Children's health and the environment
WHO training package for the health sector

MERCURY

TRAINING FOR HEALTH CARE PROVIDERS
THIRD EDITION

World Health Organization

[Date … Place … Event … Sponsor … Organizer]

Notes on this module:

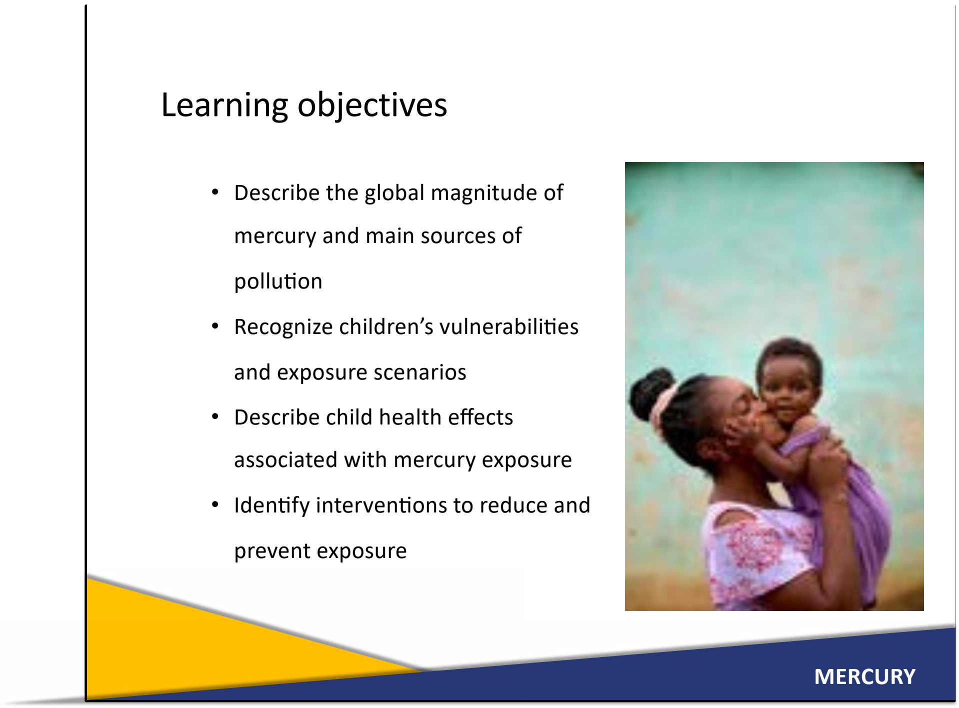
- please add details of the date, time, place and sponsorship of the meeting for which you are using this presentation in the space indicated;

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

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

- the World Health Organization (WHO) reference number for the module ***Mercury: training for health care providers, third edition*** is WHO/HEP/ECH/CHE/24.02;

- for more information on WHO's work on children's environmental health, please visit: https://www.who.int/health-topics/children-environmental-health.

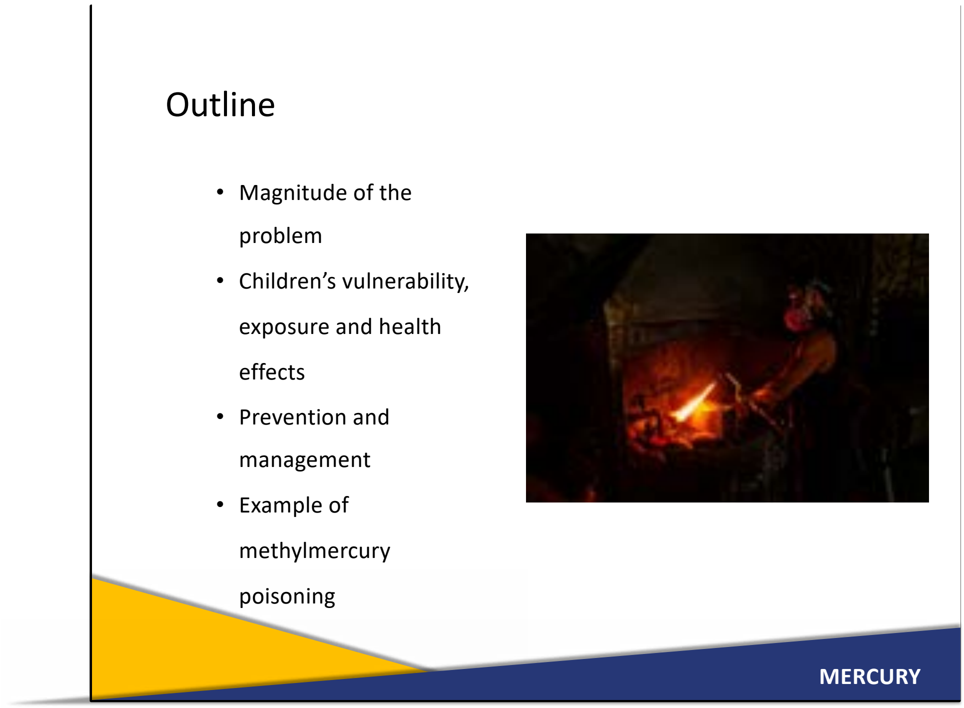


This presentation is an introduction to the effects of mercury on children's health.

By the end of this presentation, learners should be able to:
- describe the global magnitude and the main sources of mercury pollution;
- recognize children's vulnerabilities to mercury and the different scenarios in which they may be exposed;
- describe child health effects associated with mercury exposure;
- identify interventions and strategies that may reduce and prevent mercury exposure in children.

Photo:

- © WHO/ Fanjan Combrink. Rebecca and her child Mercy at home in Gyabankrom.



Note:
When selecting the slides to include in your presentation, please choose only those of relevance to the region and/or interests of your audience.

This training module includes the following sections:
- magnitude of the problem
- children's vulnerability to mercury, exposure scenarios and health effects
- prevention and management to reduce and prevent exposure
- example of methylmercury poisoning.

Photo:
- © WHO/ Yoshi Shimizu. A local miner applying the torching process using mercury to extract gold.

Outline

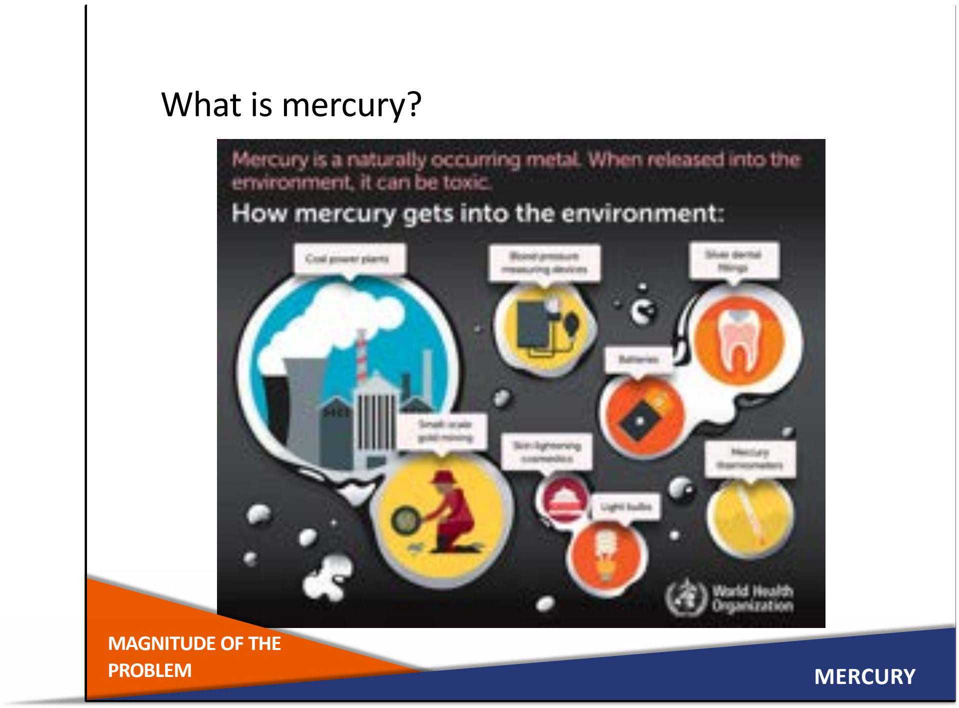
- Magnitude of the problem
- Children's vulnerability, exposure and health effects
- Prevention and management
- Example of methylmercury poisoning

MERCURY

The first section of this module begins with the global magnitude of the problem. This section also discusses the three different types of mercury, their main sources and how they are released into the environment.

Photo:

- © WHO/ Yoshi Shimizu. A local miner applying the torching process using mercury to extract gold.



What is mercury? Mercury is a naturally occurring metal found in the earth's crust. It is released from the earth's crust and into the environment due to human activities, as well as through natural processes, such as volcanic activity and degradation of rocks. It has a lengthy history in human activities, likely reaching back to ancient times. A significant proportion of mercury in the atmosphere today is the result of historic human activities and consequential mercury pollution *(1)*. Exposure to mercury is ubiquitous. Children everywhere in the world are exposed to mercury in some form, usually at very low levels *(2,3)*.

Human activities are the primary cause of mercury's release into the environment *(3)*. Mercury is released into the environment through *(3–5)*:

- artisanal and small-scale gold mining
- coal-fired power stations
- residential coal burning for heating and cooking
- non-ferrous metal production
- processing and use of gas and oil
- industrial processes
- waste incinerators, open burning practices and contaminated sites.

Mercury is also used in many consumer products found in everyday life, such as *(6)*:

- some medical equipment
- some batteries
- dental amalgams
- skin lightening products
- some light bulbs
- some thermometers
- certain components of electrical and electronic items.

Exposure to mercury through these products may occur when they are used (for example the use of skin lightening products) or when products break down, malfunction or are disposed of inappropriately. These products can then release mercury into the environment, posing a serious threat to the health of children and adults *(6)*.

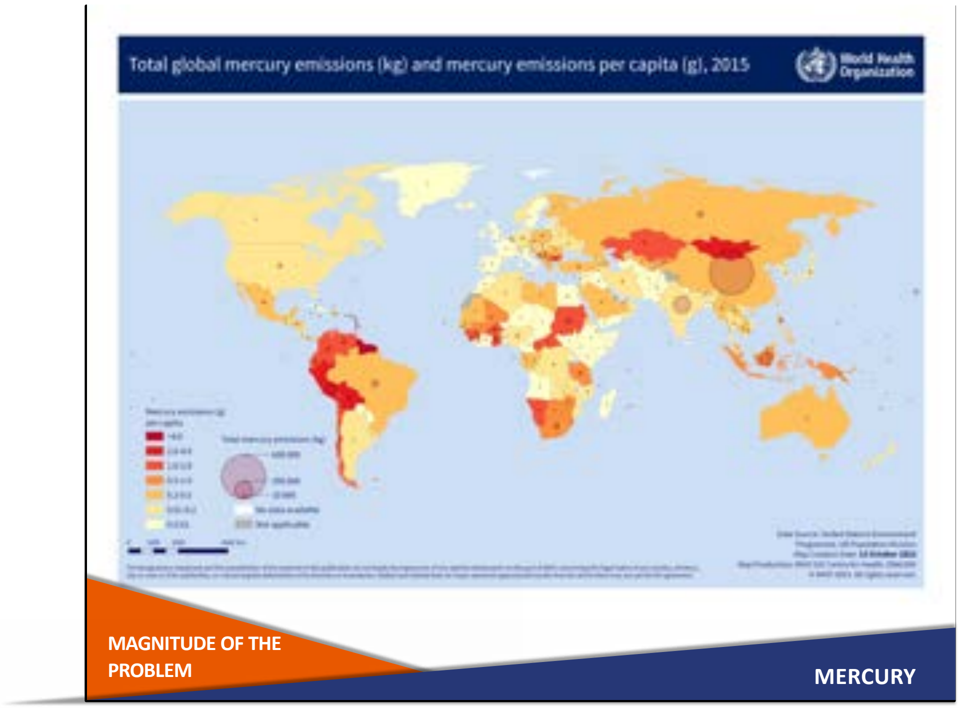
There are three forms of mercury *(6)*:

1. elemental mercury
2. inorganic mercury compounds
3. organic mercury.

It is important to recognize which form, or forms, children are exposed to. Elemental, organic and inorganic mercury compounds are found in different products and sources, may have different routes of exposure and can have different clinical effects. All three forms of mercury are toxic to humans, particularly the fetus and children, and can affect multiple systems. Mercury is considered one of the 10 chemicals or groups of chemicals of major public health concern *(7)*. Protecting children from toxic mercury exposure depends upon the form or forms of mercury *(6)*. The three forms of mercury are discussed in greater detail in the following slides.

References:

1. Global mercury assessment 2018. Geneva: United Nations Environment Programme; 2019 (https://www.unep.org/resources/publication/global-mercury-assessment-2018, accessed 15 January 2024).
2. Toxicological profile for mercury (draft for public comment). Atlanta: Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Public Health Service; 2022 (https://wwwn.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=115&tid=24, accessed 15 January 2024).
3. Mercury and health [website]. Geneva: World Health Organization; 2017 (https://www.who.int/news-room/fact-sheets/detail/mercury-and-health, accessed 15 January 2024).
4. UNEP Global Mercury Partnership study report on mercury from non-ferrous metals mining and smelting. Geneva: United Nations Environment Programme; 2021 (https://www.unep.org/globalmercurypartnership/resources/report/mercury-non-ferrous-metals-mining-and-smelting, accessed 15 January 2024).
5. UNEP Global Mercury Partnership study report on mercury from gas and oil. Geneva: United Nations Environment Programme; 2022 (https://www.unep.org/globalmercurypartnership/resources/report/mercury-oil-and-gas, accessed 15 January 2024).
6. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).
7. 10 chemicals of public health concern [website]. Geneva: World Health Organization; 2020 (https://www.who.int/news-room/photo-story/photo-story-detail/10-chemicals-of-public-health-concern, accessed 15 January 2024).



This map shows the total global mercury emissions in kilograms in 2015, which is illustrated by the circle on each country, territory and area. The larger the circle, the greater the amount of mercury emitted from each country, territory and area. The map also shows mercury emissions per capita in 2015, which is illustrated by the colouring of each country, area and territory. Pale yellow indicates the lowest amount of mercury emitted per capita in 2015, while red shows the countries, territories and areas with the highest amounts of mercury emitted per capita. Some countries, territories and areas emit a low amount of total mercury, but when it is calculated per capita the data looks different.

Most mercury in the environment today is the result of human activity. The United Nations Environment Programme (UNEP) estimated that, as of 2015, human activities have increased the total global atmospheric mercury concentrations by about 450% above natural levels. In 2015, an estimated 2220 tonnes of mercury emissions globally were released into the atmosphere from anthropogenic sources *(1)*.

In 2015, UNEP estimated that *(1)*:

- **artisanal and small-scale gold mining** was responsible for almost 38% of total global mercury emissions;
- **stationary combustion of fossil fuels and biomass, including coal,** was responsible for about 24% of total global mercury emissions;
- **non-ferrous metal production** was responsible for 15% of total global mercury emissions;
- **cement production** was responsible for 11% of total global mercury emissions;
- **emissions from waste** were responsible for 7% of total global mercury emissions.

These emissions accounted for around 30% of all mercury released into the atmosphere globally in 2015. About 60% of mercury released globally in 2015 was due to environmental processes that recycled historic anthropogenic mercury pollution back into the atmosphere. Only 10% of mercury released globally in 2015 came from natural processes, such as volcanic activity and weathering of rocks *(1)*.

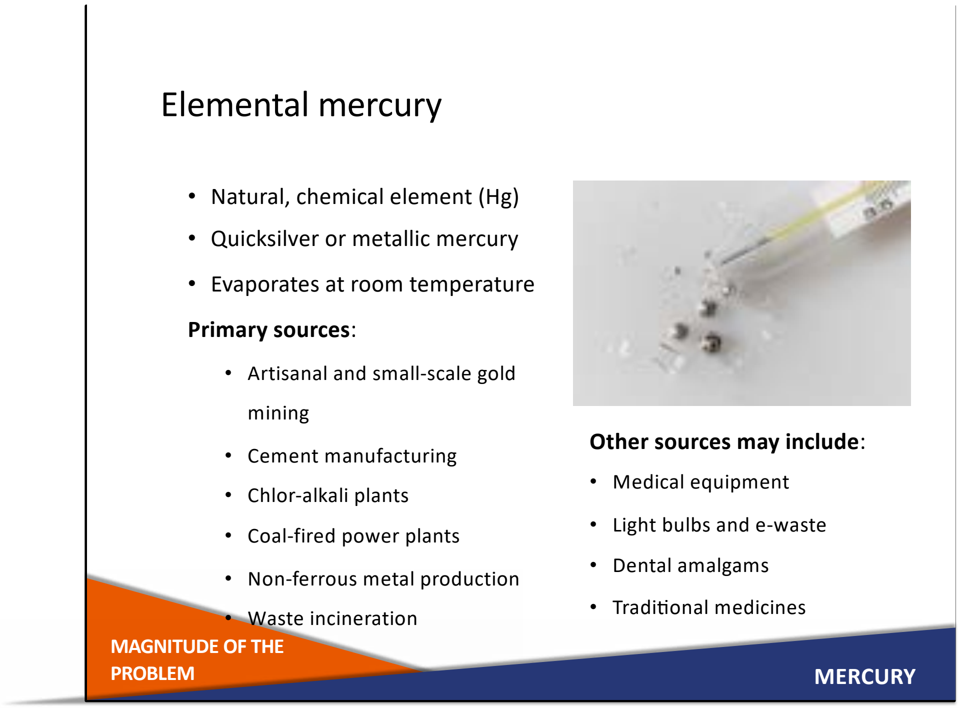
Note on the map that the highest total mercury emissions recorded in 2015 were located over the World Health Organization's (WHO) African, South-East Asia and Western Pacific Regions, as well as over countries, areas and territories in Latin America.

Note: to learn more about mercury emissions in your country in 2015 visit UNEP's interactive map here: https://www.unep.org/explore-topics/chemicals-waste/what-we-do/mercury/global-mercury-assessment.

Reference:

1. Global mercury assessment 2018. Geneva: United Nations Environment Programme; 2019 (https://www.unep.org/resources/publication/global-mercury-assessment-2018, accessed 15 January 2024).

Map:
- © WHO.
- Data: UNEP, UN Population Division.



Elemental mercury is also known as metallic mercury or quicksilver due to its silvery, liquid appearance. It is a unique and natural chemical element found in rock in the earth's crust, including coal deposits. The chemical symbol for mercury is Hg. Elemental mercury evaporates readily at room temperature and becomes an odourless vapour. Inhalation of mercury vapour is extremely harmful to human health *(1)*.

Elemental mercury is found in many consumer products and released through many anthropogenic industries and activities. The primary global sources of elemental mercury pollution include *(1–4)*:
- **artisanal and small-scale gold mining**, where mercury is used to extract gold from gold-bearing ore (see Slide 8 for more detail on artisanal and small-scale gold mining);
- **cement manufacturing**;
- **chlor-alkali plants**, which have been linked to major contamination events;
- **coal-fired power plants**, which are major sources of energy in many parts of the world;
- **non-ferrous metal production**, such as copper, lead, zinc and industrial gold;
- **waste incineration and opening burning**.

Other sources of elemental mercury may include *(1–3)*:
- **some medical equipment**, such as thermometers and sphygmomanometers (blood pressure measuring devices);
- **some light bulbs**, including fluorescent light bulbs and compact fluorescent light bulbs;
- **electrical and electronic waste (e-waste)** components and parts, such as switches and relays;
- **dental amalgams**, used in some dental fillings;
- **some traditional, complementary and integrative medical practices** use elemental mercury. For example, in Ayurvedic medicine, herbs may be deliberately combined with heavy metals, including mercury.

Note: highlight the main sources of elemental mercury contamination in your context.

Note: see Slide 11 for more detail explaining how elemental mercury can enter and transform in the environment.

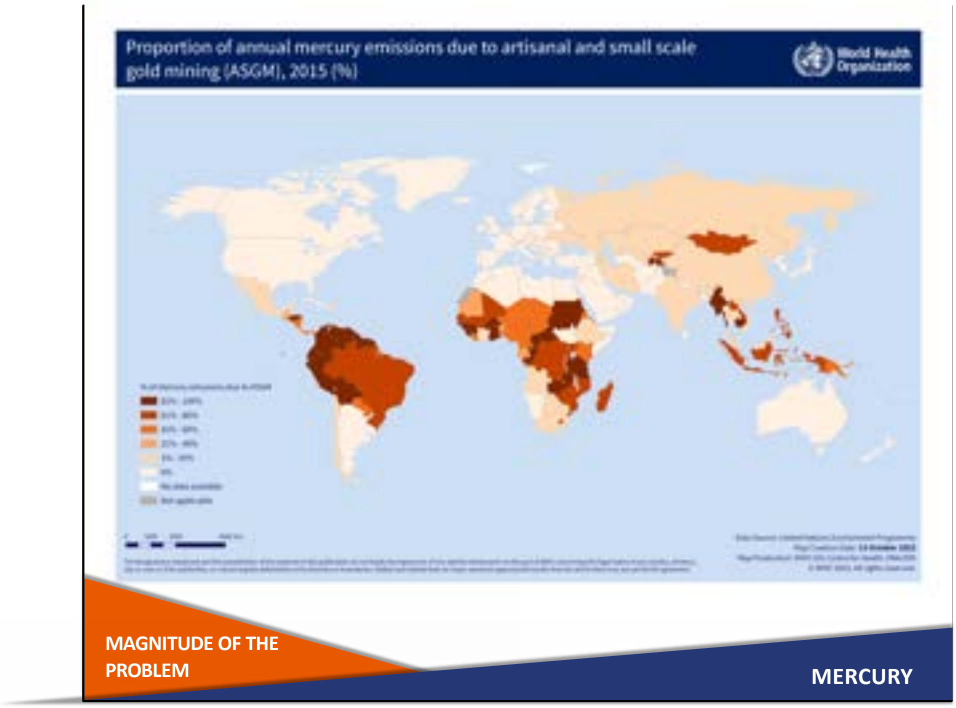
Note: for more detail on the chemical properties of elemental mercury, please visit the free virtual course *Mercury effects in human health and the environment and considerations under the Minamata Convention* provided by the Pan American Health Organization (PAHO) *(5)*.

References:
1. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).

2. Saper RB, Phillips RS, Sehgal A, Khouri N, Davis RB, Paquin J et al. Lead, mercury, arsenic in US- and Indian-manufactured Ayurvedic medicines sold via the internet. JAMA. 2008;300(8):915-23.
3. Global mercury assessment 2018. Geneva: United Nations Environment Programme; 2019 (https://www.unep.org/resources/publication/global-mercury-assessment-2018, accessed 15 January 2024).
4. UNEP Global Mercury Partnership study report on mercury from non-ferrous metals mining and smelting. Geneva: United Nations Environment Programme; 2021 (https://www.unep.org/globalmercurypartnership/resources/report/mercury-non-ferrous-metals-mining-and-smelting, accessed 15 January 2024).
5. Mercury effects in human health and the environment: considerations under the Minamata convention (2019 English edition) [online course]. Washington, D.C: Pan American Health Organization; 2024 (https://campus.paho.org/en/course/mercury-effects-human-health-and-environment-and-considerations-under-minamata-convention, accessed 15 January 2024).

Photo:

- © Shutterstock. Broken glass mercury thermometer.



The Minamata Convention on Mercury defines artisanal and small-scale gold mining as "gold mining that is conducted by individuals or small enterprises with limited capital investment and production" *(1)*. Usually, it is considered part of the informal sector. **Artisanal and small-scale gold mining is the single largest demand for elemental mercury in the world and the single largest source of anthropogenic mercury emissions globally** *(2)*. Virtually all mercury used in this kind of mining is released into the environment – into the air, water bodies and soil, as either a liquid (unwanted elemental mercury that is thrown away) or as a vapour (due to amalgamation and heating processes used to obtain gold). In 2015, the United Nations Environment Programme (UNEP) estimated that the combined combustion of coal and artisanal small-scale mining was responsible for almost 60% of all global mercury emissions released into the air *(3)*. Additionally, according to UNEP, artisanal and small-scale gold mining released about 1220 tonnes of mercury into global terrestrial and freshwater environments in 2015. However, UNEP also recognizes that there are significant uncertainties surrounding the fate of mercury released onto land or into water through activities in this sector *(3)*.

Artisanal and small-scale gold mining is largely practiced in low-and middle-income countries (LMICs) and has become an important source of livelihood, especially in communities where there are few other economic opportunities. Elemental mercury is used in the process of extracting gold from ore as it is cheap, quick and effective and requires minimal additional infrastructure or tools. UNEP reported that more than 15 million miners globally were involved in the sector in 2015 and possibly 100 million people lived in communities where artisanal and small-scall gold mining occurred. Studies of miners involved in these activities have found very high mercury exposure levels – as much as three times higher than levels measured in the average population *(3)*.

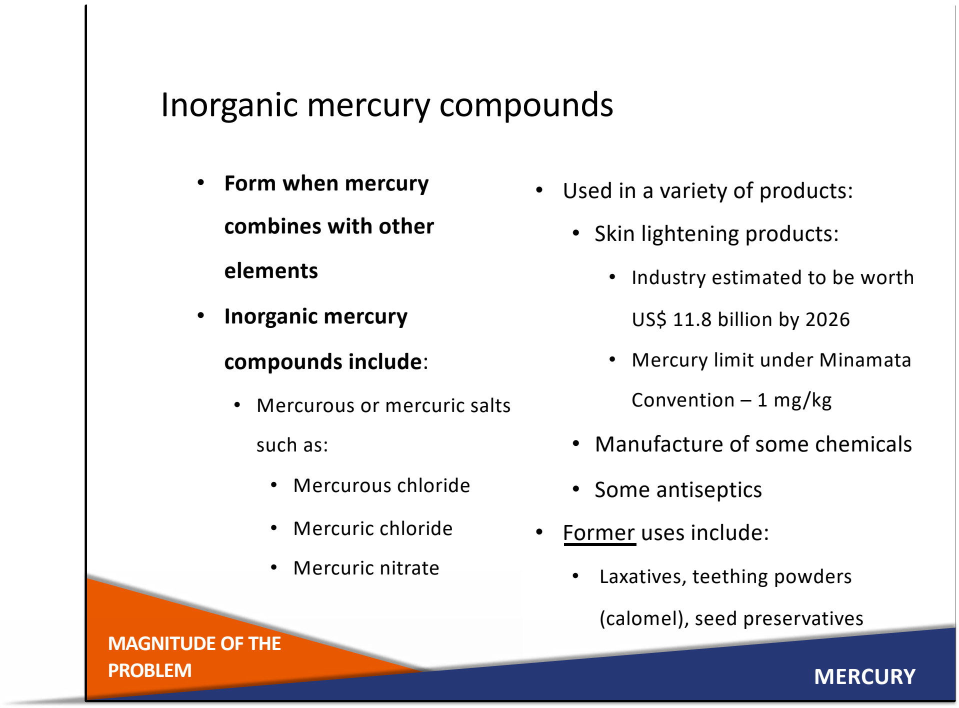
The map on this slide illustrates the proportion of annual mercury emissions due to artisanal and small-scale gold mining in 2015. The darker the colour of the country, area or territory the higher the proportion of mercury emissions due to artisanal and small-scale gold mining. The map also illustrates the distribution of artisanal and small-scale gold mining across the world. It is a significant sector in some countries, areas and territories in the World Health Organization's (WHO) African and South-East Asia Regions, as well as the Region of the Americas. Many of these countries, areas and territories also have a significant number of people living in poverty, where few alternatives means of economic opportunity are available.

