UNITED NATIONS ENVIRONMENT PROGRAMME[1]

International Mercury Assessment

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[1] This report is part of The Mercury Game, 2011, a negotiation simulation available at mit.edu/mercurygame. Portions of this assessment are directly adapted from *The Global Mercury Assessment*, UNEP Chemical Branch 2002, *Summary of supply, trade and demand information on mercury*, UNEP Chemicals Branch 2006, *The Global Atmospheric Mercury Assessment*, UNEP Chemicals Branch 2008, *Technical Background Report to the Global Atmospheric Mercury Assessment*, UNEP Chemicals Branch 2008 and *Arctic Pollution 2011*, Arctic Monitoring Assessment Protocol 2011. These reports are closely adapted in order to preserve their language and form. The representation of mercury science is realistic and as up to date as possible for the purpose of the simulation. All errors are the authors own. This report does not represent the views of UNEP and is fictionalized.

• Introduction, Purpose & Scope

Introduction

This report is the Secretariat's response to the United Nations Environment Program's (UNEP) Governing Council, who requested UNEP undertake a global assessment of mercury and mercury compounds. The report provides a global overview of scientific information on the most important mercury issues, drawing on information primarily from the scientific literature. National governments, intergovernmental and nongovernmental organizations, and private sector groups have also submitted their own assessments and reports to be incorporated into the assessment. Given that many published scientific assessments focus on devloping countries, an explicit effort was made here to include information on mercury impacts relevant to developing countries.

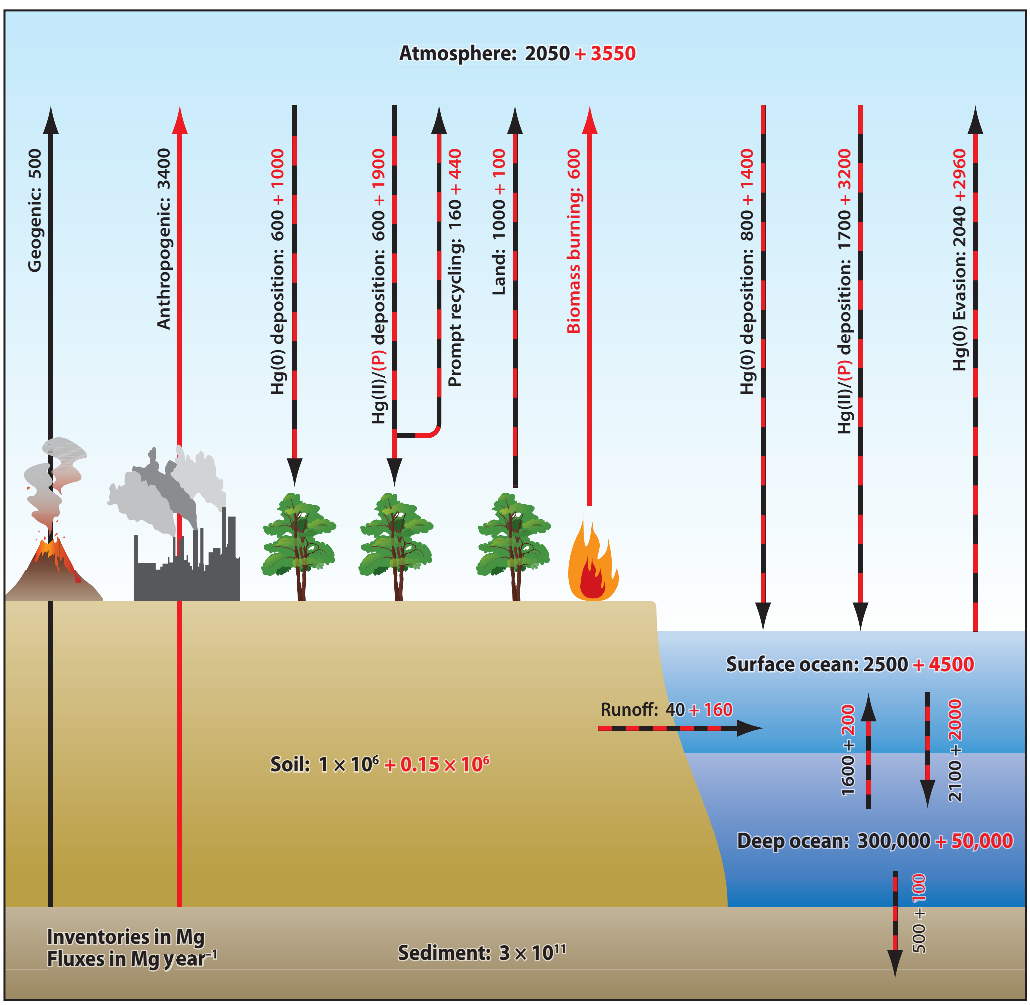
Sources of mercury:

Mercury is released from a variety sources, both natural and anthropogenic (see Figure 1). Natural emissions sources include volcanoes, geothermal vents and land emissions from areas naturally rich in mercury. Anthropogenic releases include fossil fuel combustion, biomass combustion, mining and industrial processes. Mercury is also found in various commercial and consumer products, and is released to the environment when those waste products are incinerated. Finally, artisanal and small-scale gold mining (ASGM) employs mercury, contributing to significant local and global releases. This report will address key mercury issues in each of the following sections.

Reasons for concern:

- Mercury and mercury-containing compounds are toxic for humans and ecosystems.
- Although mercury is a naturally occurring heavy metal element, and has always been present in the environment, human activity has increased mobilized mercury by a factor of three to five. Once mobilized, mercury persists, cycling for centuries to millennia until it is sequestered in deep ocean sediments (1).
- Mercury transports by air and water. In its gaseous elemental form, mercury has a long atmospheric lifetime of 6 to 18 months, allowing the element to be transported globally. Global transport is a key reason prompting international cooperation.
- Once mercury is deposited from the atmosphere, mercury can be transformed, primarily by microbial action, into methylmercury. Methylmercury is highly toxic and bioavailable, increasing in concentrations at higher levels in food webs.
- Human exposure to mercury occurs by eating fish or through occupational hazards. At high exposure levels, methylmercury is toxic. At lower exposure levels, methylmercury is associated with cognitive developmental delays in children and may be associated with heart attacks.

Figure 1. The Mercury Cycle (1)



1 Institutional Form for Future Action

Issue 1. Introduction

The question of whether mercury is a ***global*** problem, and therefore whether actions should be taken at the global level, largely concerns exposure mechanisms, toxicity, health impacts and environmental impacts. This section will address each issue in turn, in an attempt to provide the negotiating parties adequate information on the reasons for international action.

1.1 What are mercury's main human exposure pathways?

In order for mercury to be readily bioavailable, sulfate or iron-reducing bacteria can convert it to ***methylmercury (MeHg)*** under anaerobic conditions. Methylmercury is formed in aquatic ecosystems, primarily freshwater ecosystems including wetlands (Figure 2). In marine ecosystems, the exact methlyation mechanisms and the rates of methylation are unknown (2).

Once mercury is converted to methylmercury, it is highly toxic and can ***bioaccumulate*** up the food chain, particularly in fish. **MeHg can be present in predatory fish at 1,000,000 times the background level (3).** Since these fish travel long distances, bioaccumulation also contributes to global mercury transport.

Most human populations are exposed to methylmercury primarily through eating fish, with heightened exposure from eating fish at higher trophic levels. Populations that eat marine mammals, particularly whale and seals, also increase their exposure (for a summary, see AMAP 2011).

Additional exposure occurs through mercury-containing skin-lightening creams, use in medicines and rituals and in dental products.

Workers may be at an elevated risk of exposure to mercury in chlor-alkali plants, mercury mines, dental clinics and small-scale gold mines.

