhalation of this form of mercury, if it is present in air, makes a negligible contribution to total human intake.
- Exposure to airborne methylmercury is 2–3 orders of magnitude below the food-related daily intake and is regarded as insignificant.
- As such, it does not seem appropriate to set air quality guidelines for methylmercury compound.

References:

Almost all mercury in uncontaminated drinking-water is thought to be in the form of inorganic mercury (Hg\(^{2+}\)).

It is unlikely that there is any direct risk from intake of organic mercury compounds in drinking-water.

The guideline value for drinking water is 6 µg/L.

References:

Mercury is present in a number of products that many of us use, such as thermometers, sphygmomanometers, skin-lightening cosmetics, electronics, fluorescent lightbulbs and batteries, as well as in foods we eat, such as contaminated fish.

References:


Methylmercury is the major source of mercury body burden worldwide. Predatory fish can contain high levels of methylmercury. Cooking does not eliminate mercury from fish muscle.

Long-lived predatory fish can contain high levels of methylmercury, which is incorporated into their muscle from polluted marine or fresh waters. Cooking does not eliminate mercury from fish muscle.

Methylmercury is the major source of body burden in adults and children worldwide. People are exposed directly by eating contaminated fish, and fetuses are exposed transplacentally when mothers have high methylmercury blood levels. Methylmercury also passes into breastmilk, although at very low levels; most methylmercury in blood is lightly bound to red blood cells and not available for transport into breastmilk. Of the three routes, transplacental exposure is potentially the most dangerous.

References:


This map shows the global distribution of mercury risk category of contamination of marine mammals, sharks and allies.

References:


Populations at higher risks include women of reproductive age, pregnant or nursing women, breastfed infants and young children. Convincing evidence of adverse neurological/neurodevelopmental outcomes in infants and young children associated with methylmercury exposure during fetal development due to maternal fish consumption during pregnancy has been observed. Possible evidence for cardiovascular harm and other adverse effects (for example, immunological and reproductive effects) associated with methylmercury exposure has also been documented.

However, convincing evidence of beneficial health outcomes from fish consumption also exists. These benefits include a reduction in risk of cardiac death and improved neurodevelopment in infants and young children when fish is consumed by the mother before and during pregnancy.

The health attributes of fish are likely due in large part to long-chain n-3 polyunsaturated fatty acids (LCn3PUFAs). Fish also contain other nutrients (for example, protein, selenium, iodine, vitamin D, choline and taurine) that may contribute to health benefits. The health effects of consuming fish may be greater than the sum of their individual constituents.

References:

RISKS
- Populations at higher risk are:
  - women of reproductive age;
  - pregnant or nursing women;
  - breastfed infants; and
  - young children.
- Neurological/neurodevelopmental outcomes in infants and young children can be associated with methylmercury exposure during fetal development due to maternal fish consumption during pregnancy.

BENEFITS
- Beneficial health outcomes from fish consumption include:
  - a reduction in the risk of cardiac death; and
  - improved neurodevelopment in infants and young children when fish is consumed by the mother before and during pregnancy.
- The health attributes of fish are likely due in large part to long-chain n-3 polyunsaturated fatty acids (LCn3PUFAs).
- The health effects of fish consumption may be greater than the sum of the individual constituents of fish.

References:
METHYLMERCURY IN FISH: RECOMMENDED THRESHOLDS

The maximum recommended intake of mercury from fish consumption for the high-risk group (women of childbearing age and children) from the FAO–WHO is:

1.6 μg/kg body weight per week.

The provisional tolerable weekly intake is:

4 μg/kg body weight for inorganic mercury.

At its sixty-first meeting, the Joint FAO–WHO Expert Committee on Food Additives established a new provisional tolerable weekly intake (PTWI) of 1.6 μg/kg body weight. The reference level was established and confirmed based on previous information derived from epidemiological studies of the possible effects of prenatal exposure to methylmercury on child neurodevelopment. Neurodevelopment was considered to be the most sensitive health outcome, and development in utero the most sensitive period of exposure.

The calculation of the PTWI was based on a benchmark dose level/no-observed-effect level of 14 mg/kg for concentrations of mercury in maternal hair in the studies of neurodevelopmental effects in cohorts of children from the Faroe Islands and the Seychelles. The concentrations in maternal hair were calculated to be equivalent to a maternal blood methylmercury concentration of 0.056 μg/kg body weight, which was calculated to arise from a daily methylmercury intake of 1.5 μg/kg body weight. Given a total uncertainty factor of 6.4, a value of 1.6 μg/kg body weight was derived.

References:

Biogeochemical factors influence methylmercury production in rice paddies. In freshwater anoxic sediment, sulfate-reducing bacteria are considered the primary methylators of inorganic mercury, while iron-reducing bacteria also methylate mercury. Like other wetlands, rice paddies are active sites for the methylation of mercury, converting less-toxic inorganic mercury to more toxic methylmercury, which is likely translocated from paddy soil to rice grain.

In a comparison between rice and other agricultural crops cultivated in upland soil (for example, corn and tobacco), average levels of total mercury in rice were similar to the other crops; however, average levels of methylmercury in rice were more than 40 times higher, which was attributed to cultivation of rice in standing water.

Rice cultivation practices – from field preparation to post-harvest practices – transform rice paddies into hot spots for microbial mercury methylation. Analysis of 51 studies of total mercury and/or methylmercury concentrations in rice cultivated or purchased in 15 countries demonstrated that both total mercury and methylmercury levels in rice were significantly higher in polluted sites compared to non-polluted sites (Wilcoxon rank sum, p<0.001). However, the percentage of methylmercury (of total mercury) in rice did not differ statistically between polluted and non-polluted sites (Wilcoxon rank sum, p=0.35), suggesting comparable mercury methylation rates in paddy soil across these sites and/or similar accumulation of mercury species for these rice cultivars.

Studies characterizing the effect of rice cultivation under more aerobic conditions were reviewed to determine the mitigation potential of this practice. Rice management practices utilizing alternating wetting and drying (instead of continuous flooding) caused soil methylmercury levels to spike, resulting in a strong methylmercury pulse after fields were dried and reflooded; however, it is uncertain whether this led to the increased translocation of methylmercury from paddy soil to rice grain.

References:
MERCURY “HOT SPOTS” (I)

Hot spots are regions/locations where risks of higher contamination of the environment (air, soil, water or food sources) might occur following human (anthropogenic) activities, including:

- ASGM;
- energy production using fossil fuels;
- industrial activities;
- mining and other activities involving the extraction and processing of virgin and recycled mineral materials, including the production of gold, iron and steel, ferromanganese, zinc and other non-ferrous metals; and
- mercury-containing waste dumping or processing.

References:


MERCURY “HOT SPOTS” (II)

Exposure in hot spots is usually characterized by:

- combined and chronic exposure from different sources (for example, ASGM workers and their families are exposed to mercury vapour, and workers, their families, and residents of nearby and downstream communities are consuming fish heavily contaminated with methylmercury); and

- a much higher concentration of mercury in environmental media than in other areas.

References:


This map shows areas with high mercury pollution by mining, metal processing and artisanal gold mining in relation to population density. The populations around the world most at risk from mercury contamination are in South-East Asia, West Africa and South America; however, other parts of Asia, Africa and Europe are also vulnerable due to mercury pollution from mining and ore processing.

References:

Dental amalgam, made from an amalgamation of up to 50% mercury (elemental mercury, inorganic mercury) and other metals, is used in most countries. During placement, removal and daily activity, mercury vapour, ions or fine particles may be inhaled or ingested. Mercury used in dentistry can be released into the environment and dental professionals can be exposed.

The Minamata Convention on Mercury requires the phasing down of amalgam use in dental care. In 2010, a WHO expert consultation suggested a global phasing down of dental amalgam, rather than a complete ban, through:

- the development of alternatives
- disease prevention
- the education of health professionals
- public awareness-raising.

As part of the implementation of the Minamata Convention, the EU provisionally agreed to prohibit the use of dental amalgam for pregnant women, breastfeeding women and children under 15 years of age from 1 July 2018.

The EU will study the feasibility of banning all use of dental amalgams by 2030. However, a 2015 publication of the European Commission’s Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) found insufficient evidence of negative health impacts to disqualify the use of dental amalgam in the general population.

References:


continued

**DENTAL AMALGAM (I)**

- There is a political commitment to phase down use of dental amalgam.
- The risk for patients and dental professionals is evaluated as low.
- Amalgam is a source of mercury release into the environment.
- The European Commission found evidence of negative health effects to prevent the use of dental amalgam in the general population. 

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DENTAL AMALGAM (II)

The predicted mercury uptake from amalgam and the observed accumulation of mercury in the body are average values. It is also clear from the original reports that substantial individual variations exist. Dental amalgam restorations may raise mercury levels slightly, but this has no practical or clinical significance.

References:


### MERCURY IN SKIN-LIGHTENING PRODUCTS

- Skin-lightening soaps and creams, as well as other cosmetic products can contain mercury.
- Inorganic mercury is used in soaps and creams and organic mercury compounds are used as cosmetic preservatives.
- Although regulations on the sale of mercury-containing cosmetics have become more common, these products are still in use and for sale in many countries and on the internet.

<table>
<thead>
<tr>
<th>Country/Region/Convention</th>
<th>Limits for skin-lightening products</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Minamata Convention on Mercury</td>
<td>1 mg/kg (1ppm)</td>
</tr>
<tr>
<td>European Union</td>
<td>Banned</td>
</tr>
<tr>
<td>Canada</td>
<td>Banned</td>
</tr>
<tr>
<td>The United States</td>
<td>Banned</td>
</tr>
<tr>
<td>Philippines</td>
<td>Banned</td>
</tr>
<tr>
<td>Ghana</td>
<td>Banned</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Banned</td>
</tr>
<tr>
<td>Uganda</td>
<td>Banned</td>
</tr>
</tbody>
</table>

References:

Cognitive development is negatively influenced by prenatal mercury exposure.

For each ppm increase of maternal hair mercury, the child’s IQ score decreased by 0.18 points.

Prenatal exposure to mercury has been associated with adverse childhood neurologic outcomes in epidemiological studies. Researchers have investigated dose–response information for the relationship between maternal mercury body burden and subsequent childhood decrements in intelligence quotient (IQ) using a Bayesian hierarchical model to integrate data from three epidemiological studies conducted in the Faroe Islands, New Zealand and the Seychelles.

They arrived at a central estimate of $-0.18$ IQ points (95% confidence interval, $-0.378$ to $-0.009$) for each ppm increase of maternal hair mercury. This was similar to the estimates for both the Faroe Islands and Seychelles studies, and lower in magnitude than the estimate for the New Zealand study. Sensitivity analyses produce similar results, with the IQ coefficient central estimate ranging from $-0.13$ to $-0.25$.