Note: compare this map with the map shown on Slide 6. Connections between countries, areas and territories where artisanal and small-scale gold mining activities occur, and annual levels of mercury emissions can be observed.

Note: if applicable, use UNEP's interactive map to find the estimated contribution of artisanal and small-scale gold mining to mercury emissions in your country in 2015: https://www.unep.org/explore-topics/chemicals-waste/what-we-do/mercury/global-mercury-assessment.

References:
1. Minamata convention on mercury. Minamata convention on mercury: text and annexes – 2023 edition. Geneva: United Nations Environment Programme; 2023 (https://minamataconvention.org/en/documents/minamata-convention-mercury-text-and-annexes, accessed 15 January 2024).
2. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).
3. Global mercury assessment 2018. Nairobi: United Nations Environment Programme; 2019 (https://www.unep.org/resources/publication/global-mercury-assessment-2018, accessed 15 January 2024).

Map:
- © WHO
- Data: UNEP.



Inorganic mercury compounds form when elemental mercury combines with other elements, such as chlorine, sulfur or oxygen. This can occur naturally in the environment or due to human activity. Inorganic mercury compounds often form as white powders or crystals and may be known as “salts”. Inorganic mercury compounds include both mercurous and mercuric salts, such as mercurous chloride, mercuric chloride and mercuric nitrate *(1)*.

Inorganic mercury compounds are found in a variety of consumer products around the world. These compounds are common ingredients found in many **skin lightening products, including creams and soaps**. These items are commonly marketed and sold in African, Asian and Caribbean countries. They are also used by dark-skinned populations in Europe and North America, and are used by men and women, boys and girls. Skin lightening products and cosmetics constitute one of the fastest growing beauty industries (including both mercury- and non-mercury-containing products) *(2)*. This industry is estimated to be worth about US$ 11.8 billion by 2026 *(3)*. Many countries have placed bans or restrictions on skin lightening products containing mercury, however, they continue to be widespread across the world and are easily purchased, for example via online stores *(2)*. The Minamata Convention on Mercury has established a limit of 1 milligram per kg (mg/kg) for skin lightening products, but commercial items are regularly found to exceed this limit *(2)*.

Inorganic mercury compounds are also used in the **manufacture** of some chemicals, including some disinfectants, caustic soda and chlorine gas. Mercury used in these circumstances can contaminate other products, unless stringent control measures are taken *(4)*. Some therapeutic antiseptics used for topical treatment of certain skin infections still contain inorganic mercury compounds, although their use is no longer widespread *(5)*.

In the past, inorganic mercury compounds were used for several medicinal purposes that are no longer in use today due to their recognized hazards to human health. These uses included:

- mercurous chloride, also known as calomel, was previously used in a range of medical products including laxatives and infant teething powders *(6,7);*
- mercuric chloride was previously used as a preservative agent, including in antiseptic products *(8)*.

Some inorganic mercury compounds have also been used as seed preservatives in the form of fungicides *(9)*.

Note: see Slide 11 for more detail explaining how inorganic mercury compounds can enter and transform in the environment.

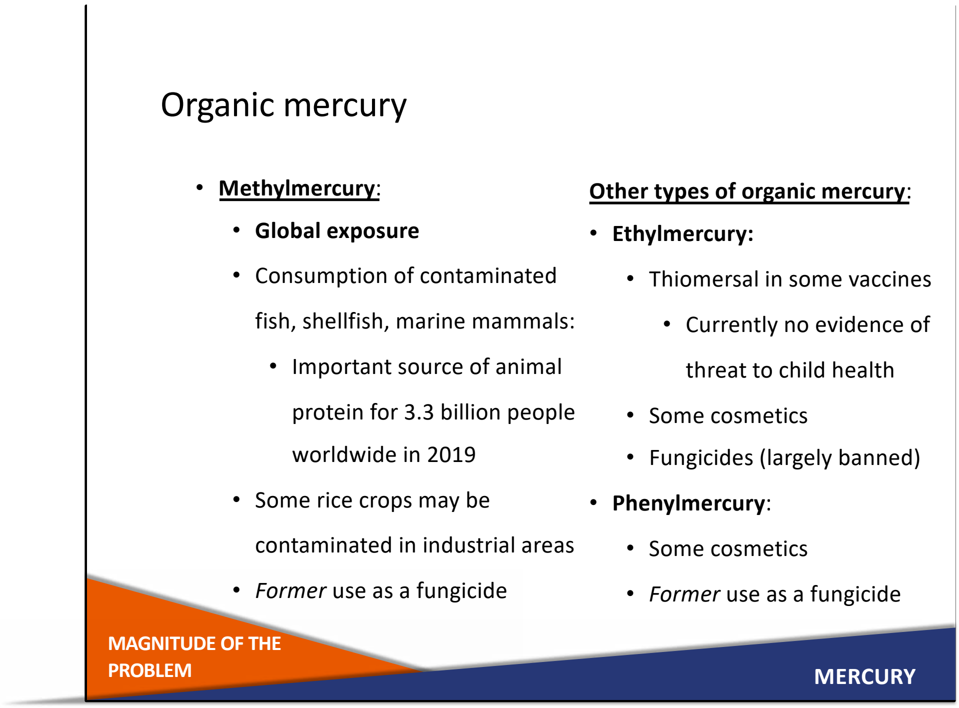
Note: access the World Health Organization’s (WHO) short video on mercury in skin lightening products here: https://www.who.int/multi-media/details/mercury-in-skin-lightening-products#.

Note: the Mercury Working Group maintains a database of skin lightening products that have been tested for mercury, if they exceed the mercury threshold limit established by the Minamata Convention, and where the products can be purchase. Visit the link to find skin lightening products that may exposure children to mercury in your region: https://www.zeromercury.org/projects/mercury-added-skin-lightening-creams-campaign-database/.

Note: for more detail on the chemical properties of inorganic mercury compounds, please see the free virtual course *Mercury effects in human health and the environment and considerations under the Minamata Convention* provided by the Pan American Health Organization (PAHO) *(10)*.

References:

1. Toxic substances portal: mercury [website]. Atlanta: Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Public Health Service; 2021 (https://wwwn.cdc.gov/TSP/substances/ToxSubstance.aspx?toxid=24, accessed 15 January 2024).
2. Mercury in skin lightening products. Geneva: World Health Organization; 2019 (https://www.who.int/publications/i/item/WHO-CED-PHE-EPE-19.13, accessed 15 January 2024).
3. Countries unite to remove mercury from hazardous skin lightening products [website]. Geneva: World Health Organization; 2023 (https://www.who.int/news/item/14-02-2023-countries-unite-to-remove-mercury-from-hazardous-skin-lightening-products, accessed 15 January 2024).
4. Environmental health criteria 118: inorganic mercury. Geneva: World Health Organization; 1991 (https://apps.who.int/iris/handle/10665/40626, accessed 15 January 2024).
5. Children's exposure to mercury compounds. Geneva: World Health Organization; 2010 (https://www.who.int/publications/i/item/9789241500456, accessed 15 January 2024).
6. Davis LE. Unregulated potions still cause mercury poisoning. West J Med. 2000;173(10):19.
7. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pediatrics; 2019.
8. Park JD, Zheng W. Human exposure and health effects of inorganic and elemental mercury. J Prev Med Public Health. 2012;445:344–52.
9. Toxicological profile for mercury (draft for public comment). Atlanta: Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Public Health Service; 2022 (https://wwwn.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=115&tid=24, accessed 15 January 2024).
10. Mercury effects in human health and the environment: considerations under the Minamata convention (2019 English edition) [online course]. Washington, D.C: Pan American Health Organization; 2024 (https://campus.paho.org/en/course/mercury-effects-human-health-and-environment-and-considerations-under-minamata-convention, accessed 15 January 2024).



Methylmercury is the most common form of mercury exposure and generally poses the most significant threat to child health due to mercury toxicity around the world. Methylmercury is found in many species of freshwater and marine fish, shellfish and marine mammals. This food source can have very high levels of methylmercury due to contamination of water and soils. Methylmercury bioaccumulates and biomagnifies up the food chain. Large, predatory and long-life fish and marine mammals, such as sharks and some species of whale, have the highest concentrations of methylmercury *(1)*. The Food and Agriculture Organization of the United Nations (FAO) estimated that, in 2019, **aquatic foods provided at least 20 percent of the average per capita intake of animal protein for 3.3 billion people globally** *(2)*. It is therefore essential that health care providers and communities carefully consider the benefits and possible risks of consuming fish, shellfish and marine mammals, especially in areas where there is known or suspected mercury pollution.

Rice grown in soils that are heavily contaminated with mercury may also be a source of methylmercury exposure for certain communities *(3)*. Methylmercury contamination in rice is highest in areas where there are high levels of industrial pollution, including artisanal and small-scale gold mining. Methylmercury was formerly used as a fungicide for some food crops, primarily as a seed protectant. In the past, this has caused widespread outbreaks of methylmercury poisoning, and its use is now banned in most countries *(3,4)*.

Some vaccinations may contain an organic form of mercury, known as **ethylmercury**, in thiomersal. Thiomersal is used in very small amounts in certain vaccines as a preservative to prevent microbial growth during storage and use. Compared to methylmercury, ethylmercury is very different. Ethylmercury is broken down by the body quickly, does not accumulate and is actively excreted via the gut. The World Health Organization (WHO) has closely monitored scientific evidence relating to the use of thiomersal as a vaccine preservative for more than 20 years and has consistently reached the same conclusion: **there is currently no evidence that the amount of thiomersal used in vaccines poses a health risk** *(5,6)*. Ethylmercury has also been used in certain fungicides in high concentrations. Due to high toxicity and mass poisoning events, the use of these fungicides have largely been banned or discontinued *(4)*.

In the past, **phenylmercury** compounds were used in some pesticides. These have been classified as highly hazardous pesticides and their use has been globally discontinued or banned due to their very high toxicity *(7)*. Additionally, some organic mercury compounds can be found in some cosmetic items as a preservative, primarily in eye makeup such as mascara. This includes ethylmercury and phenylmercuric salts *(8)*.

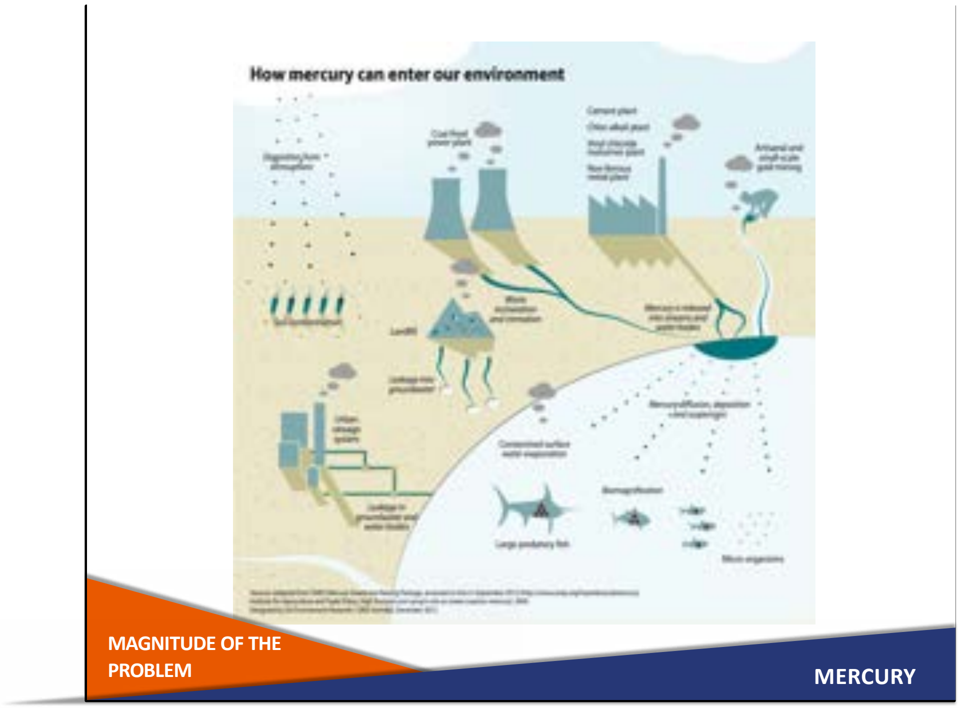
Due to its global presence and potential for adverse health outcomes, **this training module focuses on methylmercury and children's health.**

Note: discuss the known or suspected risks of methylmercury in fresh or marine fish, shellfish or marine mammals in your community or region. If possible, list which fish, shellfish or marine mammals pose the greatest threat to local populations.

Note: for more detail on the chemical properties of organic mercury, please see the free online virtual course *Mercury effects in human health and the environment and considerations under the Minamata Convention* provided by the Pan American Health Organization (PAHO) *(9).*

References:

1. Mercury and health [website]. Geneva: World Health Organization; 2017 (https://www.who.int/news-room/fact-sheets/detail/mercury-and-health, accessed 15 January 2024).
2. The state of the world fisheries and aquaculture 2022: toward blue transformation. Rome: Food and Agriculture Organization of the United Nations; 2022 (https://www.fao.org/documents/card/en?details=cc0461en, 15 January 2024).
3. Global mercury assessment 2018. Geneva: United Nations Environment Programme; 2019 (https://www.unep.org/resources/publication/global-mercury-assessment-2018, accessed 15 January 2024).
4. Schneider L. When toxic chemicals refuse to die – an examination of the prolonged mercury pesticides use in Australia. Elem Sci Anth. 2021;9:1.
5. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).
6. Thiomersal [website]. Geneva: World Health Organization; 2024 (https://www.who.int/teams/health-product-policy-and-standards/standards-and-specifications/vaccines-quality/thiomersal, accessed 15 January 2024).
7. The WHO recommended classification of pesticides by hazard and guidelines to classification, 2019 edition. Geneva: World Health Organization; 2020 (https://apps.who.int/iris/handle/10665/332193, accessed 15 January 2024).
8. Mercury in skin lightening products. Geneva: World Health Organization; 2019 (https://www.who.int/publications/i/item/WHO-CED-PHE-EPE-19.13, accessed 15 January 2024).
9. Mercury effects in human health and the environment: considerations under the Minamata convention (2019 English edition) [online course]. Washington, D.C: Pan American Health Organization; 2024 (https://campus.paho.org/en/course/mercury-effects-human-health-and-environment-and-considerations-under-minamata-convention, accessed 15 January 2024).



Unlike some other pollutants, **elemental and inorganic mercury compounds do not break down in the environment** but are transformed in the environment when acted upon by living organisms.

When either elemental and inorganic mercury compounds are burnt or heated without appropriate management and capture techniques during industrial processes, manufacture of chemicals, waste incineration, and through artisanal and small-scale gold mining activities, they vaporize and disperse into the atmosphere *(1,2)*. Mercury can remain in the atmosphere for up to a year, where it can be transported long distances and deposited globally, including to remote regions of the world. Eventually, once oxidized, atmospheric mercury is deposited onto soils, water bodies or plants *(1–3)*. From there, mercury can be re-volatized into the air, transported further by water or can enter the food chain. Additionally, unwanted liquid elemental mercury or inorganic mercury compounds may be dumped on land or in water bodies. Mercury compounds dumped on land can vaporize into the atmosphere or can persist in the soil for substantial periods of time where they may continue to be a source of mercury pollution for years to come. Historic anthropogenic emissions of mercury are important sources of pollution and exposure today *(4)*.

Mercury dumped in water bodies, or deposited from the atmosphere, can be transformed into **methylmercury** by microscopic bacteria that live in both fresh and marine water bodies and soils, absorbed by phytoplankton, and ingested by zooplankton, fish, shellfish and marine mammals. Methylation of mercury generally occurs in water bodies and aquatic animals are therefore at increased exposure compared to land animals. Methylmercury readily biomagnifies and bioaccumulates up the food chain. Top predatory fish and marine mammals in local waters can have **methylmercury tissue concentrations 10 million times higher than mercury levels in surrounding water**. Fish with elevated mercury levels are often used as bioindicators for local levels of mercury pollution *(4)*. Methylmercury is found in all tissues of fish, including muscle, and **cooking does not eliminate or reduce mercury from fish, shellfish or marine mammals** *(3)*.

Methylmercury is more toxic than inorganic forms of mercury *(4)*. Consumption of contaminated fish, shellfish and marine mammals poses a significant threat to the health of fetuses and children globally.

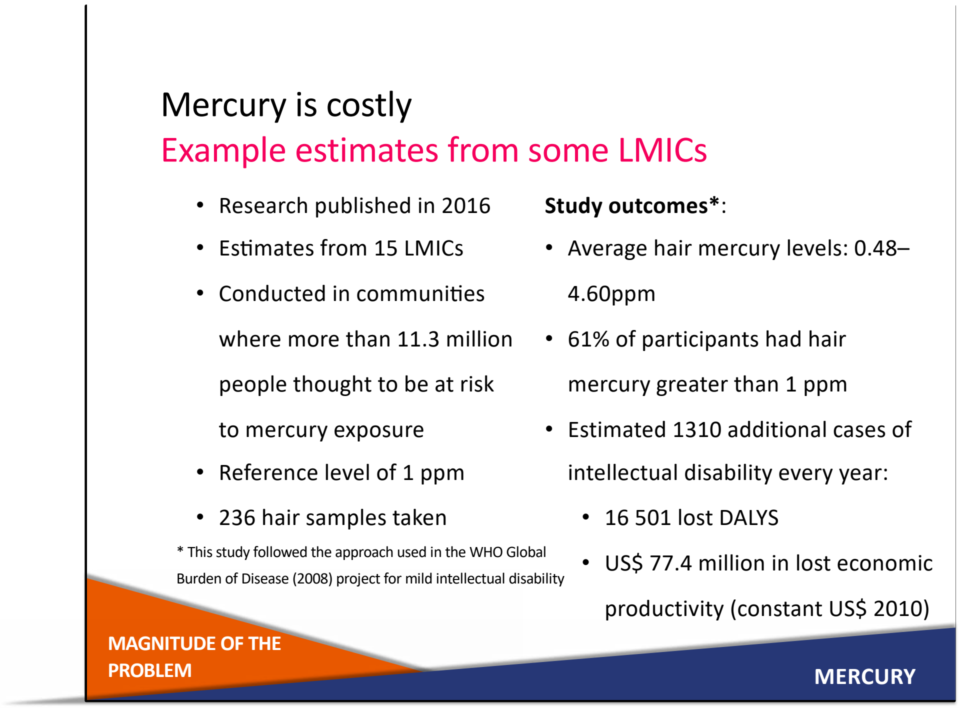
Notes: highlight the main sources of mercury pollution relevant to your community or area.

Reference:

1. Environmental and occupational health hazards associated with artisanal and small-scale gold mining. Geneva: World Health Organization; 2016 (https://apps.who.int/iris/handle/10665/247195, accessed 15 January 2024).
2. Decommissioning medical waste. Geneva: World Health Organization; 2019

(https://apps.who.int/iris/handle/10665/330095, accessed 15 January 2024).
3. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).
4. Global mercury assessment 2018. Geneva: United Nations Environment Programme; 2019 (https://www.unenvironment.org/resources/publication/global-mercury-assessment-2018, accessed 15 January 2024).

Figure:
- UNEP (2013). Mercury: time to act. Geneva: United Nations Environment Programme. (https://wedocs.unep.org/handle/20.500.11822/27436, accessed 15 January 2024).



Many countries around the world have limited or no information on local mercury exposure or pollution levels. One study published in 2016 estimated the economic implications of mercury exposure in communities in 15 low- and middle-income countries (LMICs) located close to anthropogenic mercury sources targeted by the Minamata Convention on Mercury *(1)*. Key sources of mercury pollution highlighted by the Minamata Convention include artisanal and small-scale gold mining, coal combustion and production of non-ferrous metals *(2)*. This study estimated that more than 11.3 million people were at risk of mercury exposure in the selected study areas. Using a hair mercury reference level of 1 part per million (ppm), corresponding approximately to the United States Environment Protection Agency's reference level, and following the approach used in the World Health Organization's (WHO) 2008 Global Burden of Disease project for mild intellectual disability *(3)*, the study estimated the economic costs of mercury exposure in terms of intellectual disability and lost disability-adjusted life-years (DALYs) *(1)*.

The study used hair samples from 236 people and found that *(1)*:
- average hair mercury levels ranged from 0.48 to 4.60 ppm;
- 61% of participants had hair mercury levels that exceeded the reference level of 1 ppm.

The study used a linear dose-response relationship and a previously identified estimation of 0.18 intelligence quotient (IQ) points decrement per ppm increase in hair mercury. Following the approach used in WHO's 2008 Global Burden of Disease project for mild intellectual disability *(3)*, the study estimated that an additional 1310 cases of intellectual disability occurred every year across the study areas resulting in *(1)*:
- an estimated 16 501 lost DALYs;
- US$ 77.4 million in lost economic productivity (constant US$ 2010).

This study is one example of the significant economic and development burden that mercury has on countries and communities. Given that these estimates are only for selected countries, an even larger economic burden could likely be prevented through implementation of the Minamata Convention. Additionally, the detrimental effects attributed to mercury exposure are not limited to LMICs. Studies conducted in high-income countries (HICs), including member states of the European Union and the United States of America, have indicated that reducing mercury pollution may lead to considerable health and economic benefits at country-level *(4,5)*.

Note: DALYs for a disease or health condition are the sum of years of healthy life lost due to disability and years of life lost due to premature mortality.

References:

1. Trasande L, DiGangi J, Evers DC, Petrlik J, Buck DG, Šamánek J et al. Economic implications of mercury exposure in the context of the global mercury treaty: hair mercury levels and estimated lost economic productivity in selected developing countries. J Environ Manage. 2016;183(1):229–35.
2. Minamata Convention on Mercury. Minamata Convention on mercury: text and annexes - 2023 edition. Geneva: United Nations Environment Programme; 2023 (https://minamataconvention.org/en/documents/minamata-convention-mercury-text-and-annexes, accessed 15 January 2024).
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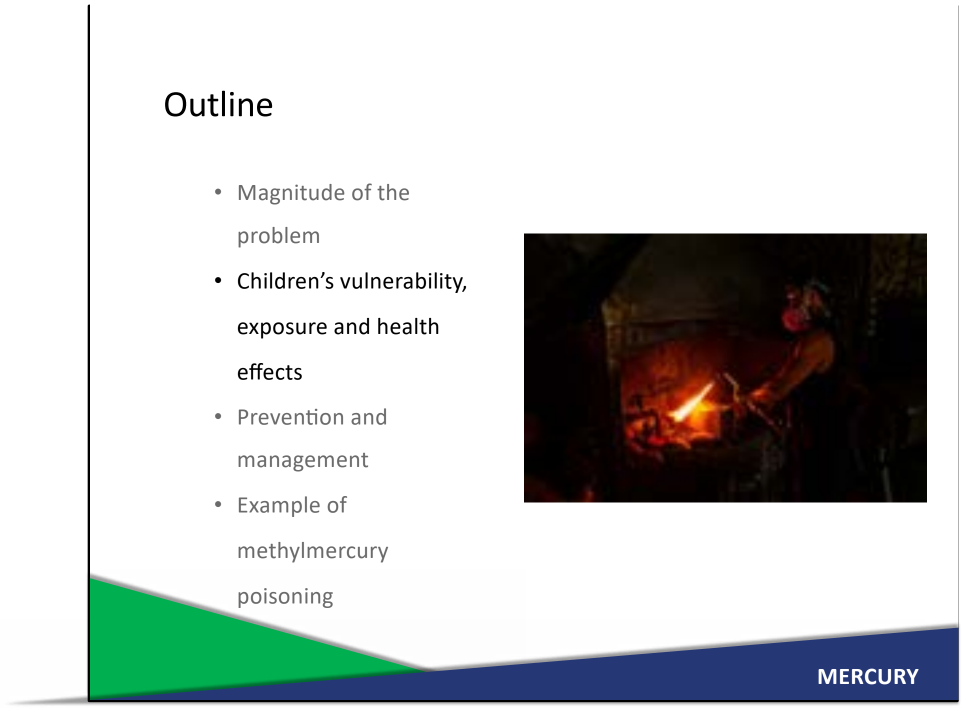
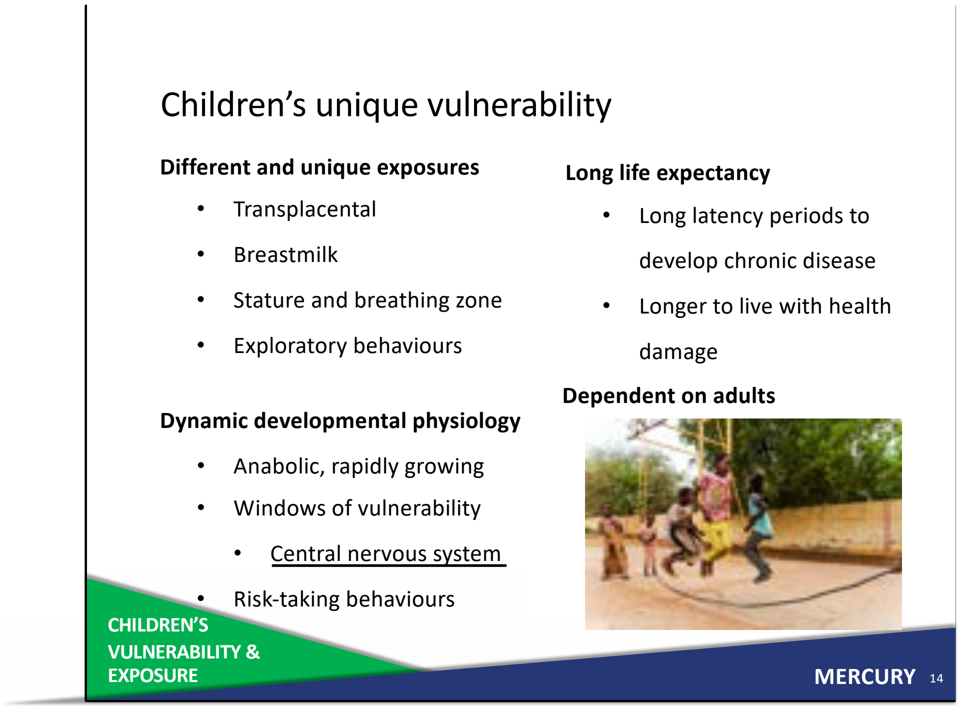


The next section of this module discusses children's unique vulnerability, primary routes and sources of exposure, and the main health effects associated with mercury. The different forms of mercury have various routes and sources of exposure and can manifest in a range of clinical signs and symptoms. Consequently, this section starts with a general slide discussing children's vulnerability to mercury compounds and the remainder of this section is organized into the three forms of mercury.