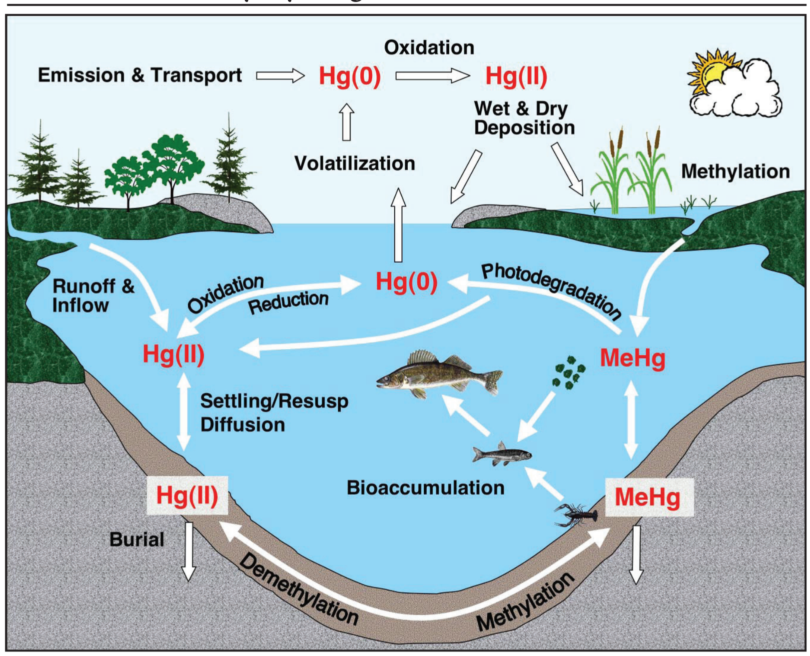
1.2 What are mercury's health impacts and toxicity?

All mercury-containing compounds are readily passable through the placental and the blood-brain barrier. Mercury's toxicity depends on its chemical form; the same exposure to elemental mercury and organic mercury compounds can produce different symptoms in the same patient. **It is well known that mercury is toxic at high levels and that methylmercury exposure poses the most severe risks.**

The developing nervous system is highly sensitive to methylmercury. For these reasons, exposure during pregnancy and infancy are of the highest concern. Exposure during fetal development and childhood may create ***long-term cognitive developmental impacts*** affecting language, attention and memory (5).

Mercury may also raise the risk for ***cardiovascular disease,*** although the epidemiological effects are uncertain. A recent review paper conducted by scientists for the US EPA found that methylmercury exposures may increase the likelihood of heart attacks. This relationship was demonstrated with moderate evidence for a number of risk factors, and expert scientists state the likelihood of a relationship between MeHg and heart attacks is between 45 to 80% (6).

Figure 2. Mercury Cycling in a Lake and Watershed (3)



At very high exposure levels, methylmercury can cause ***Minamata disease***, first observed in Japan in the 1950s. This ***neurophysiological disorder*** leads to atrophy in the brain, tremors, loss of perception, major impairments in functioning and, in severe cases, death (7, 8). For those exposed in the womb, with congenital Minamata disease, symptoms are extreme, resembling cerebral palsy with deafness and mental retardation (9) (Figure 3).

In Minamata, exposure occurred because mercury-containing effluent was discharged directly into the bay, where it bioaccumulated in fish; when the community ate this fish, they became sick. Similarly, in Canada in the 1970s, several Northern Ontario aboriginal communities were exposed to high levels of mercury because chlor-alkali plants were discharging mercury-containing effluent into a river system (10). A third case occurred in Iraq in the 1970s when MeHg was sprayed on seed as a fungicide, resulting in mass poisoning when people ate the seed (8). For a summary of the Iraq and Japanese cases, see Table 1.

Methylmercury can also have adverse effects at concentrations lower than those seen in the poisoning incidents listed in Table 1. **Three large epidemiological studies were undertaken in the Faroe Islands, Seychelles and New Zealand to examine the effects of long-term chronic exposure to mercury for children.** These studies provide evidence that methylmercury exposure in the womb creates cognitive deficits in children, even at concentrations from 10-20% of observed effect levels in adults (5, 13). The results are summarized in Table 2 (next page).