While IQ is a useful endpoint for estimating neurodevelopmental effects, it may not fully represent cognitive deficits associated with mercury exposure, and does not represent deficits related to attention and motor skills. Nevertheless, the integrated IQ coefficient provides a more robust description of the dose–response relationship for prenatal mercury exposure and cognitive functioning than the results of any single study.

References:

Inorganic mercury is more readily transferred to breastmilk than other forms of mercury.

Concentrations of both inorganic and organic mercury in breastmilk are low. Mercury and its compounds do not accumulate in breastmilk.

Data from 34 studies on mercury showed that levels in breastmilk were generally higher in populations with high fish consumption, where it may be present as organic mercury (MeHg).

Both organic and inorganic mercury can contribute to mercury in breastmilk, although more information is needed on the relative distribution of different forms of mercury into breastmilk. Inorganic mercury seems to be more readily transferred from maternal blood to breastmilk than methylmercury. Several studies have reported that maternal dental amalgam is more closely correlated with breastmilk mercury concentrations compared to maternal methymercury or fish consumption. The majority of studies have reported low risks of mercury in breastmilk for newborn health. As the natural first food for infants, breastmilk supplies essential energy and nutrients for healthy development. Exclusive breastfeeding has been shown to promote sensory and cognitive development, reduce infant mortality due to diarrhoea or pneumonia, and promote quicker recovery from illness.

References:


continued
**Thiomersal in Vaccines**

- Thiomersal (ethylmercury) is used in very small amounts as a preservative in some vaccines and pharmaceuticals.
- Compared to methylmercury, ethylmercury is very different: it is broken down by the body quickly and does not accumulate.
- WHO has closely monitored scientific evidence relating to the use of thiomersal as a vaccine preservative for more than 10 years. Studies and national regulatory agencies have consistently found no evidence of an increased risk of neurodevelopmental disorders from thiomersal in vaccines.
- The precautionary principle is applied in some countries for vaccination of children and pregnant women.

WHO has closely monitored scientific evidence relating to the use of thiomersal (thimerosal) as a vaccine preservative for over 10 years, in particular through its Global Advisory Committee on Vaccine Safety (GACVS). GACVS has consistently reached the same conclusion: there is no evidence to suggest that the amount of thiomersal used in vaccines poses a health risk. Other expert groups (for example, the United States Institute of Medicine, the American Academy of Pediatrics, the United Kingdom Committee on Safety of Medicines and the European Agency for the Evaluation of Medicinal Products) have reached similar conclusions.

Other than local sensitization and rare allergic reactions, studies and national regulatory agencies have consistently found no evidence of an increased risk of neurodevelopmental disorders from the use of thiomersal in vaccines (WHO, 2016; EMEA, 2004; EMEA, 2007; USFDA, 2015). GACVS last reviewed thiomersal in 2012 and found strong evidence for the safety of its use in inactivated vaccines as a preservative. It determined that the use of thiomersal is warranted, as it remains the safest and most effective preservative available for some vaccines.

As a precaution, all vaccines used in children under six years of age in the United States are free of thiomersal or contain only a small amount of thiomersal, with the exception of some influenza vaccines. The EU supports the goal of reducing all exposure to mercury, including reducing the use of thiomersal in vaccines when safe alternatives are available.

References:


HEALTH EFFECTS OF MERCURY

OUTLINE

HEALTH DISORDERS CAUSED BY DIFFERENT FORMS OF MERCURY:
- elemental mercury
- inorganic mercury
- organic mercury (methylmercury)

EARLY-LIFE EXPOSURE TO MERCURY
ALL FORMS OF MERCURY CAN CAUSE NEGATIVE HEALTH EFFECTS

Factors that determine whether health effects occur and their severity include:

- the form of mercury concerned
- the dose
- the age or developmental stage of the person exposed (the fetus is most susceptible)
- the duration of exposure
- the route of exposure (inhalation, ingestion or dermal contact).

The image in this slide summarizes information about sources of mercury (environmental and occupational), and the health endpoints of mercury and its compounds.

References:


Paracelsus was the first to describe the negative health effects of chronic exposure to elemental mercury.

In 1527, he introduced the word “mercurialism” to describe the symptoms of mercury workers in a mercury mine in Idrija, Slovenia.

References:
Several Chinese emperors are known or suspected to have died or been sickened by mercury poisoning; they consumed a so-called elixir to promote health, longevity or immortality that contained either elemental mercury or cinnabar.

In the 18th and 19th centuries, mercury-based compounds were used in the manufacture of felt hats. The phrase “mad as a hatter” refers to the effects of mercury poisoning among the milliners producing the hats.

During the construction of Saint Isaac’s Cathedral in Saint Petersburg, Russian Federation, 60 men died from gilding the main dome with a solution containing mercury.

The scientist Sir Isaac Newton (1642–1727) suffered two serious bouts of uncharacteristically erratic behaviour; this may have been due to a mild form of mercury poisoning – he was conducting experiments with mercury at the time of both occurrences.

Mass poisonings with methylmercury in Minamata, Japan, and Basra, Iraq, are described below.

References:


HEALTH EFFECTS OF EXPOSURE TO ELEMENTAL MERCURY
HEALTH EFFECTS OF EXPOSURE TO ELEMENTAL MERCURY (I)

Symptoms of acute poisoning by elemental mercury (via inhalation) include:

- metallic taste, nausea, abdominal pain, vomiting, diarrhea
- tremor, irritability, headache, weakness
- chest pains, dyspnea (shortness of breath), cough, sore throat, fever, pneumonitis (inflammation of the lungs), palpitations
- albuminuria (kidney dysfunction)
- skin irritation
- death.

References:


Erethism (mad hatter disease)

...is a neurological disorder affecting the central nervous system caused by chronic exposure to elemental mercury. Symptoms include shyness, timidity, loss of self-confidence, anxiety, desire to stay unobserved and unobtrusive, pathological fear of ridicule, loss of temper, delirium, personality changes and memory loss.

Other health effects include:
- tremor, coordination problems
- numbness in the hands and feet
- gingivitis, stomatitis (inflammation of the mouth and lips)
- excessive salivation; albuminuria.

Animal tests show that elemental mercury may have harmful effects on human reproduction.

Erethism, also known as erethism mercurialis, mad hatter disease or mad hatter syndrome, is a neurological disorder that affects the whole central nervous system and a symptom complex derived from mercury poisoning. Erethism is characterized by behavioural changes such as irritability, low self-confidence, depression, apathy, timidity and, in some extreme cases due to prolonged exposure to mercury vapours, delirium, personality changes and memory loss. People with erethism often have difficulty with social interactions. Associated physical problems may include decreased physical strength, headaches, general pain and irregular heartbeat. Erethism also affects the peripheral nervous system, leading to coordination disorders.

Mild subclinical signs of central nervous system toxicity can be seen in workers exposed to an elemental mercury level in the air of 20 μg/m³ or more for several years. Kidney and immune effects have also been reported.

References:


Chronic exposure to mercury vapour in ASGM causes chronic elemental mercury intoxication. Typical symptoms include:

- tremor
- ataxia (coordination problems, speech changes, abnormal eye movements)
- excessive salivation
- metallic taste.

The health effects of exposure to inorganic mercury are reversible if the source of exposure is eliminated.

This image shows a drum mill in Lombok, Indonesia, used to grind ore and extract gold with mercury.

References:


Observed health effects depend on the level of exposure to mercury vapour. The linear dose–response relationship is demonstrated in the graph.

References:


According to the United Nations Globally Harmonized System of Classification and Labelling of Chemicals (GHS):

- May be corrosive to metals
- Fatal if inhaled
- May damage fertility or the unborn child
- Causes damage to the central nervous system and the kidneys through prolonged or repeated exposure
- Very toxic to aquatic life with long lasting effects

References:

HEALTH EFFECTS OF EXPOSURE TO
INORGANIC MERCURY
HEALTH EFFECTS OF EXPOSURE TO INORGANIC MERCURY (I)

Acute effects of exposure to inorganic mercury include:

- nausea, vomiting, abdominal pains, bloody diarrhoea, circulatory collapse, shock;
- metallic taste, excessive salivation, pharyngitis (inflammation of the throat), stomatitis;
- nephritis (inflammation of the kidneys), proteinuria (excessive protein in urine), oliguria (low urine output), hematuria (blood in urine), anuria (failure of the kidneys to produce urine).

Acute exposure to inorganic mercury by the oral route may result in nausea, vomiting and severe abdominal pain.

References:


HEALTH EFFECTS OF EXPOSURE TO INORGANIC MERCURY (II)

**Chronic exposure** to inorganic mercury causes:

- kidney damage
- autoimmune disease
- neurological symptoms (similar to those from elemental mercury exposure)
- acrodynia.

Chronic exposure to inorganic mercury can result from the use of mercury compounds at work or the use of skin-lightening soaps and cream. The major effect of chronic exposure is kidney damage. Mercury in skin-lightening products may also cause skin rashes, skin discolouration and scarring, and a reduction in the skin’s resistance to bacterial and fungal infections. Other effects include anxiety, depression or psychosis, and peripheral neuropathy.

Mercury in cosmetics exists in two forms: inorganic and organic. Inorganic mercury (for example, ammoniated mercury) is used in skin-lightening soaps and creams. Organic mercury compounds (ethylmercury and phenylmercuric salts) are used as cosmetic preservatives in mascara and eye makeup cleansing products.

References:


Acrodynia is a rare idiopathic chronic toxic reaction to elemental or inorganic mercury exposure that occurs mainly in young children. It is characterized by pain in the extremities and pink discolouration with desquamation (peeling) of the skin. Clinical features of acrodynia in children include lack of mobilization, pruritus (itching), hypotonia (low muscle tone), red lips, fingers and soles of feet, and crying and unhappiness.

References:


HEALTH EFFECTS OF EXPOSURE TO INORGANIC MERCURY (IV)

Tremor

The image shows the handwriting of a 9-year-old girl in monthly intervals after an accidental intake of seed preservative containing inorganic mercury.

This image shows the handwriting of a 9-year-old girl in monthly intervals after an accidental intake of mercury-containing seed preservative in contaminated grain. It demonstrates that exposure well after infancy can also have serious consequences.

References:

This is the International Chemical Safety Card that developed by ILO/WHO to inform about occupational hazards. The card of mercury nitrate provided as an example. Mercury(II) nitrate is a toxic, colourless or white soluble crystalline mercury(II) salt of nitric acid. It was used to treat fur to make felt in a process called “carroting”.

References:

HEALTH EFFECTS OF EXPOSURE TO ORGANIC MERCURY (METHYLMERCURY)
HEALTH EFFECTS OF EXPOSURE TO METHYLMERCURY

Chronic exposure to methylmercury affects:

- the **nervous system** – developmental delays, impaired vision and hearing, ataxia, paresthesia (abnormal sensations on skin), brain function, lowered IQ;
- the **cardiovascular system** – high blood pressure, altered heart rate, increased risk of heart attack.