It is important to note that children living in high-risk communities may be **exposed to multiple forms of mercury at once**. For example, artisanal and small-scale gold mining communities in the Amazon are likely exposed to elemental mercury due to widespread pollution from unsound mining activities, as well as methylmercury from consumption of contaminated fish, a common food source in many communities.

Photo:

- © WHO/ Yoshi Shimizu. A local miner applying the torching process using mercury to extract gold.



As with many environmental hazards, children are often at increased exposure risk for several reasons. **Mercury is no exception.**

1. Children have **<u>different and unique exposures</u>** to mercury exposure compared to adults**. Elemental mercury and methylmercury can cross the placenta**, exposing the developing fetus to pollution experienced by the mother. Methylmercury concentrates in the fetus *(1)*. **Methylmercury can also pass into breastmilk**. The presence of methylmercury in breastmilk is not sufficient to outweigh its benefits. Exclusive breastfeeding up to the first six months, and continued breastfeeding with complementary foods for two years and beyond, is recommended by World Health Organization (WHO) and the United Nations Children’s Fund (UNICEF) as the best source of nutrition for children *(1,2)*. Additionally, children have a **shorter stature and live closer to the ground than adults**. This means they may have increased exposure to pollutants that settle onto or near ground, including furniture and other items. Mercury vapour, usually produced when elemental mercury is heated or burned, is heavier than air and settles close to the ground, where children spend most of their time *(3)*. Children also have **natural exploratory behaviours**, such as high rates of hand-to-mouth and object-to-mouth behaviours. These behaviours may increase their exposure to mercury pollution that has settled in dust, soil or on objects. Children may also place mercury-containing objects or products, such as thermometers, in their mouths and may be exposed if objects are broken or leaking *(1)*. Additionally, if children have skin lightening products applied to their bodies, they may ingest inorganic mercury from these products via hand-to-mouth behaviours.

2. Due to their **<u>dynamic developmental physiology</u>** children may be subjected to higher levels of mercury found in air, water and food. **As they are anabolic and rapidly growing**, children breathe more air, eat more food and drink more water per unit of body weight than adults. Therefore, mercury pollution in the air and in food can result in higher internal doses in children compared to adults. Children and fetuses also have **bodily systems** that are going through **vital maturing processes** and **windows of vulnerability**. Mercury compounds are well recognized as toxic to children and can cause irreparable harm to many systems and organs. The **developing central nervous system is of particular concern**. Elemental mercury and methylmercury are powerful teratogens and can cause disruption of neuronal migration growth, differentiation, migration, synaptogenesis, and myelination in the developing brain. Exposure to mercury during pregnancy is of particular concern for health workers, however, vulnerability to methylmercury continues into childhood and adolescence, and negative effects of elemental mercury on cognitive and behavioural function have been observed in adults *(1,3,4)*. Additionally, **risk-taking behaviours** commonly seen among adolescents may place them at heightened risk of mercury, for example through application of skin lightening products.

3. Children have **longer life expectancies** than adults, so they have longer to manifest a disease with a **long latency period**, such as chronic diseases. They also have **longer to live with health damage** from mercury exposure. Depending on the dose and mercury compound, toxic damage due to exposure may manifest in childhood or later in life. For example, women who are exposed to high levels of methylmercury during pregnancy are at higher risk of giving birth to infants severely affected by neurological issues that may become evident during infancy and childhood. Negative effects on cardiovascular system function have been linked to chronic methylmercury exposure during childhood. Exposure to mercury during pregnancy and childhood may have lifelong impacts on health, educational achievement and economic opportunities *(1,3)*.

4. Finally, **children depend upon the adults** in their lives to provide a safe environment in which to grow, learn and thrive. Children living in communities that rely on artisanal and small-scale gold mining as an important source of income may be exposed to elemental mercury and vapour in their homes and gardens, community areas and at school. Child labour has also been noted in many communities that practice artisanal and small-scale gold mining *(5)*. Children may eat fish, shellfish and marine mammals that is contaminated with methylmercury originating from distant sources. For example, elevated levels of mercury have been recorded in hair samples taken from people living in villages in the Cook Islands who have a diet rich in fish. The Cook Islands, however, has no known source of mercury pollution and it is likely that methylmercury present in local fish stocks is due to global deposition *(6)*. Children have limited agency to affect the political decisions made at local, national and international levels that can change mercury levels in their environment. Children trust the adults in their lives to nurture and protect them through actions and decisions until they can protect themselves through their own individual, collective and political action *(1)*.

Note: for more information, please see the ***Children are not little adults*** and ***Why children*** modules.

References:

1. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pediatrics; 2019.
2. Infant and young child feeding [website]. Geneva: World Health Organization; 2021 (https://www.who.int/news-room/fact-sheets/detail/infant-and-young-child-feeding, accessed 15 January 2024).
3. Children's exposure to mercury compounds. Geneva: World Health Organization; 2010 (https://www.who.int/publications/i/item/9789241500456, accessed 15 January 2024).
4. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).
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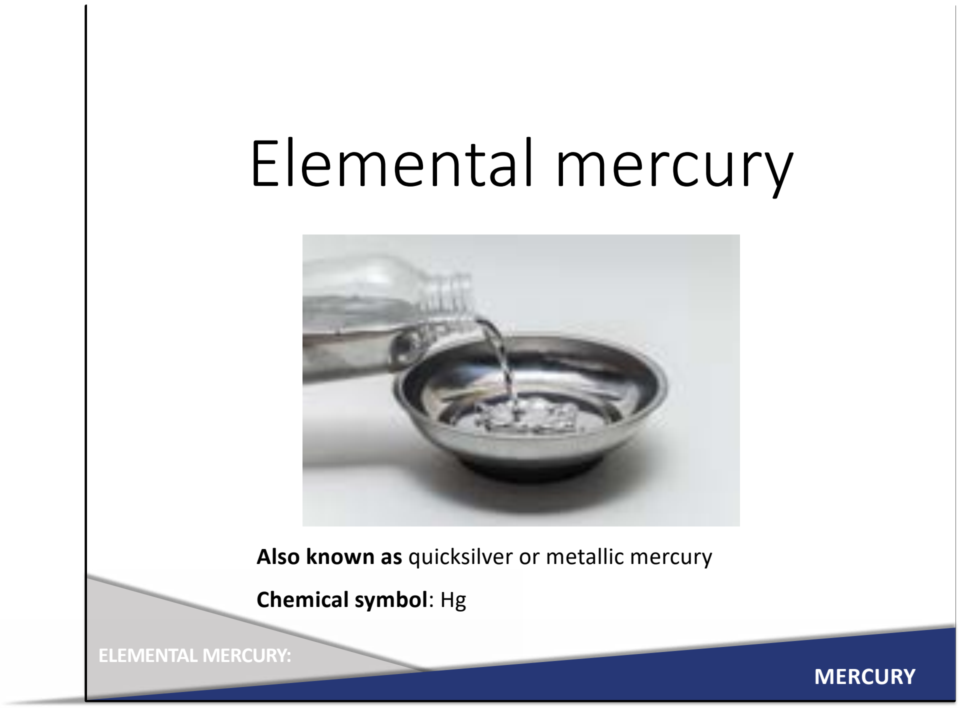
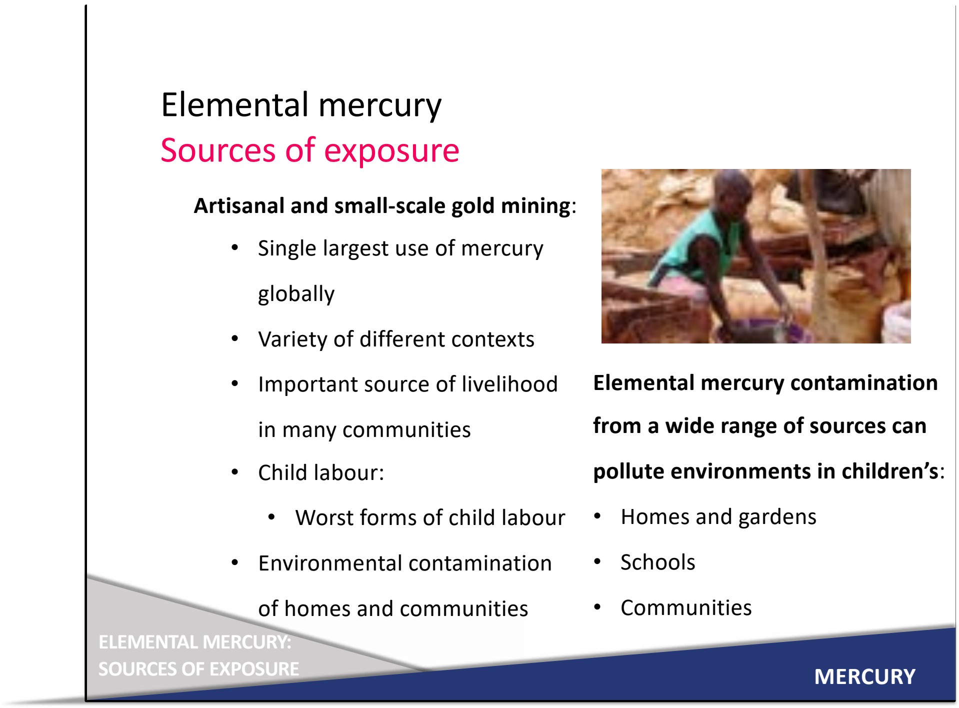
6. Trasande L, DiGangi J, Evers DC, Petrlik J, Buck DG, Šamánek J et al. Economic implications of mercury exposure in the context of the global mercury treaty: hair mercury levels and estimated lost economic productivity in selected developing countries. J Environ Manage. 2016;183(1):229–35.

Photo:
- © WHO/ Ala Kheir. Amna and her sisters Alia and Asmaa play with new friends in Alzahraa displacement camp.



Next, this module discusses elemental mercury including its routes and sources of exposure, as well as health effects in children. As indicated on the slide, elemental mercury is also commonly known as quicksilver or metallic mercury due to its silvery appearance (as illustrated in the photo). The chemical symbol for elemental mercury is Hg.

Photo:
- © Shutterstock. Pouring elemental mercury into a steel bowl.



Children may be exposed to elemental mercury through several different sources and settings. This slide discusses some of the most common global sources of exposure and the settings in which children may be exposed.

Artisanal and small-scale gold mining is the single largest use of elemental mercury globally and is a significant threat to child health, especially in some countries in the World Health Organization's (WHO) African Region, Region of the Americas, South-East Asia Region and Western Pacific Region (see Slide 8 for a visual representation) *(1)*. Elemental mercury is used in artisanal and small-scale gold mining as it is cheap, accessible and effective, and requires minimal additional infrastructure or tools. Across the world, artisanal and small-scale gold mining occurs in a variety of different contexts and settings. Usually, it is considered part of the informal sector, and it has been recorded developing into remote and informal settlements when sources of gold are found, attracting migrant and transient workers from across countries and international borders. It has also been reported occurring in homes, gardens and community areas, and involving all members of families, including children and the elderly.

Artisanal and small-scale gold mining is an important source of livelihood in many communities and children may be exposed to mercury due to:

- **child labour** in gold mining-related practices and activities. Children have been observed working in virtually all stages of artisanal and small-scale gold mining, ranging from ore extraction to processing and burning *(2)*. Children frequently work in mining as part of family business, and they are often used in informal mines due to their small size and ability to fit into small spaces *(3)*. This kind of work is hazardous labour and is considered one of the 'worst forms of child labour' by the International Labour Organization (ILO) *(4)*;
- **environmental contamination of soil, air and food sources in homes, gardens and community areas**, due to lack of infrastructure, technologies, training and polluting practices. Elemental mercury used in artisanal and small-scale gold mining activities is often heated or burned without technologies to capture the mercury vapour produced. Consequently, the vapour is released into the air, exposing workers, their families and wider communities. Additionally, unwanted elemental mercury is frequently indiscriminately dumped into water bodies and onto land, causing widespread mercury pollution, contaminating food sources, such as rice and fish, and leading to persisting sources of mercury for years to come *(2)*.

There are many other sources of elemental mercury pollution in the environment that pose threats to children's health (see Slide 7 for more sources). These sources can contaminate air, water, soil and food sources in children's *(5)*:

- homes, gardens and other outdoor areas;
- schools;
- community areas.

Other local sources of elemental mercury in children's environments may include *(1)*:

- **combustion of fossil fuels, especially coal, for energy needs**. This is the second largest source of mercury emissions in the world and a common source of energy production in many countries. Emissions from fossil fuel combustion can lead to mercury pollution in the air and deposition on land and plants, and into water bodies in regions far from the point of origin;
- **emissions from mercury-containing wastes**, such as electrical and electronic waste (e-waste) and medical waste, due to open burning practices or poor landfill management;
- **cement production**;
- **non-ferrous metal production**;
- **some traditional, complementary and integrative medical practices**.

Due to mercury's ability to travel significant distances from the point of origin, efforts to control mercury emissions must be broad in scope. While personal actions are important to protect child health, they may not be sufficient if mercury exposure is affected by transboundary emissions.

Note: adjust this slide with the most common sources and settings of elemental mercury in your context.

References:

1. Global mercury assessment 2018. Geneva: United Nations Environment Programme; 2019 (https://www.unep.org/resources/publication/global-mercury-assessment-2018, accessed 15 January 2024).
2. Environmental and occupational health hazards associated with artisanal and small-scale gold mining. Geneva: World Health Organization; 2016 (https://iris.who.int/handle/10665/247195, accessed 15 January 2024).
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5. Children's exposure to mercury compounds. Geneva: World Health Organization; 2010 (https://www.who.int/publications/i/item/9789241500456, accessed 15 January 2024).
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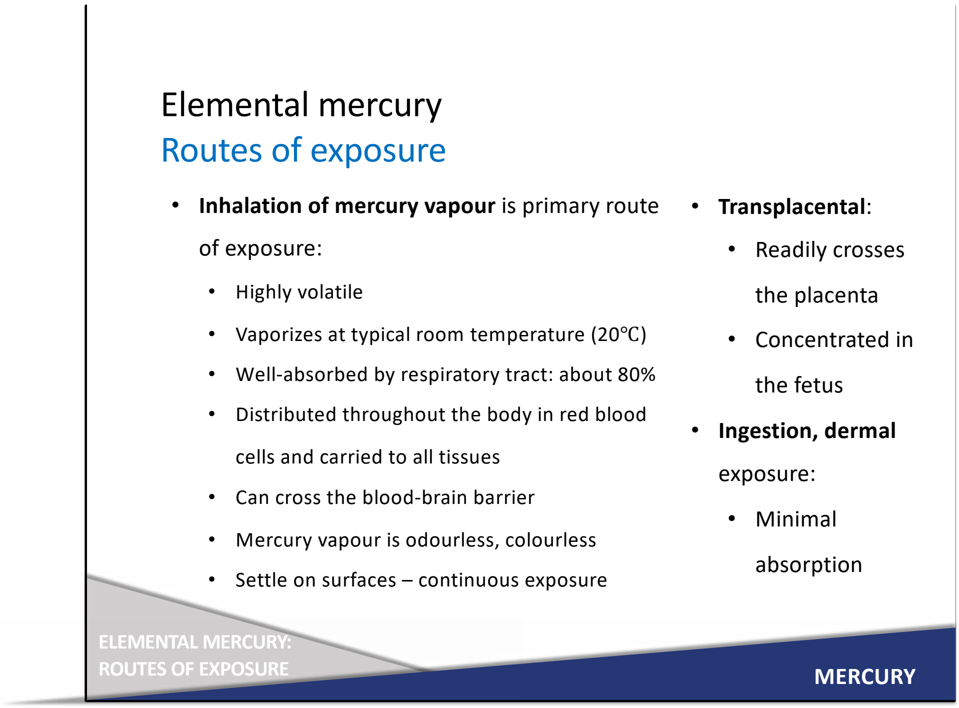
Photo:

- Stephan Böse-O'Reilly. Boy in Anka / Zamfara in Nigeria: panning the tailing with mercury, 2013. Used with permission



Children can be exposed to elemental mercury via several routes.

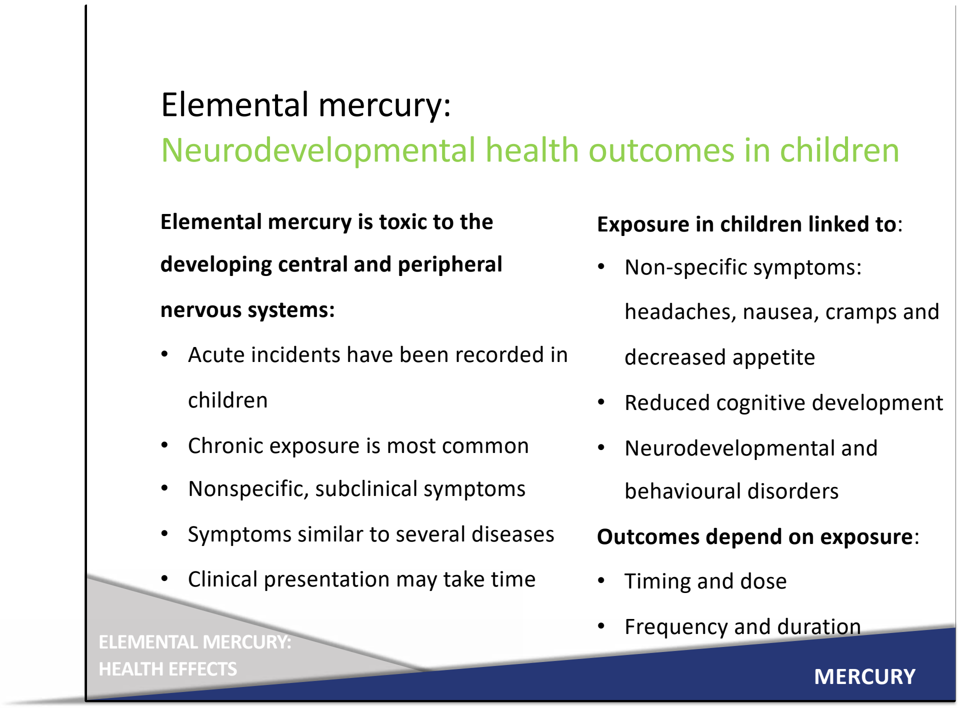
Inhalation of elemental mercury vapour is the primary route of exposure among children and adults. The respiratory tract rapidly and efficiently absorbs mercury. Research has found that about 80% of inhaled mercury vapour is absorbed into the body. Once absorbed, mercury is distributed into red blood cells where it is **carried to all bodily tissues** and **crosses the blood-brain barrier** *(1,2).* Exposure to elemental mercury in both the general population and in occupational settings is primarily through inhalation of mercury vapour or fumes. Elemental mercury is highly volatile and changes from liquid to vapour at typical room temperature (20 degrees Celsius (°C)). Mercury vapour is odourless and colourless and may contaminate surfaces including walls, floors and carpets. Mercury vapour can settle on surfaces, such as carpets, for long periods of time, even after contaminating activities have ceased. Without remediation, these sources of mercury can continue to pose a hazard to children's health *(3)*.

Transplacental transfer is another important route of exposure. As elemental mercury is lipid soluble, it readily crosses the placenta where it is concentrated in the fetus. Concentrations may be higher in the fetus than in the mother following inhalation of mercury vapour *(2)*.

Elemental mercury can also be **ingested**, for example from contamination on hands or through consumption of items used in traditional, complementary and integrative medical practices. Elemental mercury is poorly absorbed by the gastrointestinal tract, less than 0.1% is absorbed through this route. Minimal elemental mercury is absorbed through **dermal contact** *(1)*.

References:

1. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pediatrics; 2019.
2. Children's exposure to mercury compounds. Geneva: World Health Organization; 2010 (https://www.who.int/publications/i/item/9789241500456, accessed 15 January 2024).
3. Elemental mercury and inorganic mercury compounds: human heath aspects. Geneva: World Health Organization; 2003 (https://iris.who.int/handle/10665/42607, accessed 15 January 2024).



Element mercury is toxic to the developing central and peripheral nervous systems. The neurological effects of elemental mercury have been well established and recognized for decades. Historical records reaching backing hundreds of years have illustrated suspected effects of elemental mercury on the nervous system. As elemental mercury readily crosses the blood-brain barrier and the placenta, the developing fetus and children are especially vulnerable to neurodevelopmental effects *(1)*.

Elemental mercury disrupts neurodevelopmental processes through *(2)*:

- protein and enzyme inhibition
- epigenetic modifications
- oxidative stress
- cellular death.

Acute exposures in children to elemental mercury have been recorded, although today this is relatively rare. Today, acute exposure in children is primarily a risk in artisanal and small-scale gold mining communities where elemental mercury is used to obtain gold, especially if processing is conducted indoors. A limited number of studies have recorded acute exposures to elemental mercury vapour and severe neurological and cognitive effects in children. Case studies have reported mixed findings regarding the permanency of these effects *(3,4)*.

Chronic, low-level exposure to elemental mercury in children is more common. Exposure to elemental mercury can lead to a wide variety of neurodevelopmental symptoms in children. These symptoms may be nonspecific or subclinical and may be confused with a range of diseases or health conditions. Importantly, clinical presentation of symptoms may take time to appear. Months or even years can pass before symptoms of chronic mercury exposure become evident *(5,6)*. Common, early symptoms in children associated with elemental mercury exposure during prenatal and early childhood periods include:

- **Nonspecific symptoms** such as headaches, nausea, muscle cramping and loss of appetite. For example, a small study of school children exposed to broken thermometers containing mercury found symptoms of headaches, nausea, muscle cramping and decreased appetite within 6 hours of exposure. Clinical follow-up 1 month after exposure suggested that children had no lasting neurological or systemic effects *(7)*.
- **Reduced cognitive development** as measured by milestone tests. One study conducted in an artisanal and small-scale gold mining village in the Philippines suggested that prenatal exposure to elemental mercury vapour is associated with lower cognitive developmental scores at 2 years of age *(8)*. Studies conducted in Peru and Ecuador have suggested links between childhood exposure to elemental mercury from artisanal and small-scale gold mining and decreased general cognitive ability and visual-spatial processing skills, respectively *(9–11)*.
- Some research conducted on prenatal and early childhood effects of elemental mercury exposure has suggested

links to **increased risk of neurodevelopmental and behavioural disorders** *(1,12)*.

These symptoms and their long-term health effects depend upon the **dose**, **frequency, duration** and **timing** of exposure.

Many studies on elemental mercury and its effects on the nervous system have been conducted in adults and symptoms are well-characterized. Common symptoms include *(1,6,13)*:

- tremor
- memory loss
- insomnia
- headaches
- nervousness
- neuromuscular effects.

References:

1. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).
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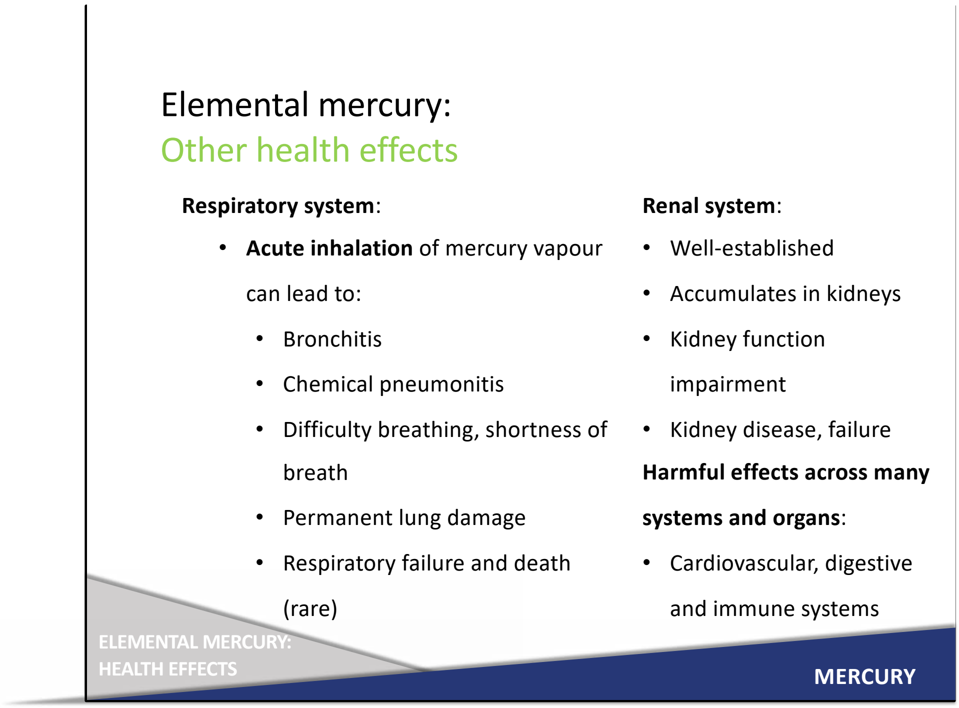

The effects of elemental mercury vapour on the **respiratory system** are well-established.