Figure 3. Congenital Minamata Disease

- The **Faroe Island study**, which is the most widely accepted figure for non-lethal neurodevelopmental effects, sets the benchmark dose level at 10 µg/g total mercury in maternal hair (5, 14, 15).
- The **Seychelles study** in contrast found no developmental effects associated with exposure levels at an average of 7 µg/g total mercury in maternal hair (16, 17).
- The **New Zealand study** found an association between maternal hair concentrations in MeHg and childrens' test scores, provided one outlier was omitted from the data. This study put the lowest benchmark dose level between 7.4 to 10 µg/g (18)

As reference, the US EPA reference dose (RfD), the maximum acceptable oral dose of a toxin, is 0.1 µg/kg body weight per day, corresponding to 5.8 µg/L in blood or 11 µg/g in maternal hair (19). The mean hair mercury level in the United States in 2000 was 0.12 µg/g in children, 0.20 µg/g in women and 0.38 µg/g in women who frequently consumed fish (19); this study also found 8% of women of childbearing age had mercury concentrations exceeding the US RfD (19; **Table 3**). However, traditional diets within some Arctic and indigenous populations put these populations at greater risk of high mercury exposure (4, 20).

Table 1. Acute Methylmercury Cases

Case	Hair Sample Exposure Level
Minamata, All patients with health effects	2 - 705 µg/g (7)
Minamata, Congenital cases	5 - 110 µg/g (7)
Minamata, Mother's hair (5-8 years after birth)	1 - 191 µg/g (7)
Iraq, Congenital cases Iraq, Congenital cases (reanalysis)	>10 µg/g (11) >80 µg/g (12)
Iraq, Severe effects[1]	125-1250 µg/g (8)
Iraq, Death[1]	750-1250 µg/g (8)

[1] These values were calculated using a hair to blood mercury conversion of 250 (38).

Table 2. Epidemiological Studies			
	Faroe Islands	**Seychelles**	**New Zealand**
Average MeHg concentration in maternal hair	3 μg/g	7 μg/g	20 μg/g or less (excluding outlier)
Observed effects level	10 μg/g	No effect found	7.4 - 10 μg/g

Table 3. Mean and Selected Percentiles of Hair Mercury Concentrations for Children (1-6 years) and Women (16-49 years) in μg/g, 1999 (19, 21)					
		Selected Percentiles			
Hair Hg	**No.**	**Mean**	**10th**	**90th**	**95th**
Children	838	0.22 μg/g	0.03 μg/g	0.41 μg/g	0.65 μg/g
Women	1726	0.47 μg/g	0.04 μg/g	1.11 μg/g	1.73 μg/g

1.3 What are mercury's environmental impacts?

Mercury harms ecosystems through ***bioaccumulation*** in individual organisms and then ***biomagnifications*** along the food chain. Concentrations are lowest in smaller, non-predatory fish and increase dramatically at higher trophic levels in the food chain.

Animals at the top of the aquatic food web, including seabirds, seals, otters and whales, are most at risk for mercury-related health impacts. Additional factors affecting population exposures include the population's location and habitat use (4). Concentrations tend to increase with the organism's age, potentially affecting population dynamics.

As a ***central nervous system toxin***, methylmercury can harm wildlife, particularly gestating animals. Inorganic mercury harms animals' kidneys and reproductive systems.

- In bird species, mercury can create adverse effects on reproduction with egg concentrations of Hg as low as 0.05 to 2.0 mg/kg (wet weight) (13).
- **Mercury levels in many Arctic species (beluga, ringed seal, polar bears, birds of prey) continue to rise, despite reduced or stabilized levels in global mercury (4)**. This is concerning since Arctic species face multiple stressors, including climate change.

Finally ***climate change***, with effects including increased flooding in areas of existing rainfall and warmer average temperatures, may increase the methylation process (13). This in turn could increase bioaccumulation of MeHg in ecosystems, and eventually, exposure through human diets (4).

2 Atmospheric Emissions

2.1 What is the scale of atmospheric emissions?

Estimating human and natural mercury emissions, including their relative contributions, is a difficult task (for a review of the literature, see Table 1 in Selin 2009 and Pacyna et al. 2010).