Methylmercury is neurotoxic. Motor disturbances such as ataxia and trembling, and dysesthesia such as impaired vision have been reported after exposure. The reproductive toxicity of methylmercury has been confirmed in animal studies. However, further studies regarding the reproductive toxicology of humans exposed to low concentrations of methylmercury should be performed to confirm evidence.

The probability of the correlation between methylmercury exposure and cardiovascular toxicity has been raised consistently through some studies. We know that mercury promotes the creation of free radicals, and that methylmercury disturbs the antioxidation effects of glutathione and catalase due to its high affinity with the thiol group; causes lipid peroxidation; promotes platelet aggregation and blood coagulation; causes sclerosis of the arteries; and raises blood pressure.

References:


HEALTH EFFECTS OF EXPOSURE TO METHYLMERCURY: MINAMATA DISEASE (I)

The Minamata incident:

- A local company dumped 27 tonnes of methylmercury into Minamata Bay from 1932 to 1968.
- Consumption of the mercury-burdened fish caused human deaths.
- Children born to mothers who consumed the fish and shellfish were born with severe congenital deformities.
- Minamata disease is a neurological syndrome caused by severe mercury poisoning.
- At least 50,000 people have been affected.
- More than 2000 cases of Minamata disease have been certified.

One of the most severe incidents of mercury poisoning occurred in Minamata, Japan, when a local company dumped an estimated 27 tonnes of methylmercury into Minamata Bay between 1932 and 1968. The methylmercury accumulated in shellfish and fish, and their consumption resulted in the deaths of cats, dogs, pigs and humans. What became known as Minamata disease – a neurological syndrome caused by severe mercury poisoning. Children of mothers who consumed the fish and shellfish were born with severe congenital deformities.

Since the identification of the disease, WHO estimates that at least 50,000 people have been affected. More than 2000 cases of Minamata disease have been certified as result of the incident.

References:

Symptoms include:

- ataxia
- numbness in the hands and feet
- general muscle weakness
- narrowing in the field of vision
- impaired hearing and speech.

Extreme cases lead to:

- insanity
- coma
- paralysis
- death.

The symptoms of Minamata disease range from motor impairments such as difficulty walking and speaking to sensory constraints in seeing and hearing. In very extreme cases, insanity, paralysis, coma and death can occur.

References:


HEALTH EFFECTS OF EXPOSURE TO METHYLMERCUROY:

POISONING IN IRAQ (I)

- Methylmercury fungicide was applied to seed grain.
- The grain was not intended for human consumption.
- Grain was imported with labelling in a foreign language.
- The grain was unintentionally used to make bread in Iraq in 1971–1972.
- 459 people died after eating bread made from the contaminated grain.

This mass poisoning took place in the winter of 1971–1972. Seed grain treated with a methylmercury fungicide was used to prepare homemade bread in rural communities throughout Iraq. Total hospital admissions rose to just over 6000, with most of these occurring in January 1972. Around 460 deaths attributed to methylmercury were recorded in hospital. Both sexes and all ages were affected. References:


HEALTH EFFECTS OF EXPOSURE TO METHYLMERCURY: POISONING IN IRAQ (II)

- A latency period of several months between consumption and the onset of symptoms has been reported.
- A strong relationship between the amount of mercury consumed and the severity of symptoms in individuals has been observed.
- Neurological symptoms included paresthesia, ataxia, dysarthria (slurred or slowed speech), and loss of hearing and vision.

In adults, a highly significant correlation between amount of bread ingested and blood mercury levels was observed. Poisoning in infants resulted from prior exposure in utero, from breastfeeding or both. Blood mercury levels were higher in infants and children than adults. Central nervous system symptoms developed on average 1–2 months after exposure. Affected children experienced mental retardation with delayed onset of speech and impaired motor, sensory and autonomic function. Severely affected children were blind and deaf. In adults, the clinical picture was classified as mild (mainly sensory symptoms), moderate (sensory symptoms accompanied by cerebellar dysfunction) and severe (gross ataxia with marked visual and hearing loss, which in some cases progressed to akinetic mutism followed by coma).

The dose–response relationship is illustrated by the so-called hockey-stick line for each sign and symptom. The frequency of paraesthesia increases in proportion to the log of the maximum body burden above the threshold.

References:


EARLY-LIFE EXPOSURE TO MERCURY
PRENATAL EXPOSURE TO METHYLMERCURY: NEURODEVELOPMENTAL EFFECTS

- Impedes nerve cell division and migration.
- Binds with microtubules required for neuronal development.
- Binds to and distorts DNA and RNA.

The fetal brain is the most sensitive human tissue to damage from this powerful neurodevelopmental toxicant. In order for the brain to develop properly, an orderly process of cell differentiation and migration must occur to produce a specific and highly organized brain architecture. Methylmercury interferes with this process by binding to critical structures such as microtubules that are crucial to normal cell division and migration. It also binds to and distorts important molecules such as DNA and RNA.

References:

Mothers were often asymptomatic. Disorders observed in their children included:

- microcephaly
- cerebral palsy/spasticity
- mental deficits
- malformation of ears, heart, skeleton and eyes.

The results of the industrial contamination of Minamata Bay revealed the extreme vulnerability of the fetus to methylmercury. Fish bioconcentrated the toxicant and mothers acquired high blood levels from eating them. While the mothers usually lacked symptoms of mercury poisoning, their babies were born with severe health effects including microcephaly, cerebral palsy, severe mental retardation, seizure disorders, blindness, deafness and other malformations. It is interesting to note that for many years cats eating fish from Minamata Bay were observed to suffer a “strange” neurological disease.

References:


Recalling that mercury inhibits cell division and migration during development, it is easy to see from this schematic why fetuses and young children are particularly at risk when exposed. Cell proliferation and migration occur during the second and third trimesters and continue in the first 2–3 years postnatally. Exposure to neurodevelopmental toxicants such as methylmercury during these periods of rapid maturation and change can have profound consequences.

References:


The susceptibility of the fetal brain is very high.

In the Faroe Islands study, altered neuropsychological tests were found in children where the prenatal mercury burden was raised by the consumption of whale meat.

Effects can be unapparent in individual children, but can manifest at the level of the wider population in the form of reduced numbers of “gifted” children and greater numbers of children with low IQ scores.

No effects were found in the similar Seychelles study.

Commonly, the neurotoxic effects of mercury, such as neurodevelopmental disorders, are not clinically manifested. Two birth cohort studies from the Faroe Islands and the Seychelles established a foundation for the evaluation of the subclinical effects of mercury, in spite of the fact that they yielded different results.

References:


Prenatal Exposure to Methylmercury: Case Studies

**Seychelles study**
- Cohort of 779 mother–infant pairs
- Exposure from mothers’ high fish consumption
- Neuropsychological tests of children at age 9
- No support for neurodevelopmental risks due to prenatal methylmercury exposure

**Faroe Islands study**
- Cohort of 1022 children born in 1986–1987
- Exposure from mothers’ consumption of pilot whale meat (episodic and potentially high) and fish (continuous, but low)
- Neuropsychological tests of children at age 7 – dysfunction detected in:
  - language
  - attention
  - memory
- Neurophysiological tests at age 14 – dysfunction detected in:
  - brainstem auditory evoked potential
  - autonomic heart rate variability
- Dysfunction attributed to prenatal mercury exposure

In the Faroe Islands, a cohort of 1022 consecutive singleton births was generated in 1986–1987. Increased methylmercury exposure from maternal consumption of pilot whale meat was indicated by mercury concentrations in cord blood and maternal hair. At approximately seven years of age, 917 of the children underwent detailed neurobehavioural examination. Neuropsychological tests included finger tapping; hand–eye coordination; reaction time on a continuous performance test; the Wechsler Intelligence Scale for Children with revised digit span, similarities and block design; the Bender Visual–Motor Gestalt Test; the Boston Naming Test; and the California Verbal Learning Test – Children’s Version. Clinical examination and neurophysiological testing did not reveal any clear-cut mercury-related abnormalities. However, mercury-related neuropsychological dysfunctions were most pronounced in the domains of language, attention and memory, and to a lesser extent in visuospatial and motor functions. These associations remained after adjustment for covariates and after exclusion of children with maternal hair mercury concentrations above 10 μg/g (50 nmol/g). The effects on brain function associated with prenatal methylmercury exposure therefore appear widespread, and early dysfunction is detectable at exposure levels currently considered safe.

In the Seychelles, 779 mother–infant pairs were involved in the survey. Mothers reported consuming fish on average in 12 meals per week. Fish in the Seychelles contain very similar concentrations of methylmercury to commercial ocean fish elsewhere. Prenatal methylmercury exposure was determined from maternal hair growing during pregnancy. Neurocognitive, language, memory, motor, perceptual–motor and behavioural functions in children at age nine were assessed. Two endpoints were associated with prenatal methylmercury exposure: decreased performance in the grooved pegboard using the non-dominant hand in males and increased scores in the hyperactivity index of the Conner’s Teacher Rating Scale. Covariates affecting child development were appropriately associated with endpoints. Data obtained in this survey do not support the hypothesis that there is a neurodevelopmental risk from prenatal methylmercury exposure resulting solely from ocean fish consumption.
References:


Depending on the dose and timing of exposure during gestation, the effects of prenatal exposure to methylmercury may be severe and immediately obvious, or subtle and delayed. Neurological symptoms include mental retardation; ataxia and cerebral palsy; seizures; vision and hearing loss; delayed developmental milestones; language disorders; and problems with motor function, visuospatial abilities and memory.

Results from long-term cohort studies suggest that the cardiovascular system is also at risk, with heart rate variability decreasing as methylmercury exposure increases. One study suggested diastolic blood pressure in boys may be associated with prenatal methylmercury exposure, but the association requires more investigation. The full expression of the health effects of methylmercury can be delayed and deficits are often irreversible.

References:


DIAGNOSIS:
A HIGH INDEX OF SUSPICION

Think about mercury!

- Careful account of history: food, activities, environment
- Clinical observation
- Urine mercury analysis (inorganic exposure)
- Blood mercury analysis (organic exposure, inorganic exposure)
- Hair mercury analysis (long-term organic exposure)

Typical signs and symptoms + increased mercury body burden = mercury intoxication

Diagnosis of mercury intoxication, particularly if it is chronic and low dose, requires a high index of suspicion. Careful history-taking is needed to determine potential sources of exposure. If symptoms are found, analysis of blood, urine or hair should be performed.