Acute exposure to elemental mercury and effects on the respiratory system have been recorded, including incidences of respiratory failure and death. Acute exposures are relatively rare and are most likely to occur in occupational contexts and incidences of unintentional exposure to very high levels of elemental mercury vapour *(1–3)*. Acute exposure is a serious event and requires immediate medical attention. Treatment may include administration of oxygen, mechanical ventilation and chelation therapy. Inhalation of elemental mercury vapour may be linked to *(1)*:

- **Bronchitis and chemical pneumonitis**. Acute lower respiratory infections, including pneumonia and bronchitis, are the second leading cause of child mortality worldwide. In 2019, an estimated 740 000 children under 5 years of age died from acute lower respiratory infections globally *(4)*. Health care professionals who treat children with suspected or confirmed elemental mercury exposure, especially those exposed to artisanal and small-scale gold mining activities, should have a high index of suspicion for acute lower respiratory infection.
- **Difficulty breathing and shortness of breath**.
- **Long-term, permanent respiratory health issues,** including persistent cough and permanent lung damage. One study conducted in an artisanal and small-scale gold mining community indicated damage to respiratory function as measured by forced expiratory capacity (FEC) and forced expiratory volume (FEV). Those who had worked with mercury for the longest periods of time had increasingly poor respiratory function *(5)*;
- **Respiratory failure and death**. Some examples of acute exposure have been recorded in artisanal and small-scale gold mining contexts where elemental mercury was heated in indoors environments with little or no ventilation *(3)*. In one example from the United States of America, one child and their mother died from respiratory failure after acute exposure to mercury vapour caused by heating elemental mercury to extract gold ore in a poorly ventilated room. Another adult patient in this case study experienced permanent neurological and respiratory health issues *(6)*.

Elemental mercury is well-established as toxic to the renal system. Inhaled elemental mercury vapour accumulates in the kidneys, causes glomerular and tubular damage, and can lead to markers of kidney damage, disease and failure. The extent of the effect on the renal system depends on the dose and duration of exposure. Studies on elemental mercury exposure and the renal system have primarily been conducted in adults in occupational settings *(1,3,7)*. Children's exposure in artisanal and small-scale gold mining contexts are of particular concern.

Elemental mercury exposure has been associated with a range of adverse health effects across multiple bodily systems and organs. These include *(1)*:

- acute exposure to elemental mercury vapour has been linked to several negative cardiovascular health outcomes including hypertension, heart palpitations and possible increased risk of diseases, such as coronary heart disease *(8);*

- while ingestion of elemental mercury is not known to pose a threat to the **digestive system**, inhalation of elemental mercury vapour may lead to a range of adverse effects. These include excessive salivation, metallic taste in the mouth, diarrhoea, vomiting and abdominal cramps. These symptoms have primarily been associated with acute exposures *(7)*;
- research has also suggested links between chronic exposure and possible adverse outcomes on the immune system *(1)*. High levels of exposure to elemental mercury may be associated with **immunological outcomes**, including changes to autoimmunity, development of allergy and increased susceptibility to infection and infectious diseases *(2)*.

References:

1. Elemental mercury and inorganic mercury compounds: human heath aspects. Geneva: World Health Organization; 2003 (https://iris.who.int/handle/10665/42607, accessed 15 January 2024).
2. Park JD, Zheng W. Human exposure and health effects of inorganic and elemental mercury. J Prev Med Public Health. 2012;445:344–52.
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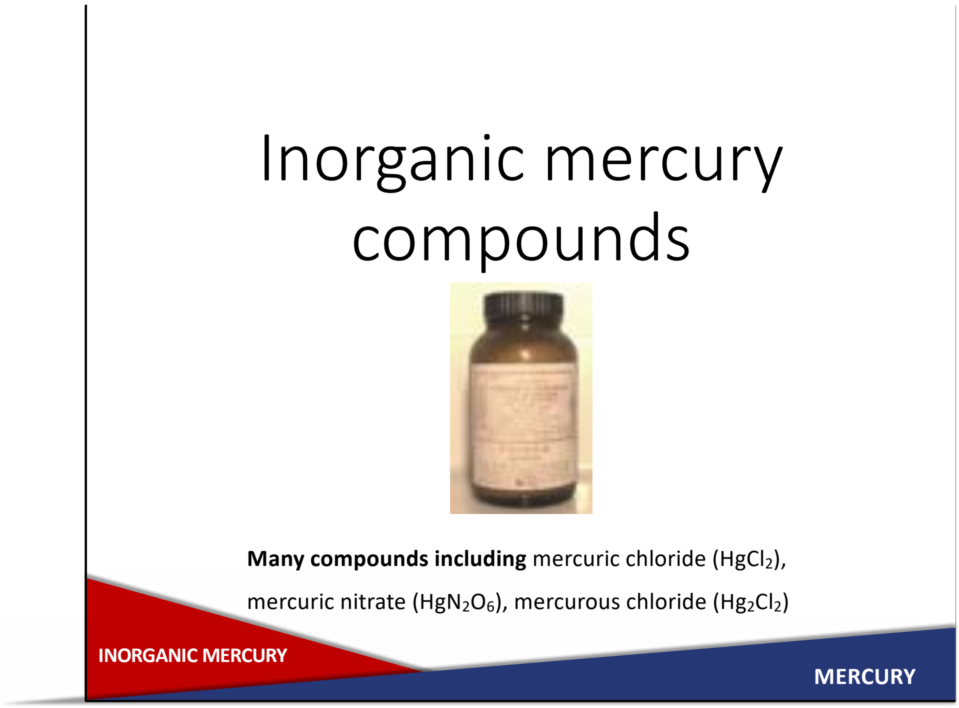
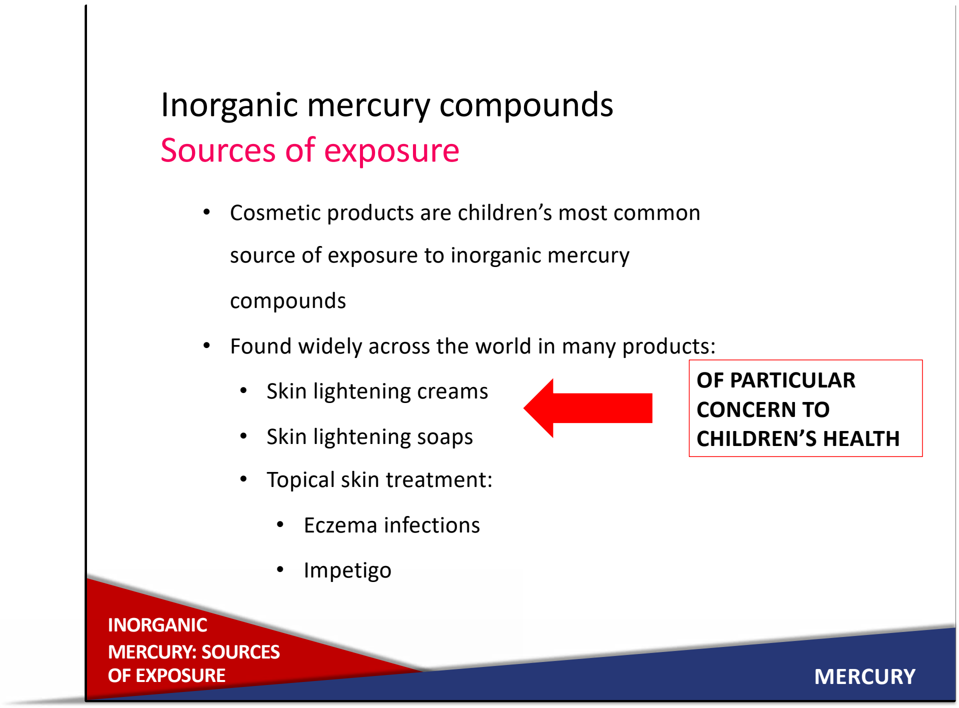


Inorganic mercury compounds include a number of different compounds. These include mercuric chloride ($HgCl_2$), mercuric nitrate (HgN_2O_6) and mercurous chloride ($HgCl_2$).

Photo:
- Splarka. This photo has been released into the public domain. https://commons.wikimedia.org/wiki/File:Mercury(II)_chloride.jpg.



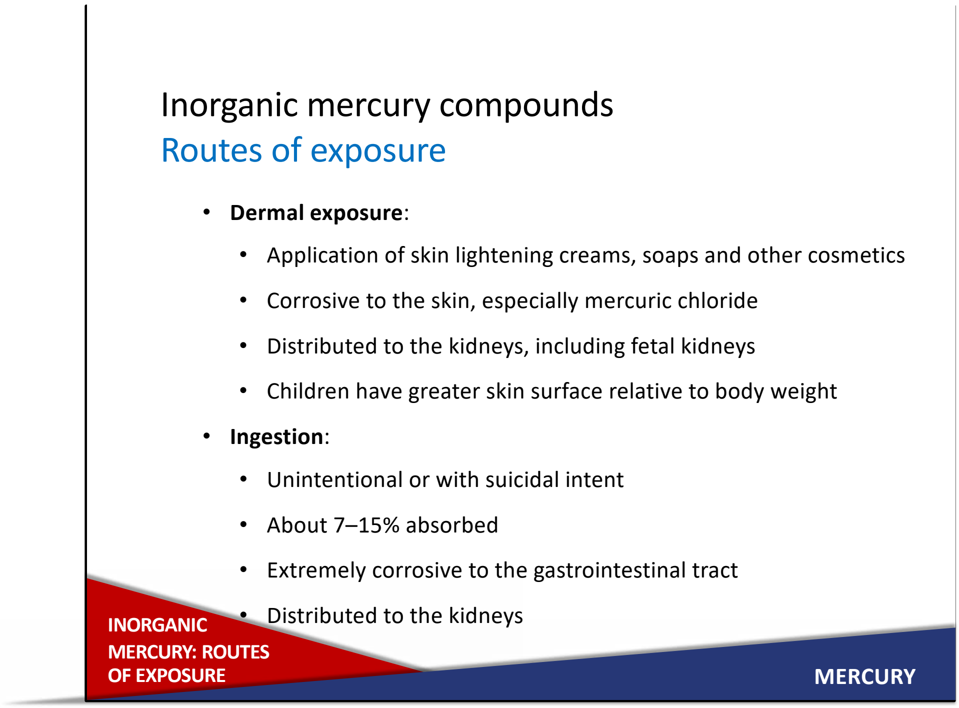
Historically, inorganic mercury compounds have been used in a wide variety of products and applications. Many products containing inorganic mercury have been banned or discontinued due to toxicity, such as calomel, a former teething powder for infants. There are, however, many products found widely in countries all over the world today that still contain inorganic mercury compounds *(1)*.

Skin lightening creams and soaps and other cosmetic products that aim to suppress melanin production and whiten the users' skin are of particular concern to children's health *(2)*. The Minamata Convention on Mercury has established a limit of 1 milligram per kg (mg/kg) for skin lightening products, but many products continue to exceed this limit. Some products that contain mercury do not list it as an ingredient on packaging, consequently exposing people without their knowledge. Children may be exposed to products in their home, either by direct application of products or from other family members' skin or contamination on clothing or household items such as towels. Young children, who have high rates of hand-to-mouth and object-to-mouth behaviours, may unintentionally ingest skin lightening products that contain mercury if they are left within reach or applied to their skin *(2,3)*. Adolescents may feel pressure to use such products due to perceived beauty standards that paler skin is more desirable *(2)*.

Another use of inorganic mercury in consumer products includes topical, therapeutic skin uses to treat eczema infections and impetigo *(1)*. These products contain mercuric chloride as an antiseptic *(4)*. Both these skin issues are common in infants and young children and health care providers should be aware of any therapeutic products in their context that contain inorganic mercury as an ingredient.

References:

1. Elemental mercury and inorganic mercury compounds: human heath aspects. Geneva: World Health Organization; 2003 (https://iris.who.int/handle/10665/42607, accessed 15 January 2024).
2. Mercury in skin lightening products. Geneva: World Health Organization; 2019 (https://www.who.int/publications/i/item/WHO-CED-PHE-EPE-19.13, accessed 15 January 2024).
3. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pediatrics; 2019.
4. Basic information about mercury [website]. Research Triangle Park: United States Environmental Protection Agency; 2023 (https://www.epa.gov/mercury/basic-information-about-mercury, accessed 15 January 2024).



Children are primarily exposed to inorganic mercury compounds via two different routes.

- **Dermal exposure** is children's most likely route of exposure to inorganic mercury. This can occur through direct application of skin lightening creams, soaps and other cosmetic products that contain mercury as an ingredient. Inorganic mercury compounds can move across the epidermis (the outmost layer of skin) and can be absorbed through sweat and sebaceous glands and hair follicles *(1)*. Application of products containing inorganic mercury can cause corrosive effects to the skin, including rashes, skin discolouration and burns *(2)*. The compound mercuric chloride is especially corrosive to the skin and is used in some skin lightening products. Once absorbed, inorganic mercury is distributed to the kidneys, including fetal kidneys, where it can cause kidney damage and it is excreted via urine and faeces *(1)*. Due to their special vulnerabilities (discussed on Slide 14), children are at higher risk to adverse health effects from dermal application of products containing mercury. Children have greater skin surface area relative to their body weight compared to adults. They, therefore, may receive a greater internal dose of mercury from skin lightening products applied to their skin *(3)*. Historically, inorganic mercury was used in teething powders and diaper powders which led to inorganic mercury poisoning in children resulting in acrodynia, or "pink disease" (see Slide 24 for more detail) *(1,4)*.

- **Ingestion** is another route of exposure through which children may be exposed to inorganic mercury compounds. Inorganic mercury compounds are poorly absorbed following ingestion *(3)*. Some research suggests that about 7–15% of inorganic mercury may be absorbed through this route *(1).* Ingestion of inorganic mercury compounds is usually unintentional, for example accidental consumption of skin lightening cosmetics, or with suicidal intention. Some inorganic mercury compounds are extremely corrosive to the gastrointestinal tract, including mercuric chloride and mercuric nitrate *(4)*. Ingestion of these compounds can lead quickly to ulceration and perforation of the gastrointestinal tract and haemorrhage. Following ingestion, inorganic mercury is also distributed to the kidneys and can lead to nephrotoxicity *(3)*. There is some evidence that inorganic mercury can be transferred to breast milk (please see Slide 14 for the World Health's Organization's (WHO) statement on breastfeeding) *(5)*.

References:

1. Park JD, Zheng W. Human exposure and health effects of inorganic and elemental mercury. J Prev Med Public Health. 2012;45(6):344-52.
2. Mercury in skin lightening products. Geneva: World Health Organization; 2019 (https://www.who.int/publications/i/item/WHO-CED-PHE-EPE-19.13, accessed 15 January 2024).
3. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pediatrics; 2019.
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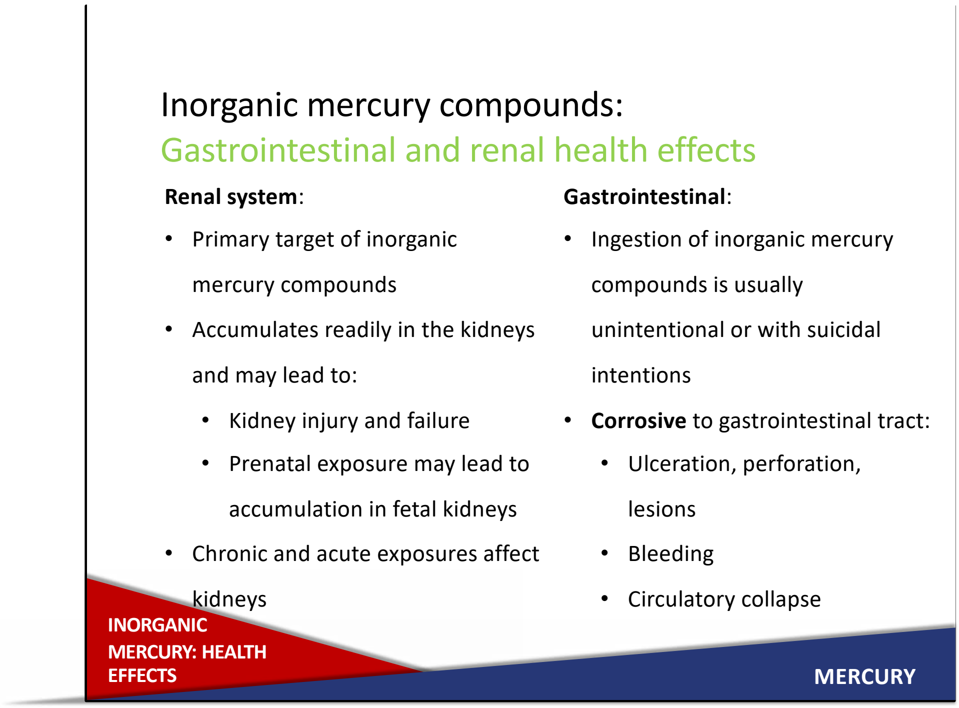
Organization; 2003 (https://iris.who.int/handle/10665/42607, accessed 15 January 2024).
5. Children's exposure to mercury compounds. Geneva: World Health Organization; 2010 (https://www.who.int/publications/i/item/9789241500456, accessed 15 January 2024).



Effects on the digestive and renal systems are the primary health concerns linked to exposure to inorganic mercury compounds. In the general population, exposure to inorganic mercury compounds is generally chronic, for example the use of skin lightening products over many years. Both acute and chronic exposures, however, can have permanent effects on child health.

The **renal system** is the primary target of ingested and dermally absorbed inorganic mercury. Mercury accumulates readily in the kidneys and can lead to kidney injury and failure. Both acute and chronic exposures have been linked to kidney injury and failure *(1–3)*. Clinical symptoms of inorganic mercury poisoning include polyuria, proteinuria, and nephritic syndrome *(3)*.

Acute exposure to inorganic mercury compounds through ingestion has been associated with mortality due to kidney failure *(4)*. Exposure to inorganic mercury compounds during pregnancy may lead to accumulation of mercury in the fetal kidneys, especially if the mother has reduced renal function *(5)*. Skin lightening products are one of the most likely sources of exposure to inorganic mercury compounds in children. Studies have linked the use of skin lightening products containing these compounds with a range of health effects including nephritic syndrome. Even if they do not use the products themselves, research has found that children can be highly exposed to inorganic mercury compounds through physical contact with household members who do use them or through contact with contaminated household objects, such as towels *(6)*.

Acute ingestion of inorganic mercury compounds, including mercuric salts, is **extremely corrosive to the gastrointestinal tract**. Ingestion is usually unintentional or with suicidal intent. It can quickly lead to ulceration, perforation and lesions of the gastrointestinal tract, internal bleeding and circulatory collapse *(2)*. A small amount can produce a catastrophic effect. For example, ingestion of approximately 1–4 grams of the compound mercuric chloride can be fatal in adults *(3)*. Mortality has been associated with ingestion of high levels of inorganic mercury compounds and attributed to cardiovascular collapse and severe gastrointestinal injuries *(4)*. Skin lightening products containing inorganic mercury compounds have also been associated with a range of less severe gastrointestinal symptoms including metallic taste in the mouth, gingivostomatitis, nausea and hypersalivation *(7)*.

Inorganic mercury compounds are corrosive to the skin and eyes and can cause contact dermatitis *(4)*.

References:

1. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).
2. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pediatrics; 2019.

3. Park JD, Zheng W. Human exposure and health effects of inorganic and elemental mercury. J Prev Med Public Health. 2012;45(6):344-52.
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6. Copan L, Fowles J, Barreau T, McGee N. Mercury toxicity and contamination of household from the use of skin creams adulterated with mercurous chloride (calomel). Int J Environ Res Public Health. 2015;12:10943–54.
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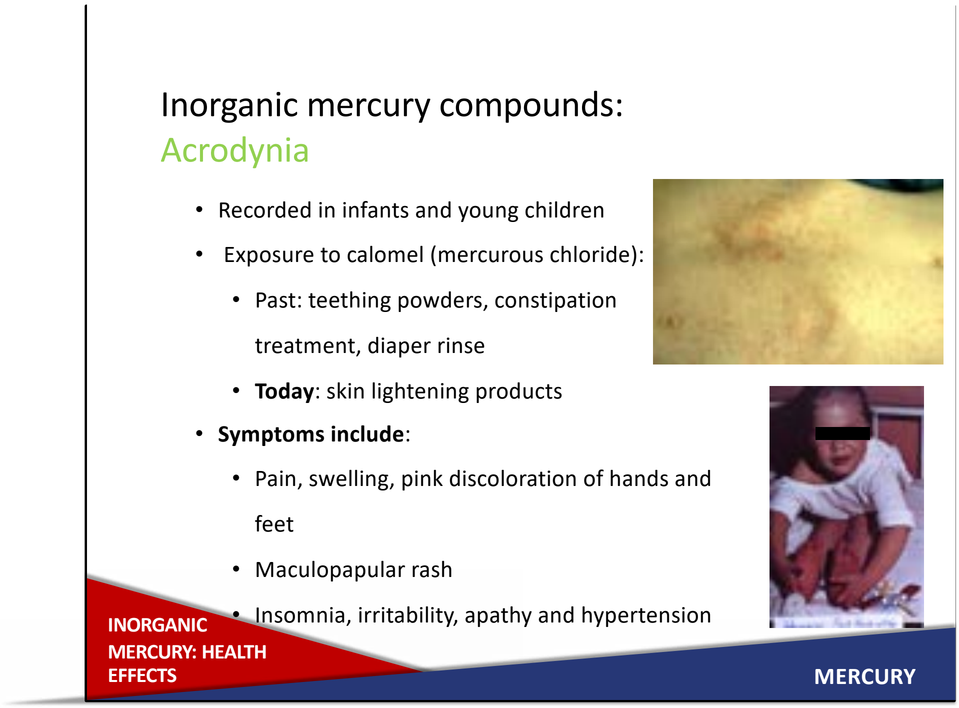

Acrodynia, or childhood mercury poisoning, was commonly reported in the mid-20th century in infants and young children exposed to calomel-containing products, particularly teething powders *(1)*.

Calomel is a form of inorganic mercury, also known as mercurous chloride, **and in the past** was an ingredient in a variety of different products used on infants and children including *(1–3)*:
- childhood teething powders;
- treatment for childhood constipation;
- diaper powder.

Acrodynia in children in characterized by *(1,2)*:
- pain in the extremities
- swelling and pink discolouration of the hands and feet (see bottom photo)
- maculopapular rash (see top photo)
- insomnia, irritability and apathy
- hypertension and other cardiovascular symptoms such as tachycardia.

Due to recognition of its toxic components and effects, calomel was widely removed from mainstream medical treatments in the mid-20th century and cases of acrodynia consequently declined and acrodynia is rarely reported today. However, **calomel has been found at harmful levels in skin lightening creams**, continuing to place children exposed to such products at risk of mercury poisoning *(4)*.

References:
1. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pediatrics; 2019.
2. Children’s exposure to mercury compounds. Geneva: World Health Organization; 2010 (https://www.who.int/publications/i/item/9789241500456, accessed 15 January 2024).
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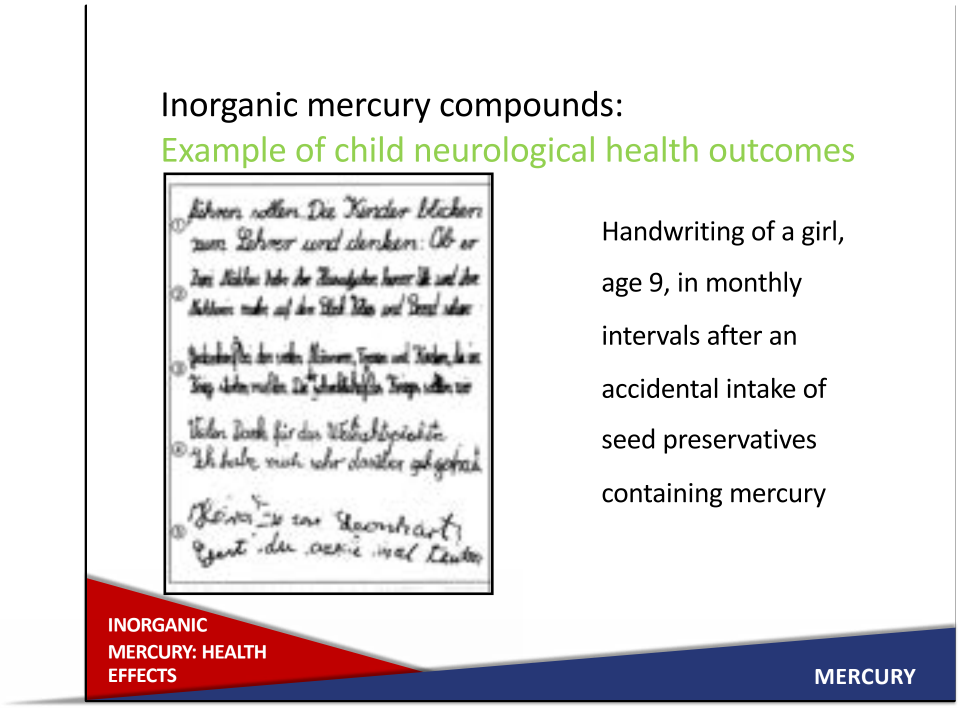
Photos:

- Top: von Mühlendahl, Schulte-Wissermann, Grips, Hautveränderungen bei Feer‘scher Krankheit. Pädiatrische Praxis (1995) 49, 647. Used with permission (copyright: Hans Marseille Verlag GmbH). Miliary rash is typical of acrodynia.

- **Bottom:** Schwarz, Feersche Erkrankung (kindliche Akrodynie), Pädiatrische Praxis (1979) 21: 85 – 89. Used with permission (copyright: Hans Marseille Verlag GmbH). 2½ year old girl. Hypotonia, constant scratching, with red fingers, foot soles, lips (acrodynia).



Tremor mercurialis, tremor caused by mercury exposure, is a typical symptom of acute and chronic mercury intoxication. The image on this slide shows monthly writing samples from a 9-year-old girl following accidental ingestion of grain contaminated with inorganic mercury-containing seed preservative. The patient consequently developed a tremor, as seen by the progressive deterioration in her handwriting in the figure on the slide. This example illustrates that exposure to mercury occurring well after infancy can have serious neurological consequences *(1,2)*.