- In 2005, global ***anthropogenic** emissions* to the atmosphere were estimated to be 1930 tonnes (range 1230–2890 tonnes).
- In 2005, ***natural emissions*** were estimated to be within the same order of magnitude as anthropogenic emissions, considering ocean emissions (400–1300 tonnes per year) and land emissions (500–1000 tonnes per year). Combined, nautral emissions were estimated between 900-2300 tonnes.
- ***Re-emissions*** of previously mobilized mercury add an additional 1800–4800 tonnes per year. Since these re-emissions are likely in the same proportion as the initial emissions, half of these re-emissions can be considered of anthropogenic origin and the other half natural.

In summary, anthropogenic emissions, natural emissions and re-emissions each contribute approximately one-third of total annual emissions (22-25; Figure 4).

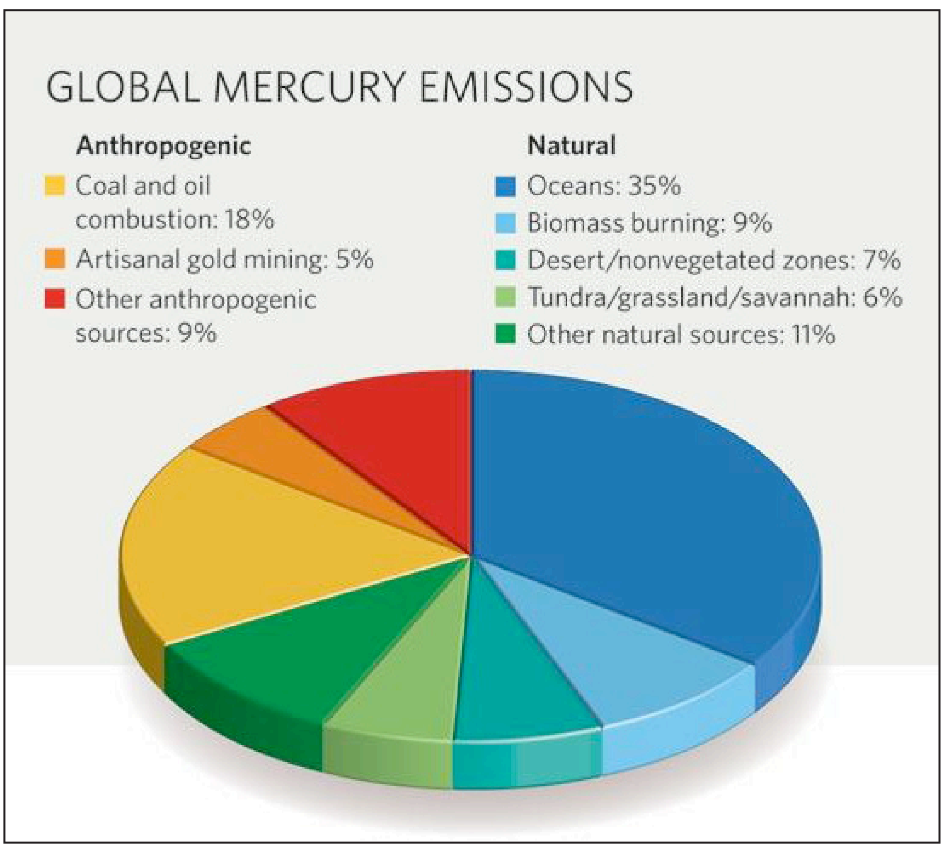
Notably, atmospheric mercury emissions are believed to have remained relatively constant between 1990 and 2005, although the location of emissions has shifted significantly (22, 25, 26; Figure 10).

2.2 What is the current state of emissions inventories?

Emissions inventories are available from 2005 with some countries reporting data. **However, many countries lack data on current or past mercury emissions. Where information is lacking, models have been used to estimate total anthropogenic mercury emissions.**

- Currently, Asia accounts for ~67% of mercury emissions (Figure 5).
- Monitoring stations are not well distributed globally, leading to significant data gaps (Figure 8).
- Overall, mercury emissions have remained stable since 1990, with some decline in the EU and USA as a result of regulations, and some amplification in Asia (22) (Figure 10). Emissions estimates associated with products, disposal and artisanal and small-scale gold mining (ASGM) are now included in this atmospheric emissions inventory, although these figures are relatively uncertain.

FIGURE 4. Natural, Anthropogenic and Re-emissions