Urine mercury typically reflects inorganic exposure. Total blood mercury reflects recent or current exposure. However, organic mercury is mainly bound to erythrocytes while inorganic mercury is in plasma. By separating the cells from plasma, a differentiation of the two species is possible. Hair analysis reflects cumulative exposure to methylmercury in the last months. Hair grows about 1 cm per month and takes three weeks to grow out of the skin. Segmental analysis can provide information about past exposure.

References:


There is no antidote for mercury exposure. Treatment consists of cessation of exposure, supportive care and timely chelation therapy when warranted.

- **Identify** the source and eliminate exposure.
- **Contact** a doctor or poison control centre.
- **Chelating agents** may reduce the body burden of mercury and may improve some symptoms.
- **Treat symptoms**.
- **Begin rehabilitation**.

References:


“Mercury has long been recognized as a major source of toxicity in children causing reduced cognitive functioning, including reduced IQ. However, we are now seeing that even low exposure levels can cause damage to the developing brain of the fetus and infant. These are mercury levels that are not known to cause acute poisoning or ill health in adults. We also know that mercury is stored up in women even before pregnancy. Therefore, preventing exposure to future children means reducing everyday exposure today.”

Dr Gavin ten Tusscher, Paediatrician, Department of Paediatrics and Neonatology, Westfries Gasthuis, Hoorn, the Netherlands

References:

Based on scientific evidence of prenatal exposure to mercury, WHO in cooperation with the UNEP developed a master protocol for designing and planning a mercury human biomonitoring survey. The protocol addresses the selection of target populations and biological matrices, survey planning, recruitment and fieldwork, data management and communication, community involvement and ethical considerations. It also includes an informed consent form, an eligibility screening form and a questionnaire for collecting epidemiological information.

References:

The organization of a human biomonitoring survey is a complex process involving professionals with different technical skills, including epidemiologists, analytical chemists, toxicologists, statisticians, physicians and communication specialists. WHO’s standard operating procedures for assessment of prenatal exposure to mercury describe the sampling and analysis of total mercury in cord blood, urine and scalp hair. The package includes the following five procedures:

1. a quality control programme for mercury human biomonitoring (defines an effective system for performing quality-control activities to ensure the reliability of mercury human biomonitoring results, with activities focused on the pre-analytical and analytical stages);
2. standard operating procedures for assessment of mercury in human scalp hair (includes sampling, analysis of total mercury, interpretation of results);
3. standard operating procedures for assessment of mercury in cord blood (includes sampling, analysis of total mercury, interpretation of results);
4. standard operating procedures for assessment of mercury in urine (includes sampling, analysis of total mercury, interpretation of results, and procedures for analysis of creatinine in urine); and
5. standard operating procedures for determination of total mercury in hair, blood and urine by the alternative method.

References:

THE MINAMATA CONVENTION ON MERCURY AND THE HEALTH SECTOR’S ROLE IN ITS IMPLEMENTATION

OUTLINE

- Minamata Convention – overview
- Articles regulating releases and emissions of mercury
- Health-related articles and actions of the health sector
THE MINAMATA CONVENTION ON MERCURY

- The Minamata Convention is a global treaty to protect human health and the environment from the adverse effects of mercury.
- The text was adopted and opened for signature at a Diplomatic Conference (Conference of Plenipotentiaries), held in Kumamoto, Japan, from 10 to 11 October 2013.
- The Convention entered into force on 16 August 2017, the 90th day after the date of deposit of the 50th instrument of ratification, acceptance, approval or accession.

The Minamata Convention follows and builds on the Basel, Rotterdam and Stockholm conventions. It sets out the substantive obligations, while providing some targeted differentiation and flexibility in specific provisions, as well as in provisions for Parties to mobilize financial resources, within their capabilities, for implementation in developing countries. The Convention outlines a life-cycle approach to the supply, trade, use, emissions, releases, handling and disposal of mercury. It also includes articles that are related to the exchange of scientific, technical, economic and legal information concerning mercury and mercury compounds, as well as measures to evaluate its effectiveness. Other Convention articles cover its objective, definitions and administrative matters. Some provisions of the Convention are obligatory while others are voluntary. For example, Article 16 on “Health Aspects” encourages Parties to implement voluntary measures, taking into account their respective circumstances and capabilities, without imposing legal obligations.

References:


Why is the Convention named after this city? One of the most severe incidents of mercury poisoning occurred in Minamata, Japan, when a local company dumped an estimated 27 tonnes of methylmercury into Minamata Bay between 1932 and 1968. The marine life in Minamata Bay displayed high levels of methylmercury contamination (5.61–35.70 ppm), and consumption of this fish and shellfish resulted in widespread mercury poisoning. The mercury content in the hair of patients, their families and inhabitants of the Shiranui Sea coastline were high (up to 705 ppm). The neurological syndrome caused by severe mercury poisoning came to be known as Minamata disease.

As mortality by mercury poisoning in the initial stage was decreasing, the numbers of patients who manifested chronic symptoms gradually over an extended period of time was increasing. In the 36 years after the first registration of Minamata disease, a total of 2252 patients have been officially recognized as having the disease. Of these individuals, 1043 have died.

Through the Minamata Convention on Mercury, the global community remembers the many lives already lost to mercury poisoning and commits to preventing similar catastrophes.

References:


ARTICLE 1
OBJECTIVE

“The objective of this Convention is to protect the human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds.”

The Minamata Convention draws attention to this globally ubiquitous metal that, in addition to occurring naturally, is used in everyday objects and is released to the atmosphere, soil and water from a variety of anthropogenic sources. The main goal of the Convention is to eliminate or reduce anthropogenic emissions of mercury into air, water and soil in order to protect the environment and human health.

References:


ARTICLES
REGULATING
RELEASES AND
EMISSIONS OF
MERCURY
The following six articles of the Minamata Convention focus on controlling the different emitting sectors and reducing mercury emissions. They deal with the use of mercury in manufacturing and ASGM, emissions into air and releases into water, and storage and disposal. In this way, in addition to regulating emissions and releases directly, the articles address restrictions on the use of mercury and proper handling to minimize risk of accidental release.

References:

ARTICLE 5
MANUFACTURING PROCESSES IN WHICH MERCURY OR MERCURY COMPOUNDS ARE USED

▪ Each Party with one or more facilities that use mercury or mercury compounds in the manufacturing processes listed in Annex B shall take measures to address emissions and releases of mercury or mercury compounds from those facilities.

▪ Each Party shall not allow the use of mercury or mercury compounds in a facility that did not exist prior to the date of entry into force of the Convention for it using the manufacturing processes listed in Annex B. No exemptions shall apply to such facilities.

Article 5 deals with emissions and releases from manufacturing processes. The goal is to phase out the use of mercury in manufacturing processes, and to reduce mercury use, emissions and release. Annex B establishes a phase-out date of 2025 for chlor-alkali production and 2018 for acetaldehyde production in which mercury or mercury compounds are used as a catalyst. It also sets out measures to restrict the use of mercury or mercury compounds in the mercury-using process of vinyl chloride monomer production; sodium or potassium methylate or ethylate production; and polyurethane production using a mercury-containing catalyst.

References:
ARTICLE 7
ARTISANAL AND SMALL-SCALE GOLD MINING

This article concerns gold mining in which mercury amalgamation is used to extract gold from ore.

- Each Party that has ASGM and processing subject to this article within its territory shall take steps to reduce, and where feasible eliminate, the use of mercury and mercury compounds in, and the emissions and releases to the environment of mercury from, such mining and processing.

Article 7 aims at establishing mercury-free ASGM. Parties are to develop strategies to prevent the diversion of mercury for ASGM, to support research on alternative practices, to educate and build capacities, and to give financial and technical assistance.

See the section on the health sector’s role in implementation for more information on protecting human health in ASGM.

References:

**ARTICLE 8 EMISSIONS**

This article concerns the control and, where feasible, the reduction of emissions of mercury from sources listed in Annex D:

- coal-fired power plants
- coal-fired industrial boilers
- smelting and roasting processes used in the production of non-ferrous metals
- waste incineration facilities
- cement clinker production facilities.

Parties can do so by implementing one or more of the following measures:

- a quantified goal
- emission limit values
- best available techniques and best environmental practices
- a multipollutant control strategy with co-benefits for control of mercury emissions
- alternative measures.

Article 8 addresses anthropogenic emissions to the atmosphere. Parties with relevant sources of mercury shall take measures to control and reduce emissions using national action plans. For new sources, Parties are to use the best available techniques and practices to reduce emissions into the air.

References:

ARTICLE 9
RELEASES

This article concerns controlling and, where feasible, reducing releases of mercury and mercury compounds to land and water.

- Parties with relevant sources shall take measures to control releases. Any plan shall be submitted within four years of the date of entry into force of the Convention for that Party.

- The measures shall include one or more of the following, as appropriate:
  - release limit values
  - the use of best available techniques and best environmental practices
  - a multipollutant control strategy that would deliver co-benefits
  - alternative measures to reduce releases.

Article 9 concerns the release of mercury into water and soil. Parties are obliged to take action to control and reduce these releases.

References:

ARTICLE 10
INTERIM STORAGE

- Where mercury is intended for future use (that is, where it is not waste mercury), each Party shall take measures to ensure that the mercury or mercury compounds are stored in an environmentally sound manner.

- The Conference of Parties (COP) shall adopt guidelines on this, taking into account any guidelines developed under the Basel Convention on the control of transboundary movements of hazardous wastes and their disposal.

Storage is an important aspect of safely handling mercury. People and the environment must be protected from mercury leaking into the ground or being emitted into the air.

References:

“Mercury waste” refers to substances or objects containing mercury or mercury compounds.

Each Party shall take appropriate measures so that mercury is managed in an environmentally sound manner, taking into account guidelines developed under the Basel Convention.

In accordance with the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, all waste containing mercury in any form is to be disposed of in an appropriate way. Apart from the international import and export of hazardous waste, the Basel Convention concluded that the generation, importation and exportation of hazardous waste, including mercury, are to be reduced to a minimum; appropriate waste disposal facilities are to be available; and pollution due to hazardous wastes is to be prevented.

References:


HEALTH-RELATED ARTICLES AND ACTIONS OF THE HEALTH SECTOR
The Minamata Convention is a unique multilateral environmental agreement in that it identifies the importance of the health sector in its implementation. In 2014, the World Health Assembly adopted resolution WHA67.11, *Public health impacts of exposure to mercury and mercury compounds: the role of WHO and ministries of public health in the implementation of the Minamata Convention*. The resolution recognized the importance of dealing effectively with the health aspects of the challenges that chemicals and wastes, including mercury, may pose, particularly to vulnerable populations. It also emphasized the benefits of the implementation of the Minamata Convention, given its objective to protect human health and the environment.