Figure:

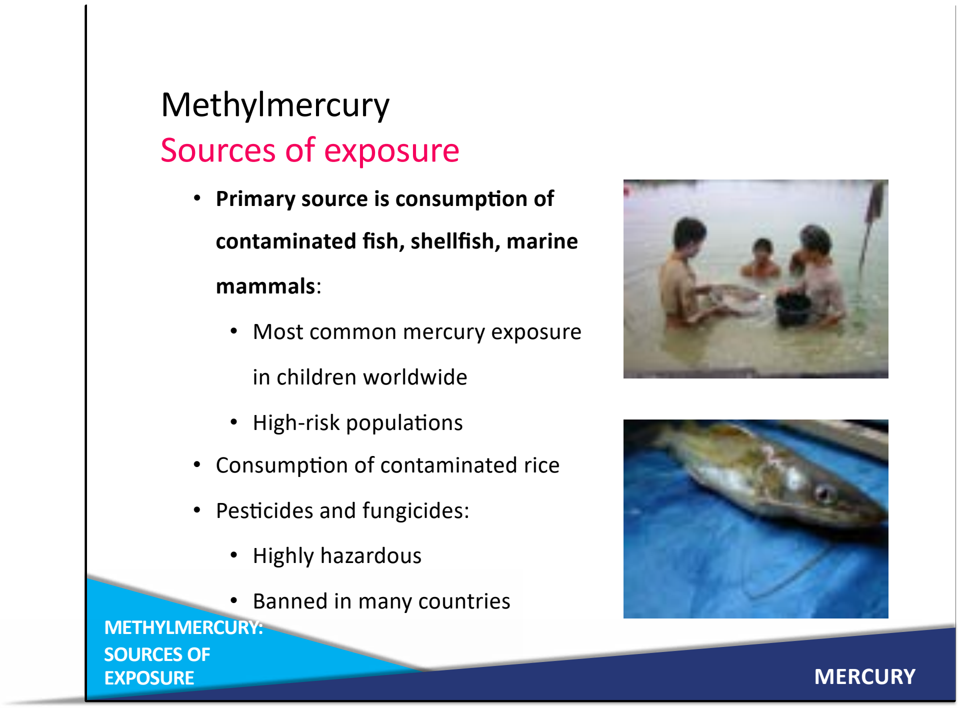
- Stephan Böse-O'Reilly. 9-year-old girl, handwriting example, 1989. Used with permission.

Reference:

1. Böse-O'Reilly S, Drasch G, Eife R, Laub MC. Chronische Metall-intoxikationen als Ursache neuropädiatrischer Erkrankungen. Paediat Prax. 1993;45:183.
2. Böse-O'Reilly S, McCarty KM, Steckling N, Lettmeier B. Mercury exposure and children's health. Curr Probl Pediatr Adolesc Health Care. 2010:40(8):186–215.

Due to the global significance of methylmercury on children's health, this training module only discusses this form of organic mercury in this section. Children are primarily exposed through consumption of fish, shellfish and marine mammals. The chemical symbol for methylmercury is CH_3Hg.

Photo:
- © WHO/ Gary Hampton. Illustration of life of survivors after the 2004 tsunami in Sri Lanka.



Methylmercury is the most common mercury exposure in children worldwide. The majority of methylmercury exposure is through consumption of contaminated fish, shellfish or marine mammals from both marine and fresh waters. Eating fish is highly beneficial to child health and development, so it is important to balance these benefits with the risk of methylmercury exposure *(1)*. Exposure to methylmercury is a global issue, however, in populations that rely on fish, shellfish and marine mammals as their primary source of protein are at increased risk *(2)*. Studies of populations living in remote regions of the world, with no known local sources of mercury pollution and high dietary reliance on fish and marine mammals, have shown high levels of methylmercury exposure. For example, indigenous populations in the Artic are among the highest mercury-exposed populations in the world due to marine mammal consumption, with a significant proportion of the population recognized as having mercury levels above health guideline levels *(3)*. Other population groups at high risk to methylmercury exposure include small island developing states and communities in the Amazon.

Contaminated rice is another potential source of methylmercury exposure in children. The top photo on this slide illustrates young men in a rice field in the Philippines that is polluted with mercury from a nearby small-scale gold mining operation. Rice is staple food in many countries around the world. Although measurements of methylmercury in rice grain have generally been found in lower concentrations than indicated in fish, elevated mercury levels in rice have been identified, especially in some areas in China, India and Indonesia. Methylmercury in rice is generally due to pollution of rice fields and patties with contaminated run-off from anthropogenic sources, particularly artisanal and small-scale gold mining and elemental mercury mining. There is a paucity of studies investigating human health and methylmercury exposure from rice, especially research on the prenatal period *(4)*.

Historically, some pesticides and fungicides contained methylmercury as an ingredient. Following widespread outbreaks of mercury poisoning due to consumption of contaminated grain in Iraq and China, these pesticides and fungicides are classified as highly hazardous and have been widely banned around the world *(6)*. Some countries have only banned mercury-containing pesticides recently, for example Australia banned them in 2020, and legacy contamination from past use may still be a concern *(7)*.

References:

1. Children’s exposure to mercury compounds. Geneva: World Health Organization; 2010 (https://www.who.int/publications/i/item/9789241500456, accessed 15 January 2024).
2. Global mercury assessment 2018. Geneva: United Nations Environment Programme; 2019 (https://www.unep.org/resources/publication/global-mercury-assessment-2018, accessed 15 January 2024).
3. Basu N, Abass K, Dietz R, Krümmel, Rautio A, Weihe R et al. The impact of mercury contamination on human health in the Artic: a state of the science review. Sci Total Environ. 2022;831:154793.

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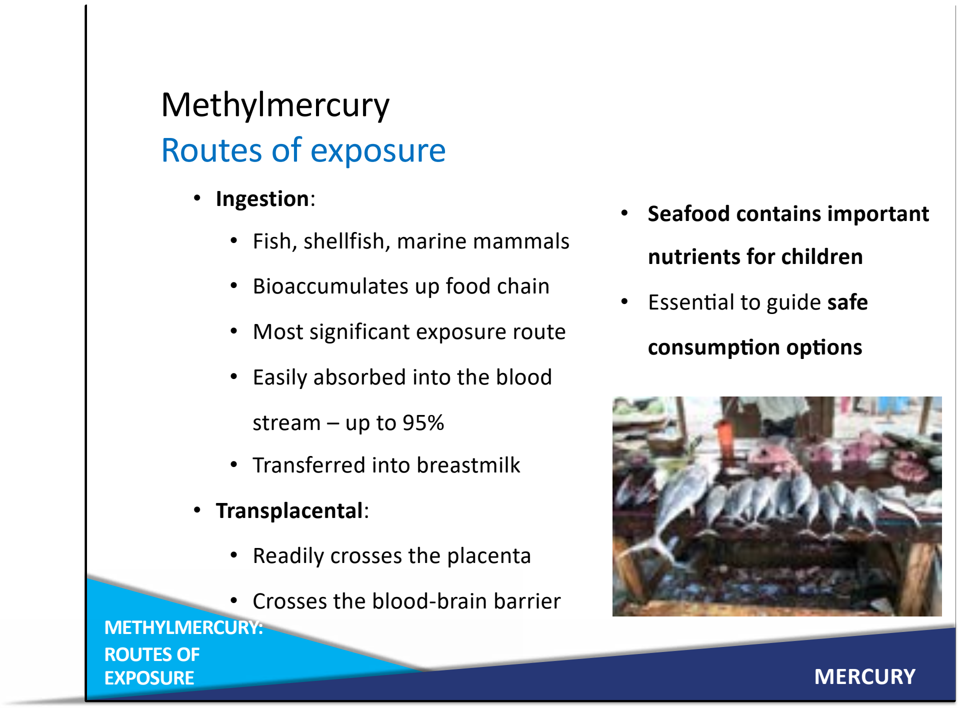
5. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pediatrics; 2019.
6. The WHO recommended classification of pesticides by hazard and guidelines to classification, 2019 edition. Geneva: World Health Organization; 2020 (https://apps.who.int/iris/handle/10665/332193, accessed 15 January 2024).
7. Schneider L. When toxic chemicals refuse to die – an examination of the prolonged mercury pesticides use in Australia. Elem Sci Anth. 2021;9:1.

Photos:

- Stephan Böse-O'Reilly. Rice field near Monkayo in Mindanao (Philippines), irrigated with tailing sediments, containing mercury from a small-scale mining operation area in Diwalwal, 1999. Used with permission.



Ingestion of contaminated fish, shellfish and marine mammals is children's primary route of exposure to methylmercury. Importantly, methylmercury is not evenly distributed throughout the aquatic food chain. Methylmercury bioaccumulates up the food chain and, consequently, large, predatory and long-life fish and marine mammals have the highest concentrations. It is also the most significant route of global exposure to any of the three types of mercury. Methylmercury is lipid soluble and is easily and readily absorbed by the gastrointestinal tract. Up to 95% of ingested methylmercury is absorbed through the gastrointestinal tract *(1)*. Methylmercury exposure in children can lead to accumulation of mercury in the developing central nervous system and can cause irreversible neurodevelopmental problems. Methylmercury is transferred into human breastmilk following ingestion and absorption. The presence of methylmercury in breastmilk is not sufficient to outweigh its benefits (see Slide 14 for the World Health Organization's (WHO) statement on breastfeeding). *(1–3)*.

Transplacental exposure to methylmercury may occur when a pregnant woman consumes contaminated fish, shellfish or marine mammals. Methylmercury can readily cross the placenta and expose the developing fetus. **Methylmercury also readily crosses the blood-brain barrier, including during pregnancy**. Methylmercury concentrates in the developing fetus and can accumulate in the sensitive and developing fetal brain. Exposure to methylmercury during pregnancy is a significant risk to the health and development of fetuses and infants *(1,2)*.

Seafood is an important source of lean proteins and essential fatty-acids that are beneficial for maternal, fetal and child health and development. It is therefore essential to guide pregnant and breastfeeding women, and families with young children on safe fish, shellfish and marine mammal consumption options in their local context *(1)*.

Note: see Slide 39 for an example of a national fish advisory guiding safe consumption of seafood, including specific suggestions for vulnerable populations.

References:

1. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pediatrics; 2019.
2. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).
3. Children's exposure to mercury compounds. Geneva: World Health Organization; 2010 (https://www.who.int/publications/i/item/9789241500456, accessed 15 January 2024).

Photo:

- © WHO/ Gary Hamptom. Illustration of life of survivors after the 2004 tsunami in Sri Lanka.

The Minamata Bay disaster in Japan was a devastating environmental event that led to new understandings of the threats that methylmercury poses to the environment and global public health.

Between 1932 and 1968, Chisso Corporation discharged industrial wastewater, including mercury compounds, directly into Minamata Bay. Over this period, many tonnes of organic mercury were released into the bay and resulted in very high levels of contamination of the local waters. Shellfish and fish in Minamata Bay became highly contaminated with methylmercury. At the time, the towns on the coast of Minamata Bay were largely populated with fishermen and farmers, and local populations had high dietary reliance on locally-caught shellfish and fish *(1)*.

In the mid-1950s, inhabitants of Minamata Bay began noticing mysterious illnesses that were affecting residents and local animal populations. Birds were reported being unable to fly, cats were reported 'dancing' erratically in the streets and fisherman reported that fish were swimming 'crazy' on the surface of the water. Local fisheries reported significant decreases in fish catches throughout the decade *(3)*. Stories circulated about adults exhibiting strange symptoms of a mysterious disease such as slurred speech and an inability to use food utensils. In 1959, doctors and scientists determined that the cause of the mysterious disease was organic mercury poisoning *(1,2)*.

Adults with acute levels of methylmercury exposure exhibited signs of serious neurodegeneration, including *(1,4)*:

- extreme tremors
- numbness in limbs
- loss of muscular control
- loss of vision and hearing
- paralysis and convulsions.

In extreme cases, patients fell into coma and died. Pregnant women, who were asymptomatic and seemingly healthy, gave birth to babies with severe congenital abnormalities and infantile cerebral palsy. Mothers who gave birth to babies with these severe health outcomes were later found to have extremely high levels of methylmercury *(4)*.

The term 'Minamata disease' was coined to described patients who developed a range of neurological symptoms after consuming methylmercury-contaminated fish or shellfish. There is no cure for Minamata disease. More than 2000 people have been officially certified as having Minamata disease, but at least 50 000 people are estimated to have had some health effects due to consumption of methylmercury-contaminated fish and shellfish *(2,4)*.

While the case of Minamata Bay may be an extraordinary example of environmental pollution, it was a global wakeup call to the dangers that methylmercury poses to public health. The following slides discuss the effects of methylmercury on child health in more detail.

References:

1. McCurry J. Japan remembers Minamata. Lancet. 2006;367(9505):99–100.
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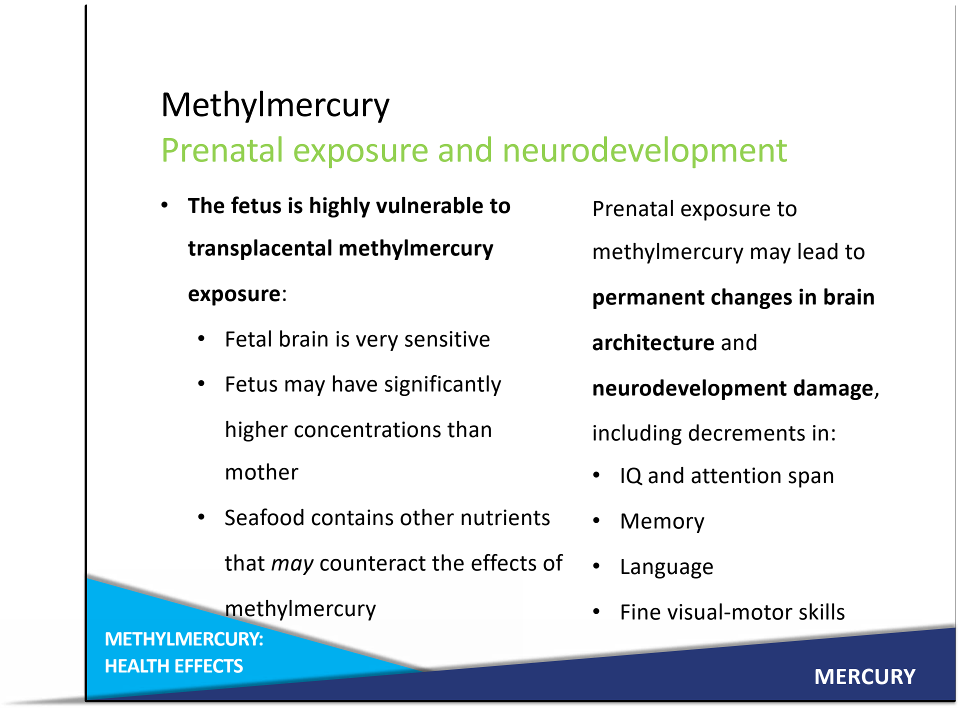
4. Yorifuli T. Lessons from an early-stage epidemiological study of Minamata Disease. J Epidemiol. 2020;30(1):12–14.



Methylmercury is an extremely toxic form of mercury and poses a global threat to public health. It is toxic to the central and peripheral nervous system *(1)*. The neurodevelopmental risks of methylmercury to the fetus are well established. Extremely high levels of exposure to methylmercury during pregnancy have been linked to severe neurological outcomes at birth and during early childhood, including microcephaly, blindness, deafness, seizures and, in some cases, infant mortality *(1,2)*. Mass methylmercury poisoning events have been recorded and documented in Iraq *(3)* and Japan *(4)*. These mass poisoning events had individual characteristics and recorded some differences in clinical symptoms and recovery in exposed adults and children. Both events, however, recorded permanent and severe neurodevelopmental outcomes in infants exposed to methylmercury *in utero*. These devasting poisoning events have helped scientists and medical researchers confirm that the fetal brain is highly sensitive to permanent damage due to methylmercury poisoning and that methylmercury is concentrated in the fetus – leading to higher concentrations in the fetus than in the mother *(5)*. Additionally, these events changed the previous belief that the fetus was protected *in utero* from external chemicals and identified the ability of toxicants to cross the placenta and negatively affect the developing fetus *(3,4)*.

Mass methylmercury poisoning events have generally been confined to specific geographic areas as a result of very high levels of environmental pollution. Chronic, low-level exposure to methylmercury, however, is a global risk to pregnant women and the development of their babies, especially in high-risk populations. Research has indicated that some populations are at increased risk of methylmercury exposure, particularly Arctic populations that rely on consumption of fish and marine mammals, small island developing states relying substantially on seafood and riverine communities who rely on locally-caught fish and may be exposed to mining, especially Amazonian communities *(6)*. A systematic review conducted in 2014 found that all three groups had substantial proportions of the population whose methylmercury exposure exceeded the reference value considered to pose no substantial risk of developmental neurotoxicity. In all three groups, high-end biomarkers indicated methylmercury body burdens that are associated with observable symptoms of neurological damage *(7)*.

A longitudinal, birth cohort study conducted in the Faroe Islands measured umbilical cord blood for methylmercury concentration and followed the children from birth through to 28 years of age, conducting behavioural and neurodevelopmental examinations every 7 years. This important study found associations between prenatal exposure to methylmercury and negative effects on intelligence quotient (IQ), memory, verbal performance and general intelligence at all ages. These associations were most significant at younger ages, but cognitive deficits were still apparent in study participants once they had reached adulthood *(8,9)*.

Exposure to methylmercury *in utero* has been associated with permanent changes to the brain's architecture through disruption of neuronal migration growth, differentiation, migration, synaptogenesis, and myelination in the developing brain *(2)*. Other studies conducted on children exposed to methylmercury *in utero* have had mixed findings and have suggested neurological deficits between prenatal exposure and changes to *(2,10)*:

- intelligence quotient (IQ)
- memory and other cognitive functions
- attention span
- verbal and language abilities
- motor function, including fine visual-motor skills.

Another longitudinal child development study, conducted in the Seychelles, among mothers who consumed large amounts of marine fish could not replicate the findings of the study conducted in the Faroe Islands. Hypothesis have suggested that beneficial nutrients from marine fish, including selenium and omega-3 polyunsaturated fatty acids, may have reduced the harmful neurdevelopmental effects of methylmercury *(11)*. This highlights the importance of guiding communities on the consumption of safe and beneficial types and amounts of local seafood before, during and after pregnancy.

References:

1. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).
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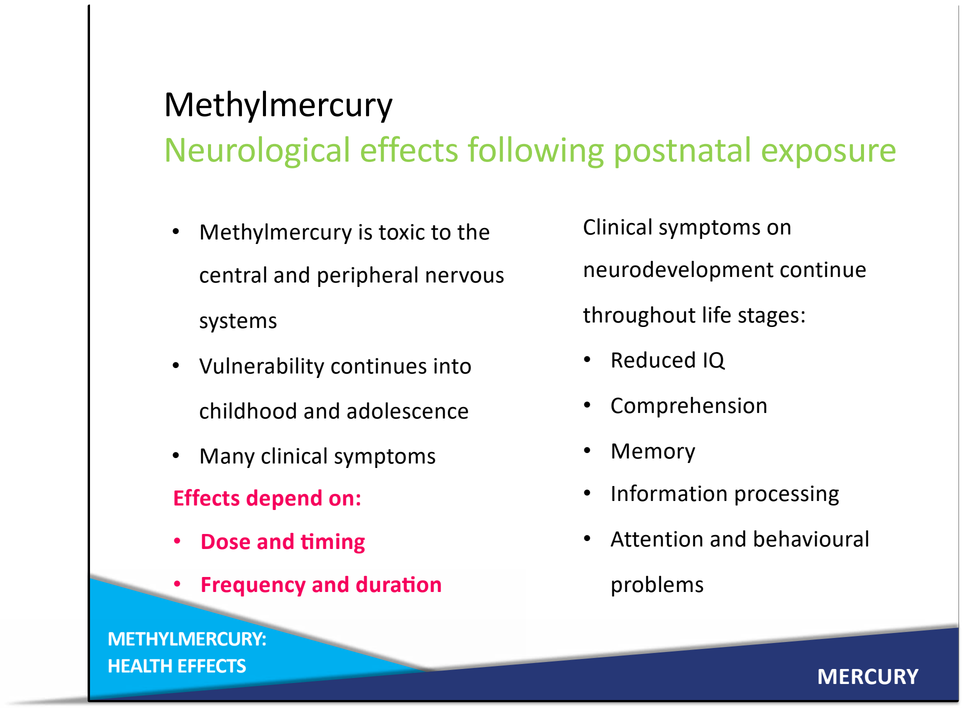


While methylmercury exposure during the prenatal period and outcomes on the central nervous system has been the subject of significant research, permanent effects may continue during childhood and adolescence. As discussed on Slides 29 and 30, the devastating events in Iraq and Japan, due to extremely high levels of methylmercury contamination and exposure, led to neurological and physiological effects in exposed children and adults. The reported clinical symptoms and recovery of patients, however, differed to some extent between these two events *(1,2)*. As with other toxicants, the effects of methylmercury depend upon the dose, timing, frequency and duration of exposure. These aspects of the events in Iraq and Japan may have led to different outcomes in each case, as well as the different form of contaminated food that was consumed (grain versus seafood, respectively) *(3)*. Additionally, these two events have helped to identify the many clinical signs of methylmercury poisoning. Clinical symptoms that have been identified as characteristic of methylmercury poisoning include ataxia, paresthesia, dystharia, hearing problems and constriction of the visual field *(3)*.

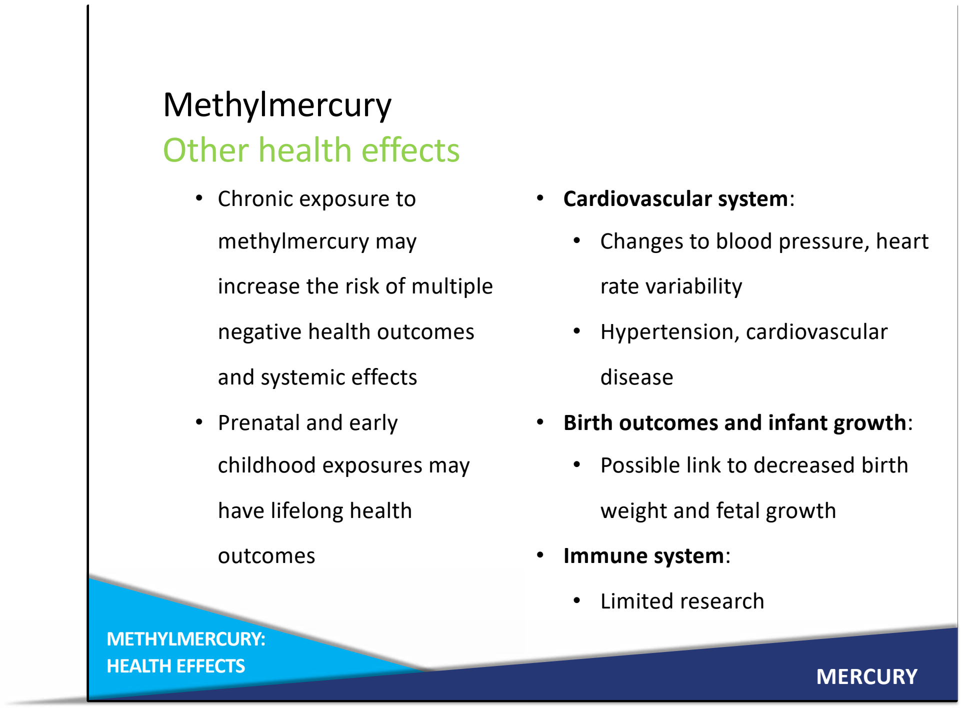
Over the past few decades, concerns have been raised over the potential effects that chronic consumption of contaminated, fish, shellfish and marine mammals may have on the health of children, adolescents and adults in high-risk communities. Postnatal exposure to methylmercury has been associated with a wide range of central nervous system dysfunction in epidemiological studies during childhood, adolescence and adulthood. Studies conducted in children exposed to methylmercury during specific childhood stages in Arctic communities have suggested that methylmercury exposure may be linked to deficits in *(4)*:

- intelligence quotient (IQ)
- processing visual information
- memory function
- comprehension and perceptual reasoning
- attention span and other behavioural problems.

A review of low-level methylmercury exposure conducted in 2012 found mixed results associating postnatal exposure at multiple life stages, including children and adults, and neurodevelopmental outcomes. It concluded that postnatal exposures during some childhood stages may have some degree of reversibility. It also concluded, however, that certain domains of neuro-behavioural function are more sensitive to methylmercury exposure than others across all age groups. These include memory, verbal and language skills and visual-motor functions *(5)*. A small number of studies have been conducted on adult populations that consume significant amounts of seafood and have found links to a range of negative neurological effects including deficits in memory and executive function *(6)*.

References:

1. Skerfving SB, Copplestone JF. Poisoning caused by the consumption of organomercury-dressed seed in Iraq. Bull World Health Organ. 1976;54:101–12.
2. Yorifuji T, Tsuda T, Harada M. Minamata disease: a challenge for democracy and justice. In: Late lessons from early warnings II: science, precaution, innovation. Luxembourg: European Environmental Agency; 2013:92–130.
3. Yorifuji T, Tsuda T, Takao S, Harada M. Long-term exposure to methylmercury and neurologic signs in Minamata and neighboring communities. Epidemiol. 2008;19(1):3–9.
4. Basu N, Abass K, Dietz R, Krümmel, Rautio A, Weihe R et al. The impact of mercury contamination on human health in the Arctic: a state-of-the-science review. Sci Total Environ. 2022;831:154793.
5. Karagas MR, Choi AL, Oken E, Horvat Schoeny R, Kamai E et al. Evidence on the human health effects of low-level methylmercury exposure. Environ Health Perspect. 2012;120(6):799–806.
6. Sheehan MC, Burke TA, Navas-Acien A, Breysse PN, McGready J, Fox MA. Global methylmercury exposure from seafood and risk of developmental neurotoxicity: a systematic review. Bull World Health Organ. 201492:254–69F.



While much research has focused on the central nervous system, recent studies have also investigated other health effects of methylmercury, including on fetal and child growth and the cardiovascular and immune systems.

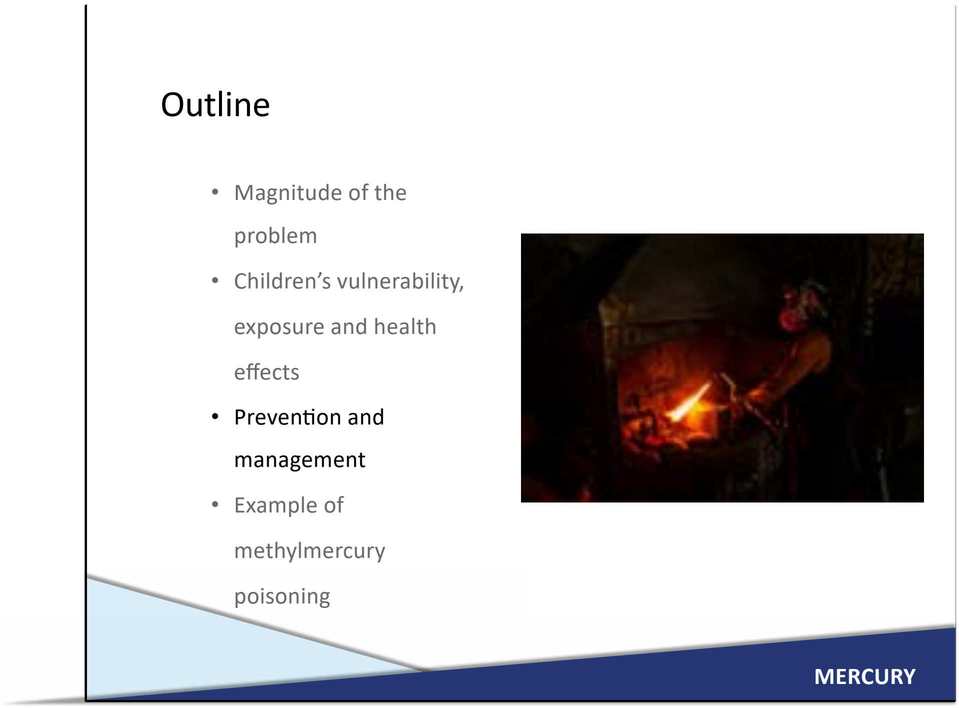
- Studies have indicated that frequent consumption of methylmercury-contaminated shellfish, fish and marine mammals may produce negative effects on the **cardiovascular system**. Most studies have been conducted in adults and have indicated links between mercury exposure from consumption of contaminated shellfish, fish or marine mammals and changes to blood pressure and heart rate variability, and increased risk of hypertension, myocardial infarction, atherosclerosis, coronary dysfunction and death from coronary heart disease or cardiovascular disease *(1,2)*. A small amount of research conducted in children has indicated that prenatal and early childhood exposure may be linked to changes in blood pressure in children 5–6 years of age *(3)*. Other studies have suggested changes in heart rate variability during childhood and early adolescence associated with methylmercury exposure from marine foods *(4,5)*. Prenatal and early childhood exposure may have lifelong effects on the cardiovascular system. Limited conclusions can be drawn due to an insufficient number of studies *(5)*. Additionally, fish are important dietary sources of selenium and omega-3 fatty acids, which can help mitigate diseases of the cardiovascular system. It is important to balance consumption of fish, shellfish or marine mammals to benefit cardiovascular health and limit exposure to methylmercury *(1)*.

- There is limited research that has investigated prenatal exposure to methylmercury and its effects on **birth outcomes and infant growth**. A systematic review published in 2021 found some evidence for a negative relationship between prenatal exposure to methylmercury and birthweight. This review reported stronger associations with high-quality studies and research reporting high levels of exposure, suggesting there may be a threshold effect *(6)*. A limited number of studies have indicated that even low-level methylmercury exposure during pregnancy may negatively affect fetal growth, as calculated by birthweight and small-for-gestational age. Other measurements of birth outcomes have had mixed results. The limited number of studies make drawing conclusions difficult *(6,7)*. Additionally, some research has investigated effects of postnatal methylmercury exposure on infant growth. More studies are required before associations can be made *(7)*.

- Finally, there is a small amount of research investigating exposure to methylmercury and adverse effects on the **immune system**. Some research has identified alterations to markers of immune system function, including changes to levels of antibodies following immunization *(8)*. One study conducted across several artisanal and small-scale gold mining communities in the Amazon found that children with poor nutritional status exposed to dietary methylmercury had decreased response to routine childhood vaccines *(9)*. Results conducted in mining communities must be carefully examined due to the likely presence of multiple risks to child health including poverty and malnutrition, inadequate access to safe water, sanitation and hygiene services, and infectious diseases *(10)*.

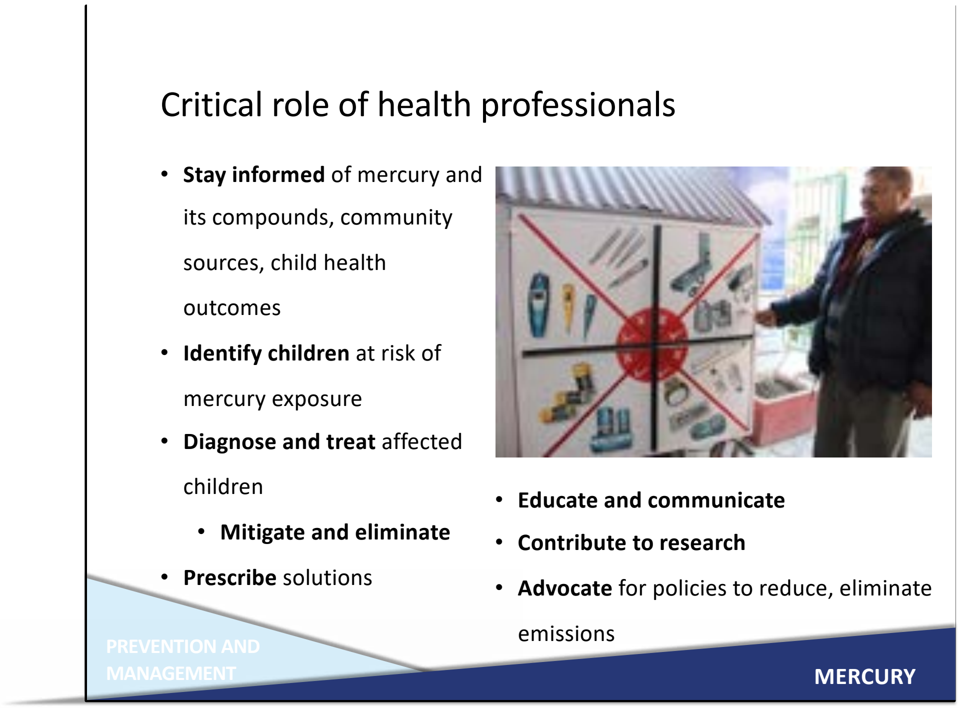
References:

1. Genchi G, Sinicropi MS, Carocci A, Lauria G, Catalano A. Mercury exposure and heart diseases. Int J Environ Res Public Health. 2017;14:74.
2. Basu N, Abass K, Dietz R, Krümmel, Rautio A, Weihe R et al. The impact of mercury contamination on human health in the Artic: a state-of-the-science review. Sci Total Environ. 2022;831:154793.
3. Farzan SF, Howe CG, Chen Y, Giilbert-Diamon D, Korrick S, Jackson BP et al. Prenatal and postnatal mercury exposure and blood pressure in childhood. Environ Int. 2021;146:106201.
4. Grandjean P, Murata K, Budtz-JørgensenE, Weihe P. Cardiac autonomic activity in methylmercury neurotoxicity: 14-year follow-up of a Faroese birth cohort. 2004;144(2):169–76.
5. Gribble MO, Cheng A, Berger RD, Rosman L, Guallar E. Mercury and heart rate variability: a systematic review. 2015;2:304–14.
6. Dack K, Fell M, Taylor CM, Havdahl A, Lewis SJ. Mercury and prenatal growth: a systematic review. Int J Environ Res Public Health. 2021;18:7140.
7. Karagas MR, Choi AL, Oken E, Horvat Schoeny R, Kamai E et al. Evidence on the human health effects of low-level methylmercury exposure. Environ Health Perspect. 2012;120(6):799–806.
8. Toxicological profile for mercury (draft for public comment). Atlanta: Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Public Health Service; 2022 (https://wwwn.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=115&tid=24, accessed 15 January 2024).
9. Wyatt L, Permar SR, Ortiz E, Berky A, Woods CW, Amouou GF et al. Mercury exposure and poor nutritional status reduce response to six expanded programs on immunization vaccines in children: an observational cohort study of communities affected by gold mining in the Peruvian Amazon. Int J Environ Res Public Health. 2019;16(4):638.
10. Allan-Blitz LT, Goldfine C, Erickson TB. Environmental and health risks posed to children by artisanal gold mining: a systematic review. SAGE Open Med. 2022;10:1–10.



The third section of the module discusses management interventions at personal, clinical, national and international levels to reduce and prevent children's exposure to mercury.

Photo:
- © WHO/ Yoshi Shimizu. A local miner applying the torching process using mercury to extract gold.



Health professionals should have a high index of suspicion for mercury exposure in children given its ubiquity in their environments. From a clinical perspective, it is important to include mercury as an environmental etiology in differential diagnoses *(1)*.

Health professionals play critical roles in protecting children from mercury exposure by *(2)*:

- **Staying informed** of mercury and its different compounds, including staying up-to-date with major sources of local emissions, main routes of exposure, related child health outcomes, and maintaining awareness of any confirmed cases of mercury poisoning. Health professionals should be aware of the best biomonitoring methods to assess mercury exposure. Different mercury compounds can be measured in blood, hair and urine and have different consequences for identifying exposure trends. For example, methylmercury can be measured in blood and hair. Typically, blood methylmercury can be used to measure exposure within 1–2 months, whereas hair methylmercury can indicate exposure over many months *(3).*
- **Identifying children at high risk of exposure to mercury and its compounds**. Health professionals can identify mercury-related risk factors by asking pertinent questions about the child's or pregnant mother's diet and environment. For example, enquiring about the location of the home to local sources of pollution, consumption of seafood and presence of any mercury-containing products in the home (see Slide 36 for some example questions). Additionally, health professionals should be aware of patients who are vulnerable and at increased risk to mercury, for example pregnant women and young children exposed to artisanal and small-scale gold mining activities or who live in areas primarily reliant on consumption of fish, shellfish or marine mammals.
- **Diagnosing and treating children affected by mercury exposure**. The most effective way to treat children with mercury poisoning is to identify, mitigate and eliminate the source or sources of exposure. **Eliminating sources of mercury is key to protecting children's health**. Children with confirmed mercury poisoning may require regular neurological assessment and support *(4)*.
- **Prescribing solutions to prevent further exposure and eliminate sources of mercury** including in the home, schools and in medical settings. Ideas to prevent, reduce and eliminate sources of mercury at personal, clinical and community level are discussed on Slides 35–41.
- **Educating and communicating** with patients, families, colleagues and students about the main local sources of mercury and poisoning risks to fetal and child health. Communicating locally-available methods to reduce exposure is important, for example the use of local or national fish advisories to guide consumption and tips to recognize products that contain mercury, such as skin lightening products *(5)*.
- **Contributing to research** on child health outcomes linked to mercury exposure and other related topics. For example, many areas of the world with high reliance on fish, shellfish and marine mammals for food have low rates of biomonitoring programmes that measure mercury concentration in these food sources. This includes countries, areas and territories in Latin America, sub-Saharan Africa and most small island developing states

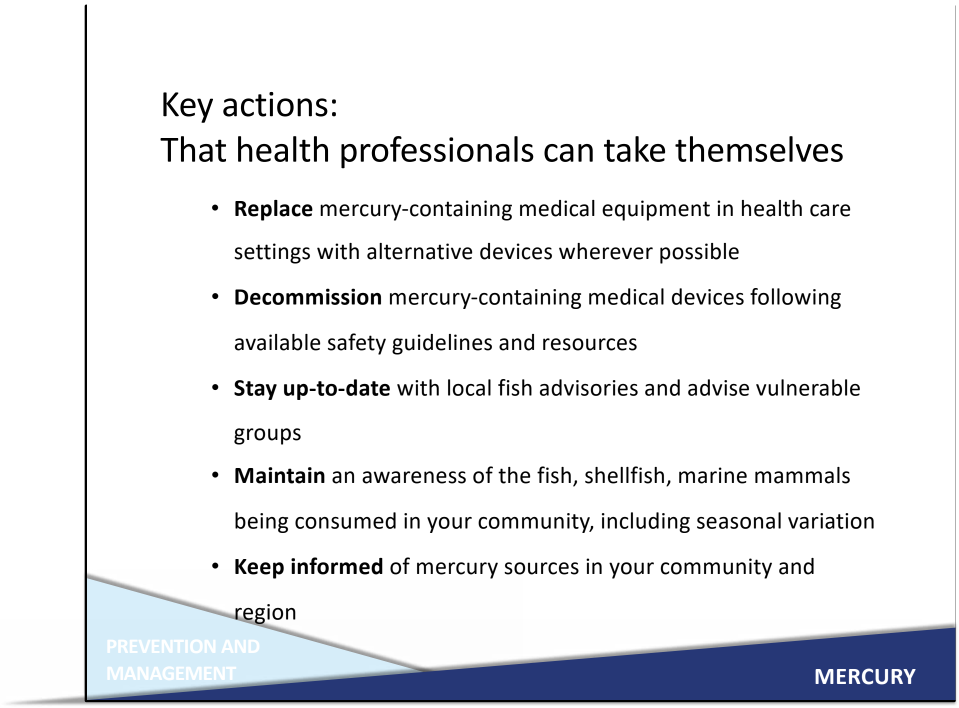
around the world. Local scientific and public health studies have made a significant impact in filling in existing gaps in the literature on contamination levels in fish, shellfish and marine mammal stocks, and consequently estimating methylmercury exposure among some local populations *(1)*.

- **Advocating for local, national and international policies and regulations to reduce and eliminate future mercury emissions**. Health professionals are well positioned to share their knowledge and convey the health burden of mercury to decision-makers, conduct health-based assessments, support improved standards and policies to reduce harmful exposure, advocate for monitoring, and emphasize the need to protect children's health. As local levels of mercury pollution and exposure are influenced by global emissions, policies and regulations must be broad in scope *(6)*.

Note: for more details on biomonitoring, see the module ***Biomarkers and human biomonitoring***.

References:

1. Global mercury assessment 2018. Geneva: United Nations Environment Programme; 2019 (https://www.unep.org/resources/publication/global-mercury-assessment-2018, accessed 15 January 2024).
2. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).
3. Basu N, Horvat M, Evers DC, Zastenskaya I, Weihe P, Tempowski J. A state-of-the-science review of mercury biomarkers in human populations worldwide between 2000 and 2018. Environ Health P erspect. 2018;126(10):1–14.
4. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pedi atrics; 2019.
5. Mercury in skin lightening products. Geneva: World Health Organization; 2019 (https://www.who.int/publications/i/item/WHO-CED-PHE-EPE-19.13, accessed 15 January 2024).
6. Addressing health when developing national action plans on artisanal and small-scale gold mining under the Minamata Convention on Mercury. Geneva: World Health Organization; 2019 (https://iris.who.int/handle/10665/329916, accessed 15 January 2024).



Health professionals are trusted and respected members of communities and this places them in a unique position to identify sources of mercury and set examples in removing potential mercury hazards in health care settings. Health professionals can:

- **Replace** mercury-containing medical equipment in health care settings with alternative devices wherever possible. Electronic alternatives are available for many medical devices that previously used elemental mercury, such as thermometers and sphygmomanometers *(1)*.
- **Decommission** mercury-containing medical devices following available safety guidelines and resources. In some areas, manufacturers of medical devices may take items back for safe disposal. In other areas, large hospitals and local or national governments may run programmes for the safe disposal of mercury-containing devices *(2,3)*.
- **Stay up-to-date** with local fish advisories, wherever possible, and advise vulnerable groups, including children and their parents and guardians, pregnant women and women of reproductive age, about safe and beneficial fish, shellfish and marine mammal consumption (see Slide 39 for more details and an example of a national fish advisory).
- **Maintain** an awareness of the fish, shellfish and marine mammals being consumed in your community, including trends and seasonal variations.
- **Keep informed** of mercury sources in your community and region, bearing in mind that there may be multiple sources and some sources, such as artisanal and small-scale gold mining, may be difficult to identify in areas where related activities are prohibited. Other important sources that may be difficult to determine include the use of skin lightening products and some traditional, complementary and integrative medical practices *(1,4)*.

The following slides have more detail on example questions that health professionals can ask and suggestions that can be made to reduce children's risk of mercury exposure

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

References:

1. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).
2. Replacement of mercury thermometers and sphygmomanometers in health care: technical guidance. Geneva: World Health Organization; 2011 (https://iris.who.int/handle/10665/44592, accessed 15 January 2024).
3. Decommissioning medical devices. Geneva: World Health Organization; 2019 (https://apps.who.int/iris/handle/10665/330095, accessed 15 January 2024).

4. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pediatrics; 2019.

Health professionals can ask their patients and families key questions that can help in detecting sources of mercury exposure and identifying at-risk children or pregnant women. Key questions can help to build a paediatric environmental history, assess whether a child is suffering from symptoms related to mercury exposure, and identify methods to eliminate and prevent exposure *(1)*. These questions must be context specific to each patient.

Examples of questions that can be asked include:

- How many servings of fish, shellfish or marine mammal do you or your child eat per week? What variety of fish, shellfish or marine mammal do you eat?
- Are you aware of any mercury-containing products in your home? This may include thermometers, batteries, or some fluorescent light bulbs.
- Do you keep any skin lightening cosmetics or products at home? Do you know if they contain mercury as an ingredient?
- Are you aware of any artisanal and small-scale gold mining activities in your home or neighbourhood?
- Are you aware of any cases of mercury poisoning in your community or neighbourhood?

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

Note: for more information on completing a paediatric environmental history please see the module ***The paediatric environmental history***.

References:

1. The paediatric environmental history: green page. Geneva: World Health Organization; 2017 (https://www.who.int/publications/m/item/children-s-environmental-record--green-page, accessed 15 January 2024).

There are suggestions that health professionals can make to children, pregnant women, their families and communities to reduce their exposure to mercury. It is important to note that reducing exposure often requires access to resources and infrastructure and, in some areas, considerations of local sources of livelihood are also necessary when considering how to reduce and eliminate mercury exposure. **Therefore, it is important to adapt these actions to the specific context of each patient**.

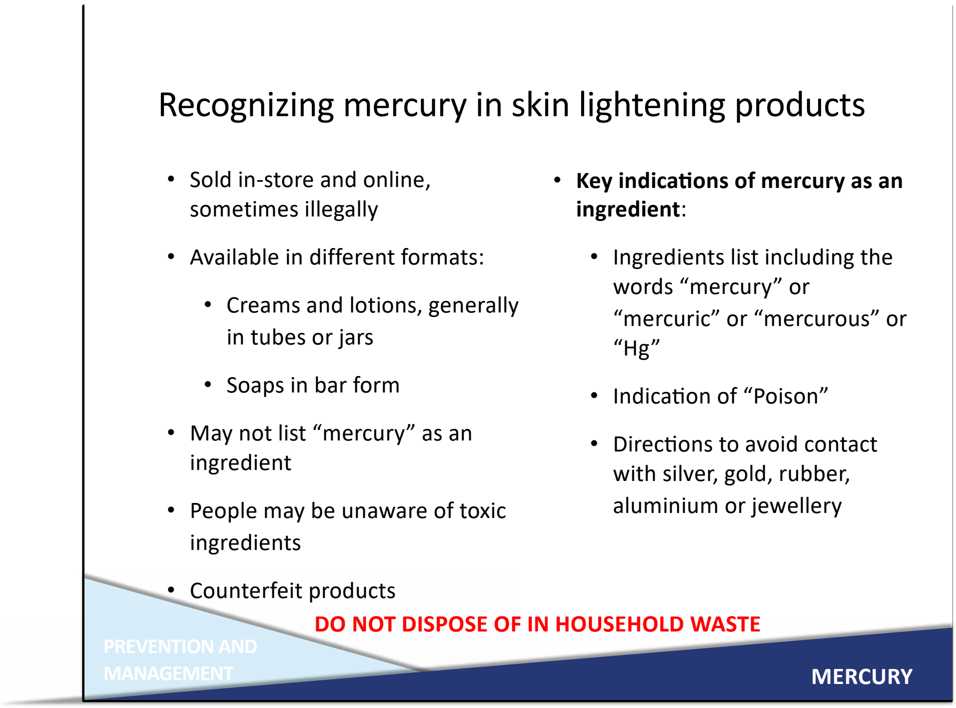
Examples of actions that can be suggested include *(1,2)*:

- **Limiting children's and pregnant women's consumption of certain fish, shellfish and marine mammals** likely to have high mercury concentrations. Common examples of fish with high mercury content may include tilefish, shark, swordfish, mackerel, some tunas and pike. Varieties of fish, shellfish and marine mammals with high mercury content depend upon geographical region and areas and local consumption may be seasonal.
- **Promoting the regular use of local fish advisories**, where possible. Slide 39 discusses fish advisories in more detail and gives a national example.
- **Promoting the use of mercury-free products in the home** and suggesting alternatives where possible. This may include batteries, light bulbs, thermometers, antiseptics, pesticides and disinfectants. See Slide 40 for more detail on preventing mercury exposure in the home.
- **Identifying and engaging with local or national programmes that are working to spread safer practices and methods in communities that rely on artisanal and small-scale gold mining** as an important source of income. Artisanal and small-scale gold mining is the single largest source of mercury pollution in the world. There are many programmes working globally to ensure that workers and communities use safer practices while maintaining their livelihoods.
- **Ensuring good dental hygiene** and practices from a young age to reduce the need for dental amalgams.
- **Advising against the use of skin lightening products and cosmetics containing mercury and educating patients and their families on recognizing hazardous products**. See reference *(3)* to check for skin lightening cosmetics and products that have been tested for mercury and may be available for sale in your country.

Note: if you have examples of successful actions that have been suggested or used in your context or region they can be mentioned here.

References:
1. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).

2. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pediatrics; 2019.
3. Zero Mercury Working Group: Mercury findings in skin-lightening products Online Database [website]. Brussels: European Environmental Bureau; 2018 (https://www.zeromercury.org/projects/mercury-added-skin-lightening-creams-campaign-database/, accessed 15 January 2024).



Skin lightening products are available widely throughout the world. Despite international regulations limiting mercury concentration in these products, many skin lightening cosmetics contain toxic amounts of mercury and are easily accessible in many parts of the world in shops and online stores *(1)*. Health professionals should have an awareness of whether their patients and families use or are exposed to skin lightening products that may contain mercury. There are some general tips and features of skin lightening products containing mercury that health professionals should be aware of and can share with their patients and wider community. Tips such as these can help people avoid products that contain mercury or report their use of mercury-containing items to their health care provider.

Skin lightening products *(1–3)*:

1. Are widely available across the world and can be bought in-store and online. Some products exceed the mercury limit set by the Minamata Convention on Mercury or are illegally exported or imported. Sometimes, skin lightening products containing mercury are sold "under the counter" in shops.
2. Come in a variety of formats. Most commonly **creams and lotions** available in tubes or jars and **soaps** in bar form.
3. May not list "mercury" as an ingredient, but there *may* be other indications that mercury is an ingredient.
4. Are commonly available and advertised in many countries. People who use them may be unaware of their toxic components.
5. Are sometimes counterfeit items that imitate other brands or products but may have dangerous levels of toxic substances, including mercury.

There are some key indications that a skin lightening product may contain mercury *(1)*:

- product ingredient list includes the word "mercury" or "mercuric" or "mercurous" or "Hg;"
- indication of "poison" on product packaging, including graphic indication;
- product packaging directs the user to avoid contact with silver, gold, rubber, aluminum or jewellery.

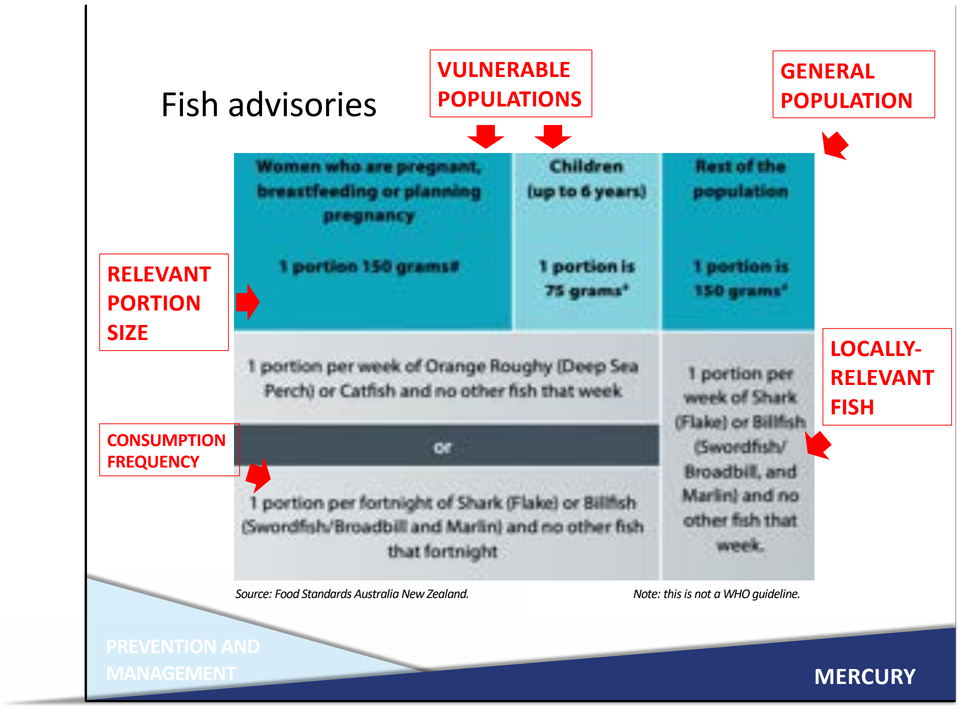
Skin lightening products that contain mercury are considered hazardous waste and should not be thrown in landfill or household waste. They should be disposed of with hazardous waste through a recognized provider *(3)*.

Note: if you have any examples of skin lightening products available in your community or region that are known to contain mercury, highlight them here.

References:

1. Mercury in skin lightening products. Geneva: World Health Organization; 2019

(https://www.who.int/publications/i/item/WHO-CED-PHE-EPE-19.13, accessed 15 January 2024).
2. Zero Mercury Working Group: Mercury findings in skin-lightening products Online Database [website]. Brussels: European Environmental Bureau; 2018 (https://www.zeromercury.org/projects/mercury-added-skin-lightening-creams-campaign-database/, accessed 15 January 2024).
3. Prevodnik A, Willcox A, Lynberidi-Settimo E, Bender M, Lane O. Mercury-added skin-lightening creams: available, inexpensive and toxic. Brussels: Zero Mercury Working Group; 2018 (https://www.unep.org/globalmercurypartnership/resources/report/mercury-added-skin-lightening-creams-available-inexpensive-and-toxic, accessed 15 January 2024).



Fish advisories are one form of dietary advice that can be effective in reducing pregnant women and children's exposure to methylmercury. High-risk populations in the Artic region, Faroe Islands and the Seychelles have experienced decreasing levels of mercury exposure, at least in part, due to localized advice on fish, shellfish and marine mammal consumption *(1)*. Where available, fish advisories can provide health care providers with guidance that they can share with their patients and families. As fish are an excellent source of lean protein and fatty acids that are essential for neurodevelopment, suggesting safe levels of consumption is key to protecting children's health.