WHA67.11 stressed that the Minamata Convention encourages Parties to:

a. promote the development and implementation of strategies and programmes to identify and protect populations at risk, particularly vulnerable populations, which may include adopting science-based health guidelines relating to exposure to mercury and mercury compounds, setting targets for mercury exposure reduction where appropriate, and public education with the participation of public health and other involved sectors;

b. promote the development and implementation of science-based educational and preventive programmes on occupational exposure to mercury and mercury compounds;

c. promote appropriate health-care services for prevention, treatment and care for populations affected by exposure to mercury and mercury compounds; and

d. establish and strengthen, as appropriate, the capacities of institutions and health professionals for the prevention, diagnosis and monitoring of health risks related to exposure to mercury and mercury compounds.

The resolution lists actions at national and international levels to do so.

References:

With the Convention’s core objective “to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds”, it could be said that all 35 articles are health-related. However, in this module, the term “health-related articles” refers to those in which health ministries play a leading role in implementation.

Two articles of the Convention – Article 4 (paragraph 1) and Article 7 – are obligatory with a set time frame of 2020 with a potential extension for 5 or 10 years upon a Party’s request. Countries that are Parties to the Convention are now legally bound to fulfil a range of mandatory measures, such as banning new mercury mines; phasing out mercury-added products, including thermometers, batteries, certain light bulbs, etc.; and regulating the use of mercury in ASGM.

In other obligatory articles, a time frame is not set. Article 16 on health aspects should be implemented on a voluntary basis.

References:


ARTICLE 4
MERCURY-ADDED PRODUCTS

The Convention’s requirement:
Each Party shall not allow, by taking appropriate measures, the manufacture, import or export of mercury-added products listed in Part I of Annex A after the phase-out date specified for those products. The phase-out date for all such products is 2020.

The health sector’s role:
Review the relevant regulations and consider whether there may be a need to revise them in order to disallow the manufacture, import or export of:
• cosmetics (with mercury content above 1 ppm), including skin-lightening soaps and creams
• topical antiseptics
• non-electronic measuring devices (thermometers and sphygmomanometers).

The Convention does not require the removal from use of mercury-added products manufactured or imported prior to 2020. A Party can register for an exemption to 2025 for the manufacture and/or import or export of a mercury-added product, and may be granted an exemption to 2030 by the Conference of the Parties (COP). However, if the main manufacturers are withdrawing from the market, then Parties and non-Parties alike may experience difficulties sourcing the products in the market. Parties can ask the COP for a further exemption to 2030, but this would be a decision of the COP and the above point about procurement would still apply.

Not included are eye-area cosmetics in which mercury is used as a preservative and for which no effective and safe substitute preservatives are available. The intention is not to cover cosmetics, soaps or creams with trace contaminants of mercury.

References:

ARTICLE 4
MERCURY-ADDED PRODUCTS:
PARAGRAPH 3

The Convention’s requirement:
Measures to be taken by a Party to phase down dental amalgam shall take into account the Party’s domestic circumstances and relevant international guidance, and shall implement two or more of the measures listed in Part II Annex A of the Convention.

The health sector’s role:
Provide guidance in phasing down the use of dental amalgam.

WHO developed recommendations on phasing down the use of dental amalgam for consideration by ministries of health. See Module 4 of this educational course for more information on dental amalgam.

References:


ARTICLE 7
ARTISANAL AND SMALL-SCALE GOLD MINING

The Convention's requirement
Each Party that has ASGM and processing subject to this Article within its territory shall take steps to reduce, and where feasible eliminate, the use of mercury and mercury compounds in, and the emissions and releases to the environment of mercury from, such mining and processing.

The health sector's role
Develop public health strategies in national action plans to reduce the health impacts of mercury in ASGM by:
• gathering health data, training health-care workers and raising awareness through health facilities;
• developing strategies to prevent the exposure of vulnerable populations, particularly children and women of child-bearing age and pregnant women; and
• conducting health risk assessments of contaminated sites.

WHO developed recommendations on the development of national strategies in national action plans to reduce the health impact of ASGM.

References:


ARTICLE 10
ENVIRONMENTALLY SOUND INTERIM STORAGE OF MERCURY OTHER THAN WASTE MERCURY

The Convention’s requirement
Each Party shall take measures to ensure that interim storage is undertaken in an environmentally sound manner, taking into account COP guidelines.

The health sector’s role
Review current policies and practices concerning any interim storage of non-waste mercury and mercury compounds (such as elemental mercury as a reference in a toxicology laboratory).

See Module 4 for more information on the storage of mercury.

References:

ARTICLE 11
MERCURY WASTES

The Convention’s requirement
Each Party shall take appropriate measures to ensure that mercury wastes are managed in an environmentally sound manner, taking into account the guidelines developed under the Basel Convention and in accordance with the requirements that the COP may adopt in the future.

The health sector’s role
Review current policies and practices concerning the management of mercury wastes (such as phased out thermometers and sphygmomanometers).

See Module 4 for more information on mercury wastes.

References:

ARTICLE 12
CONTAMINATED SITES

The Convention’s requirement
Each Party shall endeavour to develop appropriate strategies for identifying and assessing sites contaminated by mercury or mercury compounds.

The health sector’s role
Assess risks for human health in identified contaminated sites.

References:


ARTICLE 17
INFORMATION EXCHANGE

The Convention’s requirement
Parties shall facilitate the exchange of scientific, technical, economic and legal information concerning mercury and mercury compounds, including information on alternatives and their health and environment risks and economic and social costs.

The health sector’s role
Facilitate the exchange of epidemiological information concerning health impacts associated with exposure to mercury and mercury compounds.

Article 17 covers information on the reduction or elimination of the production, use, trade, emission and release of mercury and mercury compounds, as well as information on viable alternatives to mercury-added products, manufacturing processes using mercury or mercury compounds, and activities and processes that emit or release mercury or mercury compounds. It also requires Parties to facilitate the exchange of epidemiological information concerning health impacts associated with exposure to mercury and mercury compounds.

References:


ARTICLE 18
PUBLIC INFORMATION, AWARENESS AND EDUCATION

The Convention’s requirement

Each Party shall, within its capacities, promote and facilitate:

• the provision to the public of available information, and
• education, training and public awareness related to the health and environment effects of exposure to mercury and mercury compounds.

Parties shall use existing or new mechanisms to inform and educate public.

The health sector’s role

Develop appropriate education and training programmes on mercury addressing:

• current uses of mercury
• routes of entry
• uptake, absorption and distribution of mercury in the human body
• preventive measures
• vulnerable groups
• symptoms of mercury poisonings
• medical management of mercury poisonings.

Information to be provided to the public under Article 18 covers:

• scientific, technical, economic and legal information concerning mercury and mercury compounds, including toxicological, ecotoxicological and safety information;
• information on the reduction or elimination of mercury and mercury compounds;
• information on economically viable alternatives; and
• epidemiological information.

Parties shall also share the results of the research, development and monitoring activities taken to meet their obligation under the Convention.

References:


ARTICLE 19
RESEARCH, DEVELOPMENT AND MONITORING

The Convention's requirement
Each Party shall endeavour to cooperate to develop and improve, taking into account their respective circumstances and capabilities, a wide range of information emerging over time from the Parties’ research and monitoring programmes. Parties shall endeavour to develop harmonized methodologies for research and monitoring, building, where appropriate, on existing monitoring networks and research programmes.

The health sector’s role
Monitor levels of mercury and mercury compounds in vulnerable populations, and assess the impact of mercury and mercury compounds on human health.

References:

ARTICLE 20
IMPLEMENTATION PLAN

The Convention’s requirement
Each Party may develop and execute an implementation plan, taking into account its domestic circumstances, for meeting the obligations under the Convention, and review and update its implementation plan. Any such plan should be transmitted to the Secretariat as soon as it has been developed.

Parties may also coordinate on regional plans to facilitate implementation of the Convention.

The health sector’s role
Contribute to the national implementation plan in terms of its responsibilities, or develop a sectoral plan for the implementation of the Convention.

References:


ARTICLE 21
REPORTING

The Convention’s requirement
Each Party shall report to the COP on the measures it has taken to implement the provisions of this Convention and on the effectiveness of such measures and the possible challenges in meeting the objectives of the Convention.

COP shall decide upon the timing and format of the reporting.

The health sector’s role
Contribute the expected information relevant to measures in which they are playing a lead role.

References:

ARTICLE 22
EFFECTIVENESS EVALUATION

- **The COP** shall evaluate the effectiveness of the Convention, beginning no later than six years after its entry into force.
- **At the first meeting**, the COP initiated the establishment of arrangements to obtain monitoring data.
- **Evaluation** will be based on available scientific, environmental, technical, financial and economic information.

References:


ARTICLE 16
HEALTH ASPECTS (I)

Parties are encouraged to:

- **implement** health measures, taking into account their respective circumstances and capabilities, without imposing legal obligations or time frames;
- **promote** the development and implementation of strategies and programmes to identify and protect populations at risk, particularly vulnerable populations, which may include adopting science-based health guidelines relating to exposure to mercury and mercury compounds;
- **promote** the development and implementation of science-based educational and preventive programmes on occupational exposure to mercury and mercury compounds.

References:


ARTICLE 16
HEALTH ASPECTS (II)

- **promote** appropriate health-care services for prevention, treatment and care for populations affected by exposure to mercury and mercury compounds; and

- **establish and strengthen**, as appropriate, the capacities of institutions and health professionals for the prevention, diagnosis, treatment and monitoring of health risks related to exposure to mercury and mercury compounds.

References:


IMPLEMENTATION OF THE CONVENTION IN THE HEALTH SECTOR (I)

A range of preventive measures have been initiated in the health sectors of many countries, including the banning of mercury-containing skin-lightening products and antiseptics, and the removal of mercury thermometers from health-care settings.

Despite vast progress on reducing exposure to mercury in the workplace, many workers who are in contact with mercury in their professional activities are still at risk.

Close cooperation between ministries of health and of the environment, and with other sectors responsible for the implementation of different aspects of the Minamata Convention – such as labour, industry, the economy and agriculture – is important.

Joint efforts by those working in the health sector and academia will benefit the collection of evidence on the health effects of hazardous chemicals.

The WHO publication *Implementation of the Minamata Convention in the health sector: challenges and opportunities* highlights the main challenges and opportunities as well as important achievements in the Convention’s implementation.

References:

WHO has developed step-by-step planning for implementation of the health-related articles of the Convention through:

- multisectoral coordination
- analysis
- prioritization
- planning of measures
- monitoring and control.

WHO developed a guidance to support health ministries in planning measures to implement the health-related articles of the Convention and to protect public health from exposure to mercury. It covers obligatory as well as voluntary measures under the Convention. Each health ministry will need to adapt its approach to the country’s particular needs and circumstances. The measures suggested here are therefore not prescriptive but rather intended to inform health ministries and partners about key considerations for developing plans related to the Convention.