Key features of fish advisories include *(2,3)*:
1. advice for vulnerable populations, especially pregnant and breastfeeding women, women who are planning pregnancy, and infants and young children;
2. advice for the general population;
3. relevant portion size for vulnerable and general population groups;
4. frequency of consumption. In the example on the slide this includes weekly and fortnightly consumption advice, depending on the type of fish consumed;
5. locally-relevant fish species that are commonly consumed and are most likely to have elevated mercury concentrations. In the case of the fish advisory shown on the slide, high-risk species in Australia include catfish, shark (flake) and swordfish. Seafood at high risk of mercury contamination differ between regions.

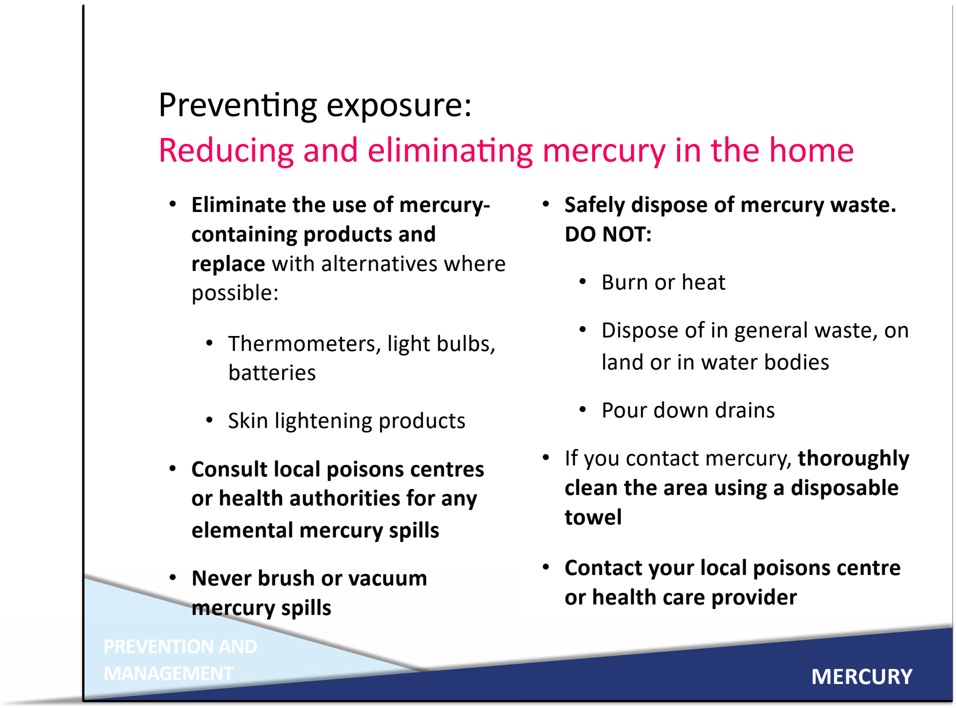
Fish advisories differ from region-to-region and country-to-country due to differing levels of contamination. The fish advisory featured on this side shows the advice for consumption in Australia *(2)*.

Note: if your country or region has a local fish advisory, use it is here.

Note: this is not a World Health Organization (WHO) guideline.

References:
1. Global mercury assessment 2018. Geneva: United Nations Environment Programme; 2019 (https://www.unep.org/resources/publication/global-mercury-assessment-2018, accessed 15 January 2024).
2. Mercury in fish: advice on fish consumption. Canberra: Food Standards Australia New Zealand; 2020 (https://www.foodstandards.gov.au/consumer/chemicals/mercury/pages/default.aspx, accessed 15 January 2024).
3. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pediatrics; 2019.

Figure:



Mercury can be found in a range of products that may be common in homes. Reducing and eliminating mercury exposure is key to protecting children's health.

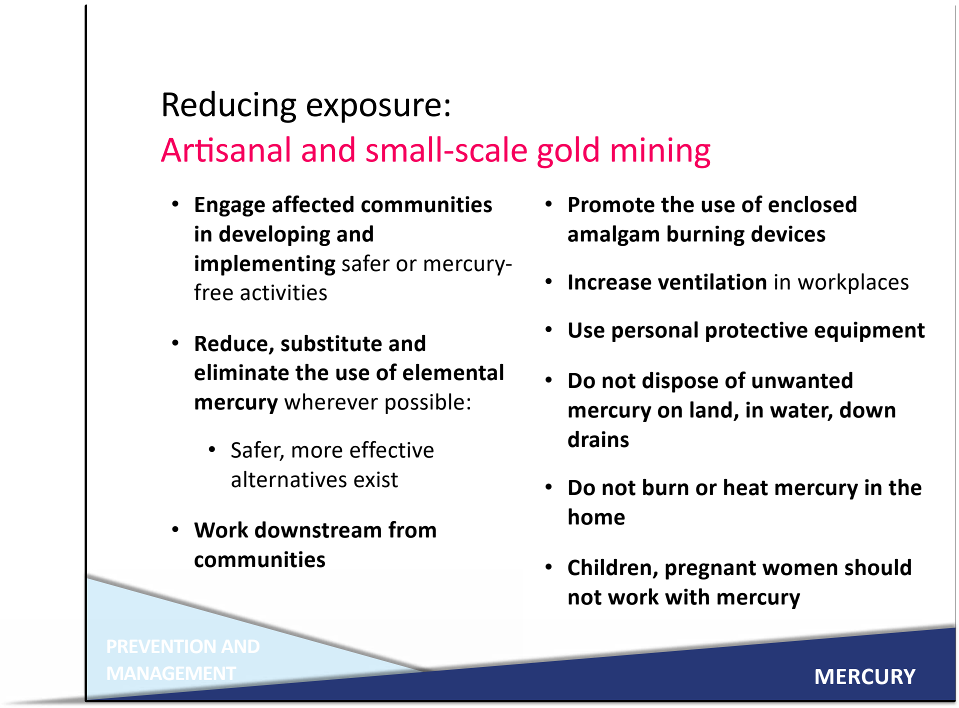
In the home, families can:

- **eliminate the use of mercury-containing products** and **replace** them with alternatives where possible, including *(1)*:
    - thermometers, light bulbs and batteries
    - skin lightening products containing mercury should be discarded following hazardous waste guidelines. Visit the link to see possible products available in your country that have been tested for mercury: https://www.zeromercury.org/projects/mercury-added-skin-lightening-creams-campaign-database/. Additionally, support groups exist in some countries to help people understand the risk of such products and to move away from beauty standards that promote lighter skin tones *(2)*;
- **consult local poisons centres or health authorities for any elemental mercury spills**. Additionally, the United States Environmental Protection Agency has detailed steps for cleaning up SMALL elemental mercury spills, including light bulbs and thermometers. Any elemental mercury spill larger than the contents of a thermometer (approximately 30 mililitres (mL)) should be removed and cleaned by professionals. **Pregnant women and children should leave any area where mercury has been spilt and should not assist in cleaning processes** *(3,4)*;
- **never vacuum or brush elemental mercury spills,** no matter how small. Brushing or vacuuming spills can cause contamination to spread and may increase vapourization *(3)*;
- **safely dispose of mercury waste and items containing mercury or contaminated by mercury**, including skin lightening products and cleaning equipment. **DO NOT** *(5)*:
    - burn or heat mercury or mercury-containing items;
    - dispose of mercury or mercury-containing items in general waste, on land or in water bodies;
    - pour elemental mercury or mercury-containing items down the drain
- **clean skin thoroughly using a disposable towel if it has come into contact with mercury**. Contaminated towels should be treated as hazardous waste. If you have used skin lightening products containing mercury, throughly wash the hands and other parts of the body that have come into contact with the product *(6)*;
- **contact the local poisons centre or health care provider** if you or your child have had contact with mercury or if you suspect mercury contact or poisoning *(3)*. Use the World Health Organization's (WHO) world directory of poisons centres to identify your local or national centre *(7)*.

Note: adapt this slide with key measures relevant to your local context to reduce and eliminate mercury in the home.

References:

1. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).
2. Zero Mercury Working Group: Mercury findings in skin-lightening products online database [website]. Brussels: European Environmental Bureau; 2018 (https://www.zeromercury.org/projects/mercury-added-skin-lightening-creams-campaign-database/, accessed 15 January 2024).
3. Etzel RA, editor. Pediatric environmental health, 4th edition. Itasca: American Academy of Pediatrics; 2019.
4. Mercury in consumer products [website]. Research Triangle Park: United States Environmental Protection Agency; 2023 (https://www.epa.gov/mercury/mercury-consumer-products#breaks, accessed 15 January 2024).
5. What to do if a mercury thermometer breaks [website]. Research Triangle Park: United States Environmental Protection Agency; 2023 (https://www.epa.gov/mercury/what-do-if-mercury-thermometer-breaks, accessed 15 January 2024).
6. Mercury poisoning linked to skin products [website]. Silver Spring: United States Food and Drug Administration; 2022 (https://www.fda.gov/consumers/consumer-updates/mercury-poisoning-linked-skin-products, accessed 15 January 2024).
7. Poison centres [website]. Geneva: World Health Organization; 2024 (https://www.who.int/teams/environment-climate-change-and-health/chemical-safety-and-health/incidents-poisonings/poisons-centres, accessed 15 January 2024).



Artisanal and small-scale gold mining is the leading source of global anthropogenic mercury emissions and is a major source of mercury exposure in some regions of the world. People who work in artisanal and small-scale gold mining operations have been shown to have highly elevated mercury levels compared to the general population *(1)*. Communities that engage in these activities and rely on the production of gold for economic reasons may have few alternatives. Consequently, it is essential to find safer ways for artisanal and small-scale gold mining operations to continue their work while reducing, and eventually eliminating, the use of elemental mercury in these activities.

Elemental mercury is generally involved in four steps of artisanal and small-scale gold mining *(2)*:

1. **extraction of material**, either from river sediments or hard-rock deposits;
2. **processing the ore**, to separate gold from other materials;
3. **amalgamation**, where elemental mercury bonds with gold forming an 'amalgam';
4. **burning of amalgam**, which evaporates the mercury and leaves behind the desired gold.

Almost all elemental mercury used in these processes is thought to be released into the environment *(1)*. Health care professionals can work with communities affected by artisanal and small-scale gold mining to reduce emissions and reduce workers' and community-wide exposure to mercury. Methods include:

- **Engaging affected communities in developing and implementing** safer or mercury-free gold mining activities. Community investment, contribution and ownership is key to ensuring successful and sustainable changes to make artisanal and small-scale gold mining activities safer and less polluting.
- **Reducing, substituting and eliminating the use of elemental mercury** in artisanal and small-scale gold mining activities, wherever possible. Safer and more effective (greater amount of gold captured) exist as an alternative to mercury. It should be noted that alternatives may require specific training and technologies *(3)*. See reference *(3)* for details on possible alternatives.
- **Working on artisanal and small-scale gold mining activities downstream from communities**. This may help reduce community exposure to elemental mercury *(4)*.
- **Promoting the use of enclosed amalgam burning devices**, such as a retort *(2)*.
- **Increasing ventilation in workplaces through open windows and use of fans** to ensure that mercury vapour does not build up in indoor workplaces *(4)*.
- **Using personal protective equipment,** such as gloves, respirators and other tools to reduce personal exposure. Workers can also remove clothing worn in mercury-contaminated environments before entering homes *(4)*.
- **Avoiding disposal of unwanted mercury on land, in water bodies or down drains**. If disposal through hazardous waste collection services is not possible, other options can reduce community exposure to mercury. Finding a solution for unwanted mercury may require community agreement on a designated area away from residential areas, farming and water bodies, and appropriate design and construction materials to protect the environment

and community from mercury. See reference *(3)* for more detail on soil-lined pits for mercury disposal.
- **Avoiding any burning or heating mercury in the home**. This can lead to widespread mercury contamination in the home and can expose family members to extremely high levels of mercury pollution.
- **Ensuring that pregnant women and children do not work with mercury** and **are not be present in areas where mercury is being used** to obtain gold *(3,4)*.

Note: only include this slide if artisanal and small-scale mining is relevant to your region or audience. If you have examples of measures that have been taken to reduce mercury emissions from artisanal and small-scale gold mining, they can be used here.

References:

1. Global mercury assessment 2018. Geneva: United Nations Environment Programme; 2019 (https://www.unep.org/resources/publication/global-mercury-assessment-2018, accessed 15 January 2024).
2. Global Mercury Partnership, UNEP. Guidance document: developing a national action plan to reduce and, where feasible, eliminate mercury use in artisanal and small-scale gold mining. Geneva: United Nations Environment Programme; 2017 (https://wedocs.unep.org/handle/20.500.11822/25473, accessed 15 January 2024).
3. Telmer K, Stapper D. Reducing mercury use in artisanal and small-scale gold mining: a practical guide. Nairobi: United Nations Environment Programme; 2012 (https://www.unep.org/resources/report/reducing-mercury-use-artisanal-and-small-scale-gold-mining-practical-guide, accessed 15 January 2024).
4. Environmental and occupational health hazards associated with artisanal and small-scale gold mining. Geneva: World Health Organization; 2016 (https://apps.who.int/iris/handle/10665/247195, accessed 15 January 2024).

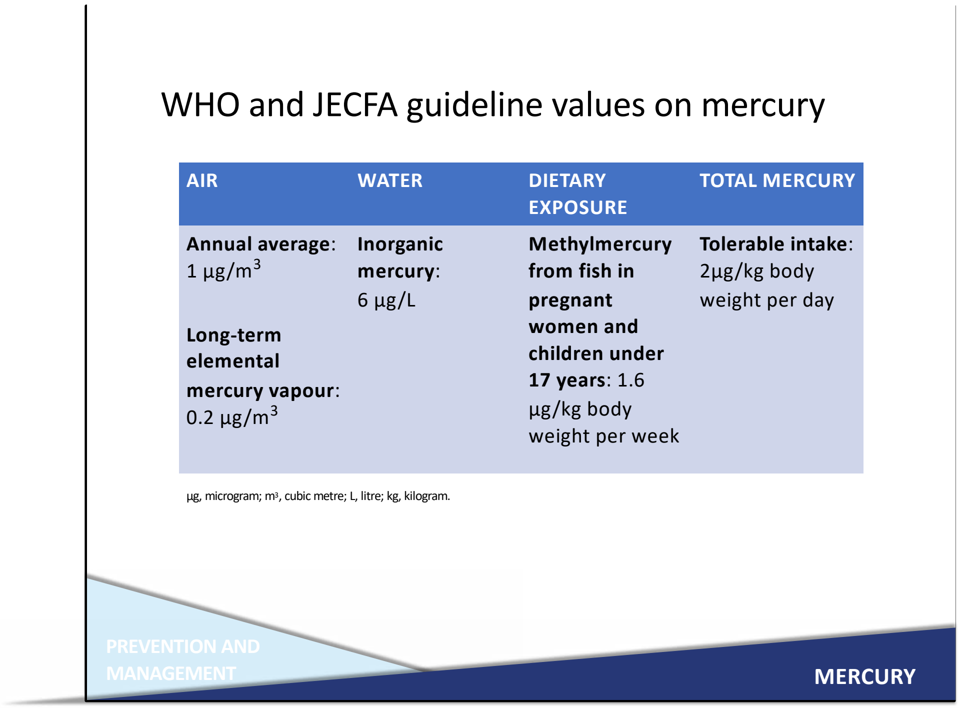
At the national level, action is vital to reduce children's exposure to mercury. National governments can take many actions to decrease local mercury emissions, reduce exposure and protect children from mercury. National governments can:

- **promote the replacement and use of mercury-free medical equipment in schools, homes and health care settings**, especially blood pressure devices and thermometers *(1)*. The United Nations Environment Programme (UNEP) has developed the *Toolkit for identification and quantification of mercury releases*, which aims to assist countries in identifying and calculating sources of mercury emissions and releases *(2)*;
- **phase out the use of mercury in non-essential products**. For example, in batteries, skin lightening products and light bulbs *(1)*;
- **research and implement safe-handling and appropriate and accessible disposal methods of mercury-containing products**, as well as ensuring that workers receive adequate training, personal protective equipment and appropriate infrastructure, and ensuring that mercury-safe disposal sites are available for the public to use *(1)*;
- **identify locally-consumed fish at high risk of methylmercury contamination** and spread awareness of acceptable portions of consumption, especially in vulnerable populations *(1)*;
- **ban the use of mercury-containing pesticides and fungicides**. While many countries have banned the use of mercury-containing pesticides and fungicides, some mercury-containing products are still available in some countries. Mercury contamination may persist in soil for years after application and continue to pose a threat to child health *(3)*;
- **establish and enforce mercury emission thresholds from industrial sources**, for example from coal-fired power plants;
- **develop public health strategies for artisanal and small-scale gold mining**, accounting for the importance that these activities may have to local economic situations and locally-specific features of activities *(4)*;
- **develop and enforce regulations on mercury in skin lightening products in line with the Minamata Convention on Mercury**, including in-store and online sales and training to identify mercury-containing products and illegal imports *(5)*;
- **conduct advocacy campaigns on the dangers of mercury in skin lightening products** *(5)*;
- **raise awareness among health care providers of local mercury threats to child health**. For example, the use of skin lightening products, highly contaminated fish or artisanal and small-scale gold mining activities *(5)*;
- **ratify the Minamata Convention** and implement relevant interventions.

References:

1. Exposure to mercury: a major public health concern, second edition. Geneva: World Health Organization; 2021 (https://www.who.int/publications/i/item/9789240023567, accessed 15 January 2024).

2. Mercury inventory toolkit [website]. Nairobi: United Nations Environment Programme; 2023 (https://www.unep.org/explore-topics/chemicals-waste/what-we-do/mercury/mercury-inventory-toolkit, accessed 15 January 2024).
3. The WHO recommended classification of pesticides by hazard and guidelines to classification, 2019 edition. Geneva: World Health Organization; 2020 (https://apps.who.int/iris/handle/10665/332193, accessed 15 January 2024).
4. A step-by-step guide for developing a public health strategy for artisanal and small-scale gold mining in the context of the Minamata Convention on Mercury. Geneva: World Health Organization; 2021 (https://iris.who.int/handle/10665/340411, accessed 15 January 2024).
5. Mercury in skin lightening products. Geneva: World Health Organization; 2019 (https://www.who.int/publications/i/item/WHO-CED-PHE-EPE-19.13, accessed 15 January 2024).



WHO and JECFA guideline values on mercury

AIR	WATER	DIETARY EXPOSURE	TOTAL MERCURY
Annual average: 1 µg/m^3 **Long-term elemental mercury vapour**: 0.2 µg/m^3	**Inorganic mercury**: 6 µg/L	**Methylmercury from fish in pregnant women and children under 17 years**: 1.6 µg/kg body weight per week	**Tolerable intake**: 2µg/kg body weight per day

µg, microgram; m^3, cubic metre; L, litre; kg, kilogram.

The World Health Organization (WHO) and the joint Food and Agricultural Organization (FAO)/ WHO Expert Committee on Food Additives (JECFA) have established guideline values and tolerable intakes for different forms of mercury that aim to protect human health. The table on this slide displays the key values and relevant environmental media to which they apply.

- **annual average concentration of mercury in air**: 1 microgram (µg)/ cubic metre (m^3) *(1)*;
- **long-term inhalation exposure to elemental vapour**: 0.2 µg/m^3 *(2)*;
- **water concentration of inorganic mercury**: 6 µg/litre (L) *(3)*;
- **dietary exposure to methylmercury from fish, seafood and marine mammals in pregnant women and children under the age of 17 years**: 1.6 µg/kilogram (kg) body per week *(4)*. This intake is protective of the developing fetus from neurotoxic effects. JECFA has established that other non-pregnant adults may consume twice the amount of methylmercury from fish without neurotoxic effects *(5)*;
- **WHO estimates a tolerable intake** of total mercury of 2 µg/kg body weight per day *(2)*.

National governments can use these guideline values to establish national standards that protect human health and address emissions from locally-relevant mercury sources.

References:

1. Air quality guidelines for Europe, second edition. Copenhagen: World Health Organization Regional Office for Europe; 2000 (https://iris.who.int/handle/10665/107335, accessed 15 January 2024).
2. Elemental mercury and inorganic mercury compounds: human health aspects. Geneva: World Health Organization; 2003 (https://iris.who.int/handle/10665/42607, accessed 15 January 2024).
3. Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. Geneva: World Health Organization; 2022 (https://apps.who.int/iris/handle/10665/254637, accessed 15 January 2024).
4. Joint FAO/WHO Expert Committee on Food Additives. Evaluation of certain food additives and contaminants: sixty-first report of the Joint FAO/WHO Expert Committee on Food Additives. Rome and Geneva: Food and Agriculture Organization of the United Nations and World Health Organization; 2004 (https://iris.who.int/handle/10665/42849, accessed 15 January 2024).
5. Joint FAO/WHO Expert Committee on Food Additives. Evaluation of certain food additives and contaminants: sixty-seventh report of the Joint FAO/WHO Expert Committee on Food Additives. Rome and Geneva: Food and Agriculture Organization of the United Nations and World Health Organization; 2006 (https://iris.who.int/handle/10665/43592, accessed 15 January 2024).

There are multiple conventions that exist to address mercury pollution at the international level.

- **Minamata Convention on Mercury** is a global treaty to protect human health and the environment from the adverse effects mercury (see Slide 45 for more details) *(1)*.

- **Rotterdam Convention** on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade promotes shared responsibility and cooperation between countries in the international trade of hazardous chemicals, including banned or controlled pesticides and industrial chemicals, to protect human health and the environment. Mercury compounds used in pesticides are listed under Annex III of the Rotterdam Convention. Chemicals listed in Annex III are banned or severely restricted in two of more countries party to the Convention. As of 2024, there are 165 parties to, and 55 chemicals are covered under, the Rotterdam Convention *(2,3)*.

- **Basel Convention** controls the transboundary movement of hazardous wastes and their disposal. It is a comprehensive environmental agreement in relation to tackling the issues surrounding e-waste and its management. As of 2024, the Basel Convention has 191 parties and 14 Basel Convention Regional and Coordinating Centres have been established for capacity building and technology transfer. In 2019, the Ban Amendment to the Basel Convention entered into force. It prohibits the movement of hazardous wastes from countries of the Organisation for Economic Co-operation and Development (OECD), the European Commission countries and Liechtenstein, to other States that are party to the Basel Convention *(4)*. The Convention classifies elemental mercury and mercury-containing or contaminated wastes as hazardous waste *(5)*. Technical guidelines on the sound management and disposal of mercury and mercury wastes are available *(6)*.

Other useful tools for international action on mercury include:

- **Joint FAO/WHO Expert Committee on Food Additives (JECFA)**: an international scientific expert committee administered jointly by the Food and Agricultural Organization (FAO) and World Health Organization (WHO). It evaluates the safety of food additives for human consumption, including mercury (see Slide 43 for relevant established tolerable intakes of mercury) *(7)*.

- **World Health Assembly (WHA) Resolution 67.11** on the *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.* This Resolution was adopted in 2014 and it encourages Member States to ratify the Minamata Convention and implement measures to address exposure to mercury in the context of the health sector and ensure the sound management of mercury and mercury compounds throughout their lifecycle. It also urged

WHO to work with Member States to support the implementation of the Minamata Convention and the development and enforcement of strategies to protect public health from mercury *(8)*.

- **United Nations Environment Programme's (UNEP) Global Mercury Partnership** works in collaboration with governments, nongovernmental organizations (NGOs), intergovernmental organizations (IGOs), industry and academia from around the world to support and implement the recommendations from the Minamata Convention. The Partnership works on eight key sectors that use or process materials that contain mercury, including artisanal and small-scale gold mining, mercury in consumer products, and waste management *(9)*.

- **planetGOLD** works with governments, NGOs and communities to make artisanal and small-scale gold mining operations safer, cleaner and more effective. According to the most recent annual report published in 2023, planetGOLD is running programmes in 23 countries. These programmes differ from context-to-context and include activities such as training for miners on safer and cleaner gold extraction, awareness raising among affected communities, strengthening regulatory frameworks and technology transfer *(10)*.

- The **Zero Mercury Working Group** is an international coalition of environmental and health NGOs from around the world. The Group supports reducing anthropogenic mercury emissions to the lowest possible level. The Group provides a range of useful resources, including an online database of skin lightening products that have been tested and found to contain levels of mercury that exceed the limit set by the Minamata Convention *(11,12)*.

References:

1. Minamata Convention on Mercury. Minamata convention on mercury: about us [website]. Geneva: United Nations Environment Programme; 2021 (https://www.mercuryconvention.org/en/about, accessed 15 January 2024).
2. Rotterdam Convention Secretariat. Rotterdam convention [website]. Rome, Geneva: Food and Agriculture Organization of the United Nations, United Nations Environment Programme; 2010 (http://www.pic.int/, accessed 15 January 2024).
3. Rotterdam Convention Secretariat. Decision guidance documents: mercury compounds. Rome, Geneva: Food and Agriculture Organization of the United Nations, United Nations Environment Programme; 1996 (http://www.pic.int/TheConvention/Chemicals/AnnexIIIChemicals, accessed 15 January 2024).
4. Secretariat of the Basel Convention. Basel convention [website]. Geneva: United Nations Environment Programme; 2022 (http://www.basel.int/, accessed 15 January 2024).
5. Secretariat of the Basel Convention. Basel convention: mercury wastes [website]. Geneva: United Nations Environment Programme; 2011 (https://www.basel.int/Implementation/MercuryWastes/Overview/tabid/3890/Default.aspx, accessed 15 January 2024).
6. Technical guidelines on the environmentally sound management of wastes consisting of, containing or contaminated with mercury or mercury compounds. Geneva: United Nations Environment Programme; 2023 (https://www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx, accessed 15 January 2024).
7. Joint FAO/WHO Expert Committee on Food Additives (JECFA) [website]. Geneva: World Health Organization; 2024 (https://www.who.int/groups/joint-fao-who-expert-committee-on-food-additives-(jecfa), accessed 15 January 2024).
8. Resolution WHA 67.11. 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. In: Sixty-seventh World Health Assembly, Geneva, 19–24 May 2014. Resolutions, decisions and annexes. Geneva: World Health Organization; 2014:11 (WHA67/2014/REC/11; https://iris.who.int/handle/10665/162849, accessed 15 January 2024).
9. Global mercury partnership: our work [website]. Nairobi: United Nations Environment Programme; 2024 (https://www.unep.org/globalmercurypartnership/our-work, accessed 15 January 2024).
10. PlanetGOLD. 2021/2022 annual progress report. Nairobi: United Nations Environment Programme; 2023 (https://www.planetgold.org/2021-2022-annual-progress-report, accessed 15 January 2024).
11. Zero Mercury Working Group [website]. Brussels: European Environmental Bureau; 2018 (https://www.zeromercury.org/, accessed 15 January 2024).
12. Zero Mercury Working Group: mercury findings in skin-lightening products online database [website]. Brussels: European Environmental Bureau; 2018 (https://www.zeromercury.org/projects/mercury-added-skin-lightening-creams-campaign-database/, accessed 15 January 2024).

The Minamata Convention on Mercury is a global treaty to protect human health and the environment from anthropogenic emissions of mercury and its adverse effects. It was agreed at the fifth session of the Intergovernmental Negotiating Committee on mercury in Geneva, Switzerland in January 2013, and adopted in October 2013 at a Diplomatic Conference (Conference of Plenipotentiaries), held in Kumamoto, Japan. It entered into force in August 2017. As of 2024, there are 147 parties to the Minamata Convention *(1)*.

The Minamata Convention is named after the mass poisoning event that occurred in Minamata Bay, Japan in the mid-20th century (please see Slide 29 for more detail) *(2)*.

The Minamata Convention calls for the phase out and phase down of mercury in key sectors, as well as in several consumer products. Countries that have ratified the Minamata Convention should *(3)*:

- **ban the manufacture, import or export of mercury in certain products**, including cosmetics, pesticides, batteries and components of electronic items;
- **take steps to reduce** and eliminate **the use of mercury and mercury compounds in**, and the emissions and releases to the environment of mercury from, **artisanal and small-scale gold mining** activities and processes;
- **set mercury emission thresholds** from industrial sources, such as coal-fired power plants;
- **not open new mercury mines** and must phase out the use of existing mercury mines;
- **ensure that mercury wastes are managed in environmentally-sound manners**;
- **take action to identify and assess contaminated sites**.

The Minamata Convention provides a platform for multisectoral engagement to address a range of health issues affecting communities that experience mercury contamination, for example artisanal and small-scale gold miners, their families and wider community. The Minamata Convention also provides access to financial support, technical assistance and technology transfer to low-and middle-income countries (LMICs). These features aim to assist countries to identify sources of mercury exposure, identify high-risk populations, and assist in estimating the cost of replacing mercury in products and industries *(3)*.

The global health sector has an important role to play in ensuring that the Minamata Convention reaches its targets. In countries party to the Minamata Convention, the health sector is working to *(4)*:

1. phase out mercury in medical devices, such as thermometers and blood devices, and replace them with mercury-free alternatives *(5)*;
2. promote oral health from a young age, to phase down and out the need for dental amalgams, and promote mercury-free alternative treatments *(6)*;
3. implement strategies to protect high-risk populations such as artisanal and small-scale gold miners *(7)*;

4. monitor mercury exposure, communicate risks and provide health advice.

Additionally, the implementation of the Minamata Convention is central to achieving several of the targets set out in the Sustainable Development Goals (SDGs), including *(8)*:

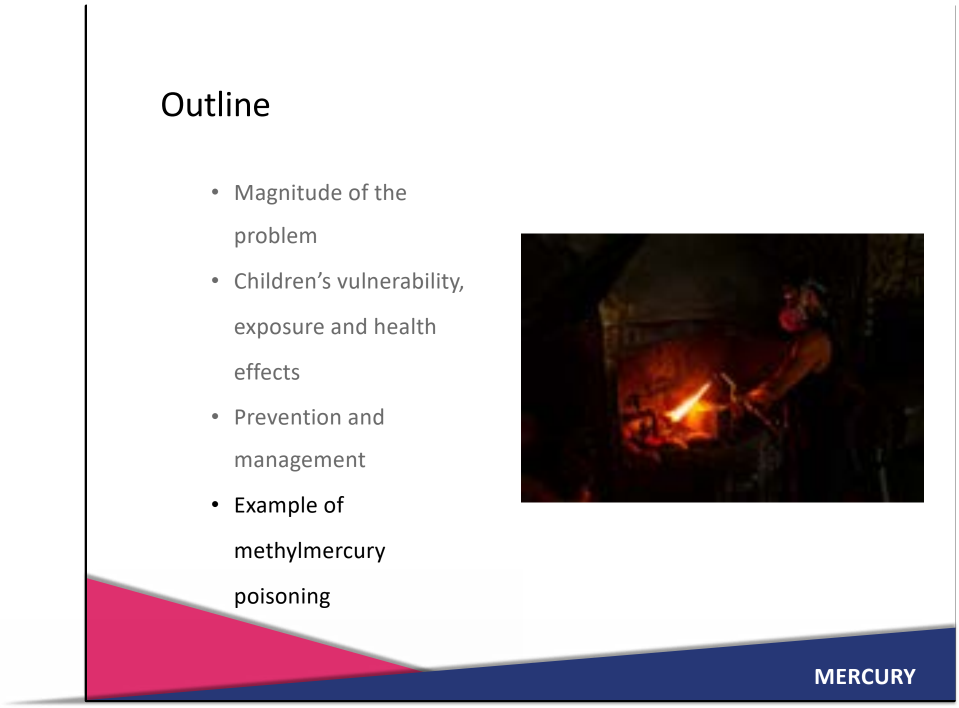
- **SDG 3.9**: by 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination;
- **SDG 6.3**: by 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally;
- **SDG 12.4**: achieve the environmentally-sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil to minimize their adverse impacts on human health and the environment.

Note: check if your country is party to the Minamata Convention here: https://www.mercuryconvention.org/en/parties.

Note: watch the short video on the Minamata Convention using the link here: https://minamataconvention.org/en/resources/what-minamata-convention.

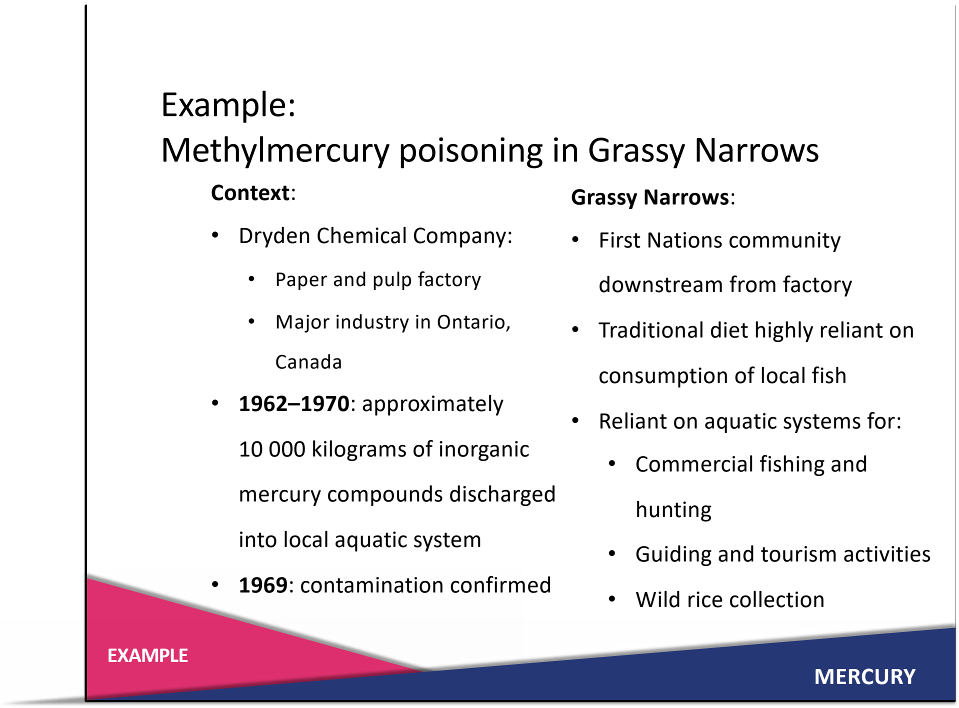
References:

1. Minamata Convention on Mercury.. About us [website]. Geneva: United Nations Environment Programme; 2021 (https://www.mercuryconvention.org/en/about, accessed 15 January 2024).
2. Heberman JD. Removing mercury, protecting people's health. Bull World Health Organ. 2018;96:6-7.
3. Minamata Convention on Mercury. Minamata convention on mercury: text and annexes – 2023 edition. Geneva: United Nations Environment Programme; 2023 (https://minamataconvention.org/en/documents/minamata-convention-mercury-text-and-annexes, accessed 15 January 2024).
4. Health sector involvement in the Minamata convention on mercury: outcomes of the World Health Organization regional workshops for ministries of health. Geneva: World Health Organization; 2018 (https://iris.who.int/handle/10665/275938, accessed 15 January 2024).
5. Developing national strategies for phasing out mercury-containing thermometers and sphygmomanometers in health care, including in the context of the Minamata convention on mercury: key considerations and step-by-step guidance. Geneva: World Health Organization; 2015 (https://iris.who.int/handle/10665/259448, accessed 15 January 2024).
6. Fisher J, Varenne B, Narvaez D, Vickers C. The Minamata convention and the phase down of dental amalgam. Bull World Health Organ. 2018;96:436–38.
7. A step-by-step guide for developing a public health strategy for artisanal and small-scale gold mining in the context of the Minamata convention on mercury. Geneva: World Health Organization; 2021 (https://iris.who.int/handle/10665/340411, accessed 15 January 2024).
8. Sustainable Development Goals [website]. New York: United Nations; 2019 (http://www.un.org/sustainabledevelopment/sustainable-development-goals, accessed 15 January 2024).



The final section of this module discusses an example of methylmercury poisoning and health in a First Nations community in Canada.

Photo:
- © WHO/ Yoshi Shimizu. A local miner applying the torching process using mercury to extract gold.



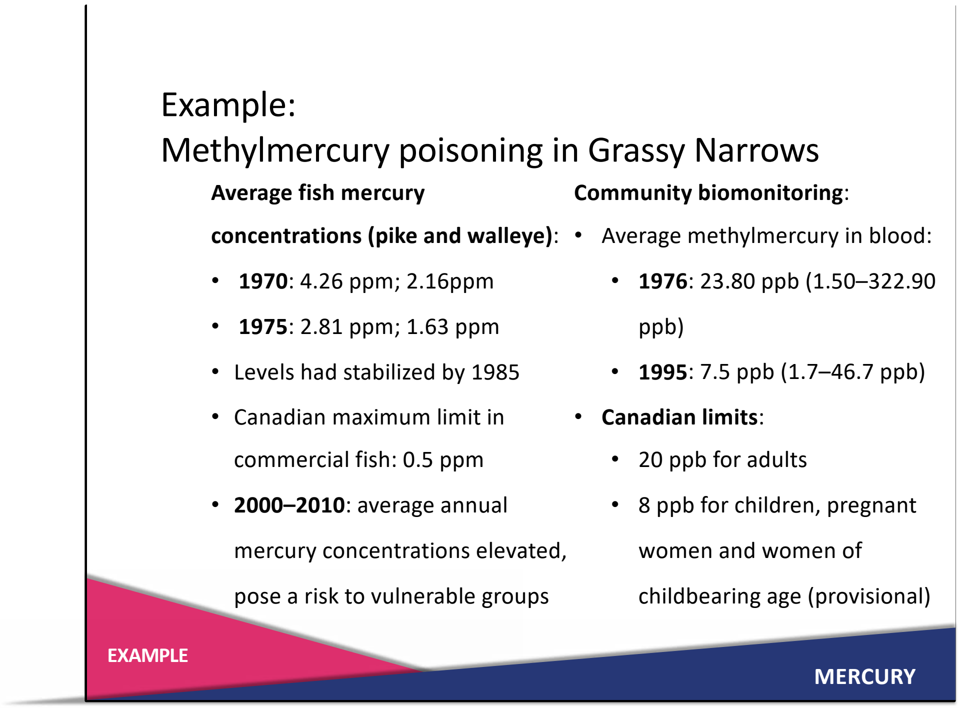
From the early 20th century until the 1970s, Dryden Chemical Company ran a paper and pulp factory based in Ontario, Canada. The paper and pulp industry was an important economical industry in Canada and several factories were found throughout Ontario. During the early 1960s, the factory used inorganic mercury compounds in processes to bleach paper. Between 1962 and 1970, the factory at Dryden discharged approximately 10 000 kilograms of inorganic mercury compounds into the English-Wabigoon river system, causing high levels of contamination in the river basin and leading to significant methylmercury contamination in local fish stocks, aquatic birds and plants *(1,2)*. High levels of mercury contamination in local aquatic systems were confirmed in 1969, prompting bans on commercial fishing in the river system and adjoining lakes in 1970 and communication with the local community to discourage consumption of locally-caught fish. In 1970, the company was ordered to cease dumping mercury into the river system. Between 1970 and 1975, however, Ontario officials continued to find environmental mercury levels 30 times higher than normal and noted an absence of fish for 64 kilometres downstream from the factory *(2)*. The factory was decommissioned in 1975 *(3).*

The contamination of the English-Wabigoon river system was one environmental event that helped to dispel the former belief that inorganic mercury compounds were relatively inert in the environment. It illustrated that these compounds are methylated in the environment by micro-organisms and bioaccumulate up the food chain – reaching their highest concentrations in top, predatory fish *(3)*. This event is sometimes referred to as one of the worst cases of environmental contamination in Canada's history *(1)*.

Grassy Narrows is a First Nations community located approximately 150 kilometres downstream from the Dryden Chemicals Company factory. It is one of two First Nations communities that were significantly affected by the contamination of the English-Wabigoon river system. Prior to mercury contamination of the local river system, members of the Grassy Narrows community primarily followed a traditional diet that relied heavily on freshwater fish consumption caught in the local river system and adjoining lakes. Additionally, the community relied heavily on the river system for socio-economic reasons, including commercial fishing and hunting, guiding and tourism activities and wild rice collection along the banks *(1,4)*. The following slides discuss the environmental and human health outcomes that followed the mercury contamination of the English-Wabigoon river system, and the actions that have been taken to reduce the impacts of methylmercury poisoning.

References:
1. Philibert A, Fillion M, Mergler D. Mercury exposure and premature mortality in the Grassy Narrows First Nation community: a retrospective longitudinal study. Lancet Planet Health. 2020;4:e141–48.
2. Mosa A, Duffin J. The interwoven history of mercury poisoning in Ontario and Japan. CMAJ. 2017;189(5);e213–215.

3. Wheatley B, Barbeau A, Clarkson TW, Lapham LW. Methylmercury poisoning in Canadian Indians – the elusive diagnosis. Can J Neurol Sci. 1979;6(4):417–22.
4. Harada M, Hanada M, Tajiri M, Inoue Y, Hotta N, Fujino T et al. Mercury poisoning in First Nations groups in Ontario, Canada: 35 years of Minamata disease in Canada. J Minamata Stud. 2011;3:3–30.



In the late 1960s and early 1970s, high concentrations of environmental methylmercury contamination were found through provincial monitoring programmes in the English-Wabigoon river system. High methylmercury concentrations were measured in fish species commonly eaten by residents of Grassy Narrows, as well as in birds that lived along the river system, including waterfowl and turkey vultures *(1)*. In particular, two freshwater fish species that formed an important part of the local traditional diet (pike and walleye) were found to have extremely high methylmercury concentrations. Both pike and walleye are predatory fish that are high on the food chain. Monitoring of fish species in Grassy Narrows lake found that *(2)*:

- in 1970, the average mercury concentration in pike was 4.26 parts per million (ppm), while average mercury concentration in walleye was 2.16 ppm;
- In 1975, the average mercury concentration in pike and walleye were 2.81and 1.63 ppm, respectively.

According to Canadian guidelines, the acceptable maximum limit for total mercury in commercial fish is 0.5 ppm *(4)*. The concentrations measured in the 1970s were so high that authorities decided that there was no alternative but to advise residents of Grassy Narrows to cease consuming locally-caught fish *(3)*.

Since the closure of the factory in 1975, mercury levels in the English-Wabigoon river system and fish stocks have decreased over time. Concentrations monitored in pike and walleye had largely stabilized by 1985. One study published in 2012, however, indicated that average annual mercury concentrations in pike and walleye over the period 2000–2010 remained elevated above acceptable limits. Average mercury concentrations in the four lakes closest to the Dryden factory were well above the 75th percentile compared to the same fish species found in lakes in other parts of Ontario (that were not affected by mercury discharge). This data indicated that vulnerable populations, especially children and pregnant women, were still possibly at risk to health effects from consuming these fish even 40 years after contamination had ceased *(5)*.

In the Grassy Narrows community, mercury biomonitoring of both hair and blood was initiated in 1970 by Health Canada. Following concerningly high levels of methylmercury exposure found in residents of Grassy Narrows and another First Nations community on the English-Wabigoon river system, this monitoring programme was extended to First Nations and Inuit communities across the entire country. Between 1972 and 1992, the monitoring programme collected and analyzed samples from 38 571 individuals from 514 communities across Canada, including Grassy Narrows *(3)*. The highest level was found in a fishing guide from Grassy Narrows who measured 660 parts per billion (ppb) in blood *(3)*. The monitoring programme ran until 1997 *(6)*.

Retrospective analyses of biomonitoring results highlighted a significant downward trend in methylmercury concentrations in Grassy Narrows residents since monitoring was initiated. These trends have mirrored similar trends in mercury concentration in local fish stocks. As shown on the slide, while average levels have decreased over time, some community members continued to return high blood mercury levels in 1995 *(7)*:

- **1976**: average methylmercury in blood was 23.80 ppb (range: 1.5–322.9 ppb)
- **1995**: average methylmercury in blood was 7.5 ppb (range: 1.7–46.7 ppb).

According to Health Canada, acceptable levels of methylmercury in blood is 20 ppb for adults and the provisional limit for children under 18 years of age, women of childbearing age and pregnant women is 8 ppb *(8)*.

References:

1. Harada M, Hanada M, Tajiri M, Inoue Y, Hotta N, Fujino T et al. Mercury poisoning in First Nations groups in Ontario, Canada: 35 years of Minamata Disease in Canada. J Minamata Stud. 2011;3:3–30.
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4. Mercury in fish: questions and answers [website]. Ottawa: Government of Canada; 2019 (https://www.canada.ca/en/health-canada/services/food-nutrition/food-safety/chemical- contaminants/environmental-contaminants/mercury/mercury-fish-questions-answers.html, accessed 15 January 2024).
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6. Philibert A, Fillion M, Mergler D. Mercury exposure and premature mortality in the Grassy Narrows First Nation community: a retrospective longitudinal study. Lancet Planet Health. 2020;4:e141–48.
7. Wheatley B, Paradis S, Lassonde M, Giguere MF, Tanguay S. Exposure patterns and long term sequelae on adults and children in two Canadian Indigenous communities exposed to methylmercury. Water Air Soil Pollut. 1997;97:63–73.
8. Mercury in Canadians. Ottawa: Health Canada; 2021 (https://www.canada.ca/en/health- canada/services/environmental-workplace-health/reports-publications/environmental- contaminants/human-biomonitoring-resources/mercury-canadians.html, accessed 15 January 2024).

Example:
Methylmercury poisoning in Grassy Narrows

Health outcomes:

- Fetal and early life exposure and neurological outcomes later in life:
  - Affect/ mood disorders
  - Emotional disturbances and intellectual deficits
- Youth emotional disturbances
- Indirect social, health outcomes
- Intergenerational effects

Interventions:

- Commercial fishing banned
- Biomonitoring programme:
  - First Nations health centres
  - Local health authorities
  - Training of residents to carry out programme and report findings to individuals
- Locally-specific fish advisory
- Annual provincial fishing regulations

EXAMPLE

MERCURY

Following the development of the biomonitoring programme, and findings that indicated high concentrations of methylmercury in fish and high exposure in community members, clinical examinations were conducted with residents to determine if symptoms of neurological damage due to methylmercury poisoning were present. While some individual patients recorded symptoms similar to those registered in patients with Minamata disease in Japan, no definitive diagnosis was given for any member of the Grassy Narrows community *(1,2)*. More recent research, however, has indicated that methylmercury exposure in Grassy Narrows may be linked to long-term and generational health outcomes:

- One study published in 2022 found a positive association between total mercury concentration in cord blood and development of neurological symptoms later in life, specifically clustered affect/ mood disorders in adults *(3)*;.
- Specialists from Japan visited the Grassy Narrows community on several occasions and conducted neurological examinations of residents. During the most recent visit, in 2010, the specialists used the protocol for the diagnosis of Minamata disease in Japan and indicated that out of 73 people examined: 30 were found to have Minamata disease, 12 had suspected Minamata disease, 15 exhibited emotion disturbances and 10 showed intellectual deficits. The researchers also highlighted that Minamata disease is difficult to diagnose due the variety of possible symptoms and that their study relied heavily upon self-reported symptoms *(4)*.
- One study published in 2023 found that after 1970 the prevalence of youths ever having attempted suicide in Grassy Narrows increased dramatically and is currently three times higher than any other First Nations community in Canada *(2)*. The study suggested that generational exposure to methylmercury may have negative effects on children's mental health and may have contributed to high rates of youth emotional disturbance identified in the community today.
- Indirect social and health outcomes in Grassy Narrows received a significant amount of attention in early research. Prior to mercury contamination, data has suggested that 80% of Grassy Narrows households had at least one member who worked as a fishing guide in the area and, during season, almost all guides brought fish home for their families *(2)*. The contamination of the English-Wabigoon river system resulted in the destruction of the economic, social and cultural fabric of the community through loss of employment, income and an important traditional food source. This has been linked to increased rates of noncommunicable diseases (NCDs), such as diabetes, and increased rates of violence and substance abuse in the community *(5)*.

Interventions implemented in Grassy Narrows have largely focused on protecting community members from methylmercury exposure. Actions taken have included:

- banning commercial fishing in the river system in 1971 *(5)*;
- development of a biomonitoring programme measuring community methylmercury exposure levels from 1970 until 1997. The programme was conducted in collaboration with the local nursing station and health centre, as well as local health authorities. Additionally, researchers hired community residents and trained them to carry

out the monitoring programme and report individual findings to community members *(1);*

- development of locally-specific fish advisory that allows users to view fish consumption advice in different lakes and water systems around Ontario *(6)*. For example, as of 2021, the fish advisory for Grassy Narrows lake advises that sensitive populations (children under 15 years of age and people who are pregnant or may become pregnant) do not eat pike or walleye of any size *(7)*;
- publication of annual provincial fishing regulations in Ontario, which detail regulations on fishing licenses, open seasons and catch limits. In 2024, for example, the fishing regulations restrict fishers to catching a maximum of one walleye no greater than 46 centimeters *(8)*.

Today, the Grassy Narrows community continues to be affected by mercury contamination in the English-Wabigoon river system and high concentrations of methylmercury in particular fish species. Research is ongoing into the effects that mercury exposure is having on the community.

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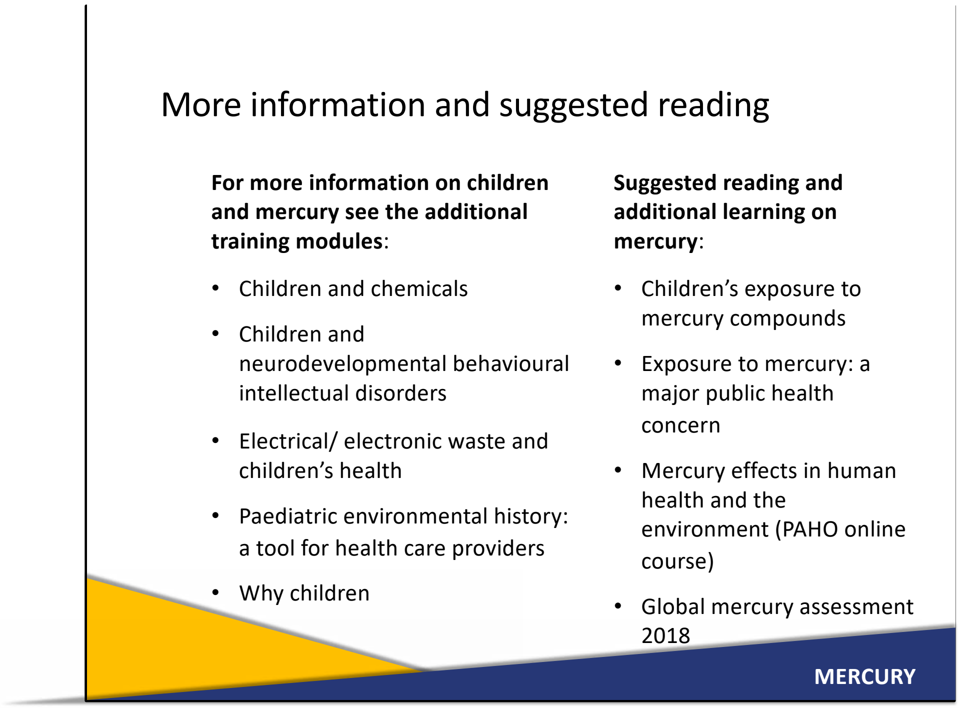

For more information on mercury and child health please see the World Health Organization (WHO) training package on children's environmental health for the health care sector *(1)*. The following modules may be of particular interest:

- ***Children and chemicals***
- ***Children and neurodevelopmental behavioural intellectual disorders***
- ***Electrical/ electronic waste and children's health***
- ***Paediatric environmental history: a tool for health care providers***
- ***Why children***.

To read and learn more on mercury see the below suggested resources:

- ***Children's exposure to mercury compounds*** *(2)*
- ***Exposure to mercury: a major public health concern*** *(3)*
- ***Mercury effects in human health and the environment and considerations under the Minamata Convention*** *(4)*
- ***Global mercury assessment 2018*** *(5)*.

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Acknowledgements from past versions

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Approach to development

The World Health Organization's (WHO) Training package for the health sector is a collection of modules with internationally harmonized information and peer-reviewed materials. A team of experienced professionals from over 15 countries and nongovernmental organizations (NGOs) participated in the original conception and development of the package over several in-person workshops between 2004 and 2016. These workshops identified key areas of concern related to child health and the environment, including emerging issues, on which the global health sector requires additional training.

Subsequent updates of individual modules have been completed, including *Mercury: training for the health care providers, third edition*. This update has been completed using a thorough literature search and review of the medical research database PubMed for relevant research published over the past 10 years. This literature search focused on published systematic reviews and meta-analyses, as well as some cohort, case-control and cross-sectional studies. WHO's online repository was searched for any relevant publications. Literature searches were also conducted across other United Nations (UN) agencies repositories for relevant reports, data, figures and other source material. Other major repositories were searched as relevant.

All recommendations discussed in this module come from official, publicly available WHO guidelines and guidance. Other suggestions for action are *not* official WHO guidelines or guidance and are examples of local or national actions taken and are accordingly indicated and referenced.

The example of methylmercury poisoning featured in this module was identified by the WHO Collaborating Centre for Children's Environmental Health at the University of Alberta, Canada.

This module has been through an extensive review process with experts and has been reviewed by the relevant technical teams and departments within WHO.

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