The document includes recommendations on analysis and planning of health ministries’ measures, including:

- establishing a coordination mechanism
- taking stock of existing mercury risk assessment and control programmes
- analysing gaps
- planning strategically and setting priorities
- planning and implementing actions.

Practical tools in the guidance include a national action plan on ASGM activities (see Annex C of the Convention), worksheets for gap analysis and a strategic planning worksheet.

References:

Refer to the WHO website for more information on mercury, its health effects, the guidance document and the Minamata Convention on Mercury.

References:

MERCURY IN THE HEALTH SECTOR

CONTENTS

- Medical devices
- Dental amalgam
- Waste management and spill clean-up
- Thiomersal as a preservative in vaccines
A number of mercury-containing products are used in hospitals and other health-care settings. This leads to the production of mercury-containing wastes that must be managed as hazardous wastes. In laboratories, fixatives, preservatives and other products may also contain intentionally added mercury. Below is a non-exhaustive list of instruments, products used in hospitals that may contain mercury.

- Thermometers
- Sphygmomanometers
- Gastrointestinal tubes
- Dental amalgam
- Fluorescent light bulbs
- Pharmaceutical supplies
- Batteries (for both medical and nonmedical use)
- Electrical equipment
- Float control (septic tanks and sump pumps)
- Thermostats (non-digital)
- Reed relays (low-voltage, high-precision analytical equipment)
- Plunger or displacement relays (high-current/high-voltage applications)
- Thermostat probes in gas appliances (flame sensors, gas safety valves)
- Pressure gauges
- Devices such as personal computers that utilize a printed wire board
- Laboratory chemicals.

References:

SPHYGMOMANOMETERS AND THERMOMETERS IN HEALTH CARE

- These instruments are used to measure blood pressure and temperature – two key indicators in the evaluation of a patient’s health.
- They have been used in this way for more than 100 years.
- With the enforcement of the Minamata Convention, mercury-containing versions should be phased out. Time-bound targets were set for the prohibition of the manufacture, export or import of mercury-added products, including for health care.

References:


# MERCURY IN MEDICAL DEVICES

## Medical Device

<table>
<thead>
<tr>
<th>Medical device</th>
<th>Approximate amount of mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical thermometers</td>
<td>0.5–1.5 g</td>
</tr>
<tr>
<td>Lab thermometers</td>
<td>3.0–4.0 g</td>
</tr>
<tr>
<td>Portable and wall-mounted blood pressure units</td>
<td>110–200 g</td>
</tr>
<tr>
<td>Maloney or Hurst bougies (oesophageal dilators)</td>
<td>One tube may contain up to 1361 g of mercury</td>
</tr>
<tr>
<td>Cantor tubes(^1)</td>
<td>54–136 g</td>
</tr>
<tr>
<td>Miller-Abbott tubes(^1)</td>
<td>136 g</td>
</tr>
<tr>
<td>Dennis tubes(^1)</td>
<td>136 g</td>
</tr>
<tr>
<td>Foley catheter(^1)</td>
<td>68 g</td>
</tr>
</tbody>
</table>

\(^1\) Information from the Medical Device Reporting system of the United States Food and Drug Administration.  
\(^2\) Maloney or Hurst bougies are approximately 75 cm long with diameters ranging from 0.5–2 cm. They are commonly found in operating rooms, gastrointestinal labs and endoscopy departments.

(Source: reproduced from HCWH, 2017.)

Different mercury-added devices used in health-care settings contain different amounts of mercury. According to available information, it can vary significantly – from 0.5 g to 1.0 kg of mercury.

References:


MERCURY-CONTAINING MEDICAL THERMOMETERS

- Each thermometer contains a mean content of 1 g mercury.
- Until 1992, a typical large hospital (1000 beds) in the United Kingdom would order about 2000 thermometers a year.
- Sweden was the first country to ban mercury-containing thermometers in 1992.

References:


Digital thermometers are an alternative to mercury-containing thermometers. These are more expensive and require batteries or another source of energy, but they are just as accurate as mercury-containing thermometers and do not break as easily. Calculating all costs related to the management of mercury-containing devices demonstrates that alternatives are not expensive.

References:


Cost is a common concern in relation to the replacement of mercury-containing devices. While the cost of a single mercury-containing thermometer is much less than that of a digital device, such thermometers break far more often and therefore necessitate higher spending over the long term. For example:

- the National Institute of Traumatology and Orthopedics in Rio de Janeiro, Brazil, saved 33% of its outlay for thermometers by phasing out mercury-containing devices;
- Federico Gomez Children's Hospital (250 beds) in Mexico City, Mexico, saved an estimated US$ 10 000 over six years by switching to digital thermometers; and
- Hospital São Luiz (116 beds) in São Paulo, Brazil, estimated that it recovered its initial investment of US$ 9000 for the switch to mercury-free thermometers and sphygmomanometers, and is saving an additional US$ 2000 each year.

References:

# SPHYGGMOMANOMETERS

## Mercury-containing:
- **Content:** 100 g mercury per sphygmomanometer
- **Calibration/refilling** done in-house, usually without protection or training
- **Dangerously high vapour levels** in a typical calibration room

## Electronic:
- **Aneroid sphygmomanometers** are the most common alternative to mercury-containing devices
- **Same level of accuracy** for measurement
- **Require calibration** but no risk of release of toxic compounds
- **More expensive**

On average, a sphygmomanometer contains 100 g of mercury. The calibration and refilling of these devices is usually done by technical staff within the hospital. Staff members frequently lack training on safe mercury handling, and due to lack of awareness often do not use any protection. The open handling of mercury results in dangerously high mercury levels in the air of calibration rooms, which poses an intoxication risk. When out of use and turned to waste, mercury-containing sphygmomanometers create risks for the environment as well.

**References:**


GLOBAL POLICY, NATIONAL IMPLEMENTATION:
THE MINAMATA CONVENTION

- Phase out the manufacture, export or import of specified mercury-added products, including thermometers and sphygmomanometers.

- No further mercury-containing thermometers or sphygmomanometers can be procured after 2020* for routine use in health-care settings.

**Short term:** Develop and implement plans to reduce the use of mercury-containing devices and replace them with mercury-free alternatives. Address mercury clean-up, waste handling and storage procedures.

**Medium term:** Increase efforts to reduce the use of unnecessary mercury-containing devices.

**Long term:** Support a ban of mercury-containing devices and promote alternatives.

*For Parties afforded the maximum exemptions this will be 2030.

The Minamata Convention on Mercury acknowledges the risks of mercury-containing devices used in health care. It sets clear, time-bound targets for Parties to phase out the manufacture, export or import of a number of mercury-added products. For thermometers and sphygmomanometers that are included in a wider category of non-electronic medical devices regulated under Article 4 of the Convention, the phase-out date for their manufacture, export and import is 2020, with the possibility of Party-specific exemptions up to 2030.

To support Member States, WHO published key considerations and step-by-step guidance for developing national strategies to phase out mercury-containing devices from the health-care sector, including through substitution and replacement with alternatives.

**References:**


GUIDANCE FOR PHASING-OUT
MERCURY-CONTAINING DEVICES

WHO’s guidance on developing national strategies is based on its long-standing collaboration with Health Care Without Harm (HCWH) on the Global Initiative to Substitute Mercury-based Medical Devices in Health Care. In the last years, several successes have demonstrated the feasibility of phasing out mercury. The following documents, as well as the references below, provide valuable information on this issue.

• Guide for eliminating mercury from health care establishments. Prague: HCWH.

References:


DENTAL AMALGAM
WHAT IS DENTAL AMALGAM?

- Dental amalgam is a combination of metals containing about 50% mercury in elemental form, as well as silver, tin, copper and other trace metals.
- It has been used in the last 150 years for dental restoration due to its mechanical properties and its long-term use in dental practice.

References:

MAIN CONCERN RELATED TO DENTAL AMALGAM

- Dental amalgam is the primary source of exposure to inorganic mercury for most people with mercury-containing dental fillings.

- Workers in dental offices (dentists, dental hygienists) can be exposed to mercury through the preparation and use of mercury fillings. An elevated body burden of mercury in dentists and dental hygienists has been observed.

- Dental amalgam is a source of mercury into the environment (soil, air and water).

References:


ENVIRONMENTAL BURDEN OF DENTAL AMALGAM

Dental amalgam is often the largest source of mercury in municipal wastewater.

It also contaminates soil and air via:
- wastewater sludge
- land disposal
- burial of bodies.

<table>
<thead>
<tr>
<th>Main pathways</th>
<th>Mercury (metric tonnes/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>50–70</td>
</tr>
<tr>
<td>Surface water</td>
<td>35–45</td>
</tr>
<tr>
<td>Groundwater</td>
<td>20–25</td>
</tr>
<tr>
<td>Soil</td>
<td>75–100</td>
</tr>
<tr>
<td>Recycling of dental amalgam</td>
<td>40–50</td>
</tr>
<tr>
<td>Sequestered, secure disposal</td>
<td>40–50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>260–340</strong></td>
</tr>
</tbody>
</table>

(Source: reproduced from UNEP, 2013.)

References:


EMISSIONS OF MERCURY FROM DENTAL AMALGAM

Emissions from the cremation of bodies with dental amalgam account for 3.6 tonnes, or 0.2% of global anthropogenic emissions into the atmosphere.

Global anthropogenic atmospheric emissions

(Source: designed by the authors.)

References:


A number of epidemiological studies explore the possible health effects of mercury released from dental amalgam fillings. A variety of study designs has been used to evaluate risks for human health. The available studies show little evidence of effects on general chronic disease incidence or mortality.

In a New Zealand retrospective cohort study of 20,000 military personnel (84% male) followed up for 20 years, data on dental history were linked with national mortality, hospital discharge and cancer incidence databases. The study design was highly appropriate, but no association was found between dental amalgam and chronic fatigue syndrome or kidney diseases.

Investigation involving 49 healthy individuals with amalgam fillings and 51 matched controls showed collations between the mercury concentration in urine and the number of amalgam fillings. However, no high risks were revealed.

In a randomized clinical trial, referred to as the New England Children’s Amalgam Trial (534 children), groups with amalgam restorations and alternative composite resins were compared. After five years, renal data were obtained on 409 children. A significantly higher mean urinary mercury level was noted in the amalgam group, but the renal function was comparable in the two groups as measured by creatinine-adjusted albumin levels. A follow-up of the same group of children showed an increased prevalence of microalbuminuria among children with amalgam fillings, but no change in biomarkers for tubular function.

In the Casa Pia Children’s Amalgam study, 507 children from Lisbon, Portugal, were randomized to amalgam or composite resin dental care groups and evaluated annually over a seven-year period. Analyses showed no significant association of amalgam with various renal biomarkers including microalbuminuria.

The same conclusion about the health effects of dental amalgam was made by the European Commission’s non-food scientific committees – the Scientific Committee on Health and Environmental Risks (SCHER), the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) and the Scientific Committee on Consumer Safety (SCCS). In particular, the committees concluded that neurological effects associated to dental amalgam have not been convincingly demonstrated in humans.
References:


DENTAL AMALGAM – POLICIES

Global

Minamata Convention Article 4, Annex A, Part II: Phase-down of dental amalgam

Parties shall select at least two measures from the list provided in Annex A of the Convention:

i. Setting national objectives aiming at dental caries prevention and health promotion
ii. Setting national objectives aiming at minimizing its use
iii. Promoting the use of cost-effective and clinically effective mercury-free alternatives for dental restoration
iv. Promoting research and development of quality mercury-free materials for dental restoration
v. Encouraging representative professional organizations and dental schools to educate and train dental professionals and students on the use of mercury-free dental restoration alternatives and on promoting best management practices
vi. Discouraging insurance policies and programmes that favour dental amalgam use over mercury-free dental restoration
vii. Encouraging insurance policies and programmes that favour the use of quality alternatives to dental amalgam for dental restoration
viii. Restricting the use of dental amalgam to its encapsulated form
ix. Promoting the use of best environmental practices in dental facilities to reduce releases of mercury to water and land

Article 4 of the Minamata Convention (paragraph 2) on mercury-added products states: “Each Party shall take measures for the mercury-added products listed in Part II of Annex A in accordance with the provisions set out therein.” Paragraph 3 of Annex A, Part II focuses on dental amalgam. It states that measures to be taken by a Party to phase down the use of dental amalgam shall take into account the Party’s domestic circumstances and relevant international guidance, and shall include two or more measures from the following list:

• setting national objectives aiming at dental caries prevention and health promotion, thereby minimizing the need for dental restoration;
• setting national objectives aiming at minimizing its use;
• promoting the use of cost-effective and clinically effective mercury-free alternatives for dental restoration;
• promoting research and development of quality mercury-free materials for dental restoration;
• encouraging representative professional organizations and dental schools to educate and train dental professionals and students on the use of mercury-free dental restoration alternatives and on promoting best management practices;
• discouraging insurance policies and programmes that favour dental amalgam use over mercury-free dental restoration;
• encouraging insurance policies and programmes that favour the use of quality alternatives to dental amalgam for dental restoration;
• restricting the use of dental amalgam to its encapsulated form; and
• promoting the use of best environmental practices in dental facilities to reduce releases of mercury and mercury compounds to water and land.

References:
ii. Setting national objectives aiming at minimizing its use

iii. Promoting the use of cost–effective and clinically effective mercury-free alternatives for dental restoration

iv. Promoting research and development of quality mercury-free materials for dental restoration

v. Encouraging representative professional organizations and dental schools to educate and train dental professionals and students on the use of mercury-free dental restoration alternatives and on promoting best management practices

vi. Discouraging insurance policies and programmes that favour dental amalgam use over mercury-free dental restoration

vii. Encouraging insurance policies and programmes that favour the use of quality alternatives to dental amalgam for dental restoration

viii. Restricting the use of dental amalgam to its encapsulated form

ix. Promoting the use of best environmental practices in dental facilities to reduce releases of mercury to water and land

Global

Minamata Convention Article 4, Annex A, Part II:

Phase-down of dental amalgam

Parties shall select at least two measures from the list provided in Annex A of the Convention.

DENTAL AMALGAM – POLICIES

1. Setting national objectives aiming at dental caries prevention and health promotion
2. Setting national objectives aiming at minimizing its use
3. Promoting research and development of clinically effective mercury-free alternatives for dental restoration
4. Promoting the use of cost–effective and clinically effective mercury-free alternatives for dental restoration
5. Discouraging insurance policies and programmes that favour dental amalgam use over mercury-free dental restoration alternatives and on promoting best management practices
6. Encouraging representative professional organizations and dental schools to educate and train dental professionals and students on the use of mercury-free dental restoration alternatives and on promoting best management practices
7. Discouraging insurance policies and programmes that favour dental amalgam use over mercury-free dental restoration alternatives and on promoting best management practices
8. Promoting the use of quality alternatives to dental amalgam for dental restoration
9. Restricting the use of dental amalgam to its encapsulated form
10. Promoting the use of best environmental practices in dental facilities to reduce releases of mercury to water and land


## ADVANTAGES AND DISADVANTAGES OF RESTORATIVE MATERIALS

<table>
<thead>
<tr>
<th>Dental amalgam</th>
<th>Resin-based composites</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Moderate leakage</td>
<td>• Low leakage</td>
</tr>
<tr>
<td>• Good-to-excellent durability</td>
<td>• Moderate-to-good durability</td>
</tr>
<tr>
<td>• High resistance to wear</td>
<td>• Up to moderate resistance to wear</td>
</tr>
<tr>
<td>• Requires removal of tooth structure</td>
<td>• Adhesive bonding requires less removal of tooth structure</td>
</tr>
<tr>
<td>• Tolerant to a wide range of clinical conditions</td>
<td>• Requires well-controlled field of operation</td>
</tr>
<tr>
<td>• Affordable and easy to use</td>
<td>• 2/3 times more expensive than dental amalgam</td>
</tr>
<tr>
<td>• Longevity of 10–15 years</td>
<td>• Longevity of 5–8 years</td>
</tr>
</tbody>
</table>

The most commonly used alternatives to dental amalgam are:

- resin-based composite materials;
- modifications of resin-based composites (polyacid modified composites), compomers and giomers (glass-filler modified composites);
- glass-ionomer cements/water-based cements, self-setting “pure” glass ionomers or, more frequently, light-cured (resin-modified) glass ionomers; and
- long-term temporary materials such as reinforced zinc oxide-eugenol cements.

The development of so-called smart composites, amorphous calcium phosphate polymeric composites that respond to oral microflora by releasing chemotherapeutics or antimicrobials such as calcium and fluoride may circumvent some of the shortcomings of composite restorations. Research on a material based on glass-ionomer technology, on low-shrinking resins and on high-strength fillers with simple handling and acceptable longevity is in progress.

Dental amalgam shows more material leakage than the composites, and its implantation requires the removal of a greater amount of tooth material. However, the newer composites cannot compete with the durability and longevity of dental amalgam. Furthermore, the composites require a well-controlled field of operation for implantation and are more expensive. Further research is needed to improve the characteristics of the new composites.

References:


RECOMMENDATIONS

Strengthen health promotion and the prevention of dental caries.

Consider the sanitation and waste management practices of medical facilities using dental amalgam.

Encourage health facilities to adopt environmentally sound waste management practices.

Ensure that decisions on the use of dental restoration materials are made through informed interaction between patients and providers of dental care.

Increase responsibility of the dental industry.

Ensure that dental care interventions are financially affordable and included into Universal Health Coverage.

Strengthening disease prevention and health promotion is the most relevant approach to reducing the need for restorative dental care and the most efficient way to phase down the use of dental amalgam. Public health intervention is needed to foster healthy lifestyles – including low-sugar diets, good dental hygiene and the effective use of fluoride – and to orient oral health systems towards disease prevention and health promotion.

In countries where dental-care facilities are underdeveloped and where essential requirements such as water, electricity, suction and equipment are restricted or lacking, efforts should be made to improve conditions. Good management practices should be adapted accordingly and a phase-down programme for amalgam should be instituted. The availability of alternative restorative materials that do not require sophisticated equipment for manipulation and placement must also be encouraged.

In the vast majority of countries around the globe, the current cost of applying glass ionomer or composite materials for restoration is high to both the patient and society compared to that of using dental amalgam. Actions are therefore needed to ensure that dental services are financially fair. The dental-care provider should be able to identify a restorative material that is best for the patient, and to provide patients with accurate information on the advantages/disadvantages and safety of available materials.

Industry can contribute to appropriate dental care by improving the standard of existing tooth-coloured materials and by developing new materials of high quality. In low-resource communities, it is imperative to increase the availability of new dental materials and develop the market for alternatives to amalgam. Better supply and distribution of materials should also be established.

References:

The WHO report on phasing down the use of dental amalgam summarizes different successful intervention strategies and provides helpful recommendations, including:

- creating awareness of the environmental risks of dental amalgam;
- promoting alternatives for dental amalgam in dental restoration when clinically indicated;
- building the capacities of dentists to promote oral health and disease prevention;
- supporting best management practices and environmentally sound management of waste; and
- ensuring that regulatory frameworks and legislation are in place.

**References:**


MANAGEMENT OF MERCURY-CONTAINING WASTES
MERCURY RELEASES INTO ENVIRONMENT
FROM HEALTH-CARE FACILITIES

• Health-care facilities contribute up to 5% of mercury releases into water bodies through untreated wastewater.

• Health-care waste incineration is one of the main sources of mercury releases into the atmosphere from health-care facilities.

• The United States Environmental Protection Agency estimates that medical incinerators may have historically contributed up to 10% of mercury releases into air.

• In the United Kingdom, more than 50% of total mercury emissions come from mercury contained in dental amalgam and laboratory and medical devices.

References:

HAZARDOUS WASTES
FROM HEALTH-CARE SETTINGS

- Mercury is one example of a highly toxic yet common substance in health-care facilities.
- Mercury wastes are typically generated by spillage from broken clinical equipment (for example, mercury-containing thermometers and sphygmomanometers).
- Residues from dentistry also contain mercury.

References:

Mercury is an example of a highly toxic yet common substance in health-care facilities. Mercury wastes are typically generated by spillage from broken clinical equipment. Whenever possible, spilt drops of mercury should be recovered. Residues from dentistry also have high mercury contents. Example of management of mercury-containing wastes are presented on the slide.

References:
The preferred solution to the problem of hazardous health-care wastes is simply not to produce the wastes in the first place. To achieve lasting waste reduction (or minimization), the focus should be on working with medical staff to adopt clinical practices that use less mercury. The replacement of mercury-containing devices with mercury-free ones is the best option for minimizing mercury-containing wastes in health-care settings.

References:


According to Global Environment Facility (GEF) guidance, the following steps should be considered when establishing a storage site for mercury waste.

- The storage space should be located in a secure, restricted-access area. If the storage space is in a multipurpose building, it should be a locked room or locked partitioned space.
- The storage space should be readily accessible to personnel who are authorized to collect, store and transport the waste.
- The exhaust vent from the storage space should not direct air towards crowded areas and should be far from any air intake vents.
- An estimate should be made of the anticipated volume of mercury and mercury waste to be stored and this value should be used to determine the minimum size of the storage space, and the types and sizes of containers.
- Mercury waste should be kept segregated from regular waste, infectious waste and other types of waste.
- The entrance and exit doors of the storage space should be marked with warning signs, such as “Danger: hazardous mercury waste” and the skull-and-crossbones symbol for toxic or poisonous waste.
- The waste containers should be labelled “Hazardous mercury waste" along with a description of the contents and the initial date of storage.

General principles for the containment of different types of mercury are as follows.

- Store mercury waste in primary and secondary containers: a primary container for the waste and a secondary container that prevents release of mercury if the primary container breaks.
- Label the primary container, and label the secondary container if it is not transparent.
- Place a spill-containment tray directly under the containers in storage.

See the next slides for more information on the design of a storage space and storage practices.

References:

The area selected for mercury-containing wastes storage should be:

- secure and restricted to prevent theft;
- readily accessible to mercury waste handlers;
- separate from regular or infectious waste storage areas; and
- kept cool with natural or forced ventilation and kept dry if using steel containers (< 40% humidity).

References:

DESIGN OF A STORAGE AREA (II)

- The space should be enclosed with a roof and walls and a locked door.
- Its size should be based on the amount of waste to be stored plus space for the movement of materials.
- Ventilation should lead outside and away from people.
- Seamless, smooth flooring should be made of impervious material.
- A binding or spill-containment tray should be placed on the floor below the waste containers.
- A spill clean-up kit, personal protective equipment (PPE) and wash area should be near (but not in) the storage area.

References:

STORAGE PRACTICES (I)

**SPECIAL TRAINING** on mercury waste management, including spill clean-up, should be provided to all personnel involved in the collection, storage, transport and supervision of mercury waste.

**MATERIAL SAFETY DATA SHEETS** and International Chemical Safety Cards on mercury should be discussed with employees.

**REPLENISHMENT** of the contents of spill kits should be ensured by the most senior staff involved in a clean-up. Spill kits should have a signed sheet indicating when they were used and replenished.

**NO SMOKING OR EATING** should take place in or around the storage space.

References:
STORAGE PRACTICES (II)

The storage space should be inspected every month for:

- leaks
- corroded or broken containers
- improper storage methods
- ventilation
- conditions of PPE and wash area
- spill kit contents
- updated records.

Inventory records should be kept of the types of mercury waste being stored, descriptions, quantities and initial dates of storage.

References:

SPILL CLEAN-UP
Mercury vapours from a spill are invisible but can be seen under ultraviolet light and a fluorescent screen.

Mild, subclinical signs of central nervous system toxicity can be seen in workers exposed to an elemental mercury level in the air of 20 μg/m³ or more for several years.

The common problem of mercury spillage is due to incorrect and insufficient removal of mercury. Mercury evaporates at room temperature and poses a health hazard when handled incorrectly. The vapour is invisible and odourless, and can therefore only be detected under ultraviolet light. The WHO occupational exposure limit of 0.02 mg/m³ of air is easily exceeded: for example, in a room of 20 m² with normal ceiling height, a vaporizing of 0.074 µl or 74 nl of mercury is enough to reach the limit.

References:


PPE FOR MANAGING A MERCURY SPILL

The following PPE are needed to clean a spill:

- A pair of rubber or nitrile gloves
- Safety goggles or protective eyewear
- Coveralls, apron and other protective clothing
- Disposable shoe covers
- Respiratory protection.

References:

1. Quickly determine the area affected by the mercury spill.

2. Immediately block off foot traffic for a radius of about 2 m around the spill.

3. Contain the spill – use rags or impervious materials to prevent mercury balls from spreading or falling into cracks or drains.

4. Evacuate the immediate area – give priority to pregnant women and children.

5. Minimize the spread of vapours to interior areas – close doors to interior areas, turn off ventilation or air conditioning that circulates air to other areas.

References:

PROCEDURE TO CLEAN UP A MERCURY SPILL (II)

6. Reduce vapour concentrations in the spill area if possible – open doors or windows that lead to outside areas that are free of people.

7. Prepare for the clean-up by getting the mercury spill kit and remove jewelry, watches, mobile phones and other metallic items that could amalgamate with mercury. Cover metal eyeglass frames.

8. Put on PPE: old clothes, an apron or coveralls, shoe covers, rubber or nitrile gloves, eye protection and respiratory protection.

References:

PROCEDURE TO CLEAN UP A MERCURY SPILL (III)

9. First, remove visible mercury balls and broken glass beginning from the outer edge of the spill and moving towards the center of the spill:

- place the wide-mouth jar on the plastic tray;
- use tweezers to remove broken glass;
- use playing cards or pieces of plastic to slide mercury balls into the scoop, then into the jar over the tray to catch spillage; and
- use the eye dropper or syringe to capture small mercury beads.

References:

10. Search for and remove tiny mercury droplets using the flashlight at low angles to see their reflections. Use sticky tape to pick up tiny droplets and place the tape with the mercury in a sealable plastic bag.

11. Clean up cracks and hard surfaces:

- sprinkle sulfur powder, zinc or copper flakes on cracks, floor crevices and hard surfaces that have come in contact with mercury;
- use a brush to collect the powder or flakes and put them in a resealable bag; and
- wipe with vinegar-soaked and peroxide-soaked swabs.

References:

PROCEDURE TO CLEAN UP A MERCURY SPILL (V)

12. Remove contaminated soft material (carpets, rugs, etc.) using a knife to cut them out. Put them in a sealable bag.

13. Clean out contaminated drains. Carefully transfer any mercury in the J or S trap and transfer to an air-tight container before replacing the trap.

14. Dispose of decontaminated material as mercury waste in leak-proof, sealable plastic bags.

15. Label and seal all contaminated material.

References:

**PROCEDURE TO CLEAN UP A MERCURY SPILL (VI)**

16. Wash hands and all exposed skin with soap and water.

17. Ventilate the spill area:
   - place heaters and fans to volatilize residual mercury and to blow contaminated air to the outside for at least 48 hours; and
   - in facilities with central ventilation, increase air exchange rates for several days.

18. Conduct medical monitoring of staff or patients that were exposed to high levels of mercury.

19. Write a report on the spill incident and recommend improvements to prevent future spills.

References:

MANAGING A MERCURY SPILL

- **Never use a vacuum cleaner** to clean up mercury.
- **Never use a broom** to clean up mercury.
- **Never pour** mercury down a drain.
- **Never wash** contaminated clothing or fabrics in a washing machine.
- **Never walk around** if your shoes might be contaminated with mercury.

References:

Each health-care facility should have 2–3 spill clean-up kits available.

Once a kit is used it must be replaced.

Kits must be used by trained personnel.

A kit must include instructions.

A kit should also include:

- 4–5 resealable zipper bags;
- trash bags (at least 2 mm thick);
- a plastic container with a lid that seals (for example, a 35 mm film canister);
- nitrile or latex gloves;
- paper towels;
- cardboard strips.

Spill clean-up kits can be purchased or assembled. Each facility using mercury devices should have 2–3 kits readily available. Once used, the material must be replaced to avoid contamination. The kits should be used by trained personnel and should include instructions.

References:

MERCURY CLEAN-UP AND DISPOSAL

Requirements:

- Maintenance protocol
- Education and training
- Spill clean-up kits
- Waste collection
- Disposal and storage

This slide lists the requirements for properly handling mercury and mercury-containing devices. Staff should be trained in handling mercury and mercury spills. There should be maintenance protocols for mercury-containing devices and the facilities in contact with mercury. As previously mentioned, spill clean-up kits are necessary. There must be mercury waste collection as well as proper containers and facilities to store and dispose of the mercury.

References:

THIOMERSAL AS A PRESERVATIVE IN VACCINES
Thiomersal (ethylmercury) is a mercury-containing organic compound. Since the 1930s, it has been widely used as a preservative in a number of biological and drug products, including many vaccines, to help prevent potentially life-threatening contamination with harmful microbes. The documented antimicrobial properties of thiomersal contribute to the safe use of vaccines in multidose vials.

Multidose vials are used in many countries because they require less storage space in the cold chain and lead to less wastage, both of which have a significant impact on programme costs. In many countries, the presence of a preservative is a regulatory requirement for inactivated vaccines supplied in multidose vials. Thiomersal-containing vaccines are being used in over 120 countries. The ability to package certain vaccines in multidose vials facilitates immunization campaigns around the world that save lives.

References:


SAFETY OF VACCINES WITH THIOMERSAL

Global Advisory Committee on Vaccine Safety (GACVS) conclusions:

- The half-life of ethylmercury is 3–7 days. It is efficiently excreted and does not accumulate.
- No evidence for an association with neurodevelopmental disorders or autism has been found.
- Levels of ethylmercury from cumulative doses of vaccines do not reach toxic levels.
- Thiomersal allows millions of people worldwide to access vaccines.
- No safer and equally efficacious alternative has been identified for many vaccines.

The Global Advisory Committee on Vaccine Safety (GACVS), an expert clinical and scientific advisory body, was established by WHO to provide independent, scientifically rigorous advice on vaccine safety issues of potential global importance. Between 2002 and 2008, GACVS reviewed several pharmacokinetic and epidemiological studies concerning thiomersal. Pharmacokinetic data in human infants, including premature and low-birthweight infants, established that the half-life of ethyl mercury is 3–7 days, and that ethyl mercury is efficiently excreted in faeces. The data showed that ethyl mercury does not accumulate over the long term in blood, since levels returned to baseline within 30 days of vaccination.

At its June 2012 meeting, GACVS comprehensively reviewed the most recent information concerning the safety of thiomersal since its last review in 2008. It identified 28 publications that addressed mercury blood levels in the short and long term following vaccine administration, and epidemiological studies that examined the relation between thiomersal receipt and several health outcomes. All studies conducted with more robust epidemiological designs and in different countries failed to identify any association of thiomersal with neurodevelopmental disorders. In addition, the continuous increase in the number of cases of autism diagnosed in the United States despite the removal of thiomersal from most vaccines strongly argues against a causal association (fulfilling the exposure and removal criteria).

GACVS concluded that animal or human toxicity studies suggest that the levels of thiomersal attained in the blood and brain from cumulative doses of vaccines do not reach toxic levels, making any relation between thiomersal in vaccines and neurological toxicity biologically implausible.

Based on the current evidence, GACVS considers that no additional studies of the safety of thiomersal in vaccines are warranted and that available evidence strongly supports the safety of the use of thiomersal as a preservative for inactivated vaccines. Thiomersal allows millions of people worldwide to have access to life-saving vaccines and, to date, no other safer and equally efficacious alternative has been identified for many vaccines.

References:

The WHO Regional Office for Europe

The World Health Organization (WHO) is a specialized agency of the United Nations created in 1948 with the primary responsibility for international health matters and public health. The WHO Regional Office for Europe is one of six regional offices throughout the world, each with its own programme geared to the particular health conditions of the countries it serves.

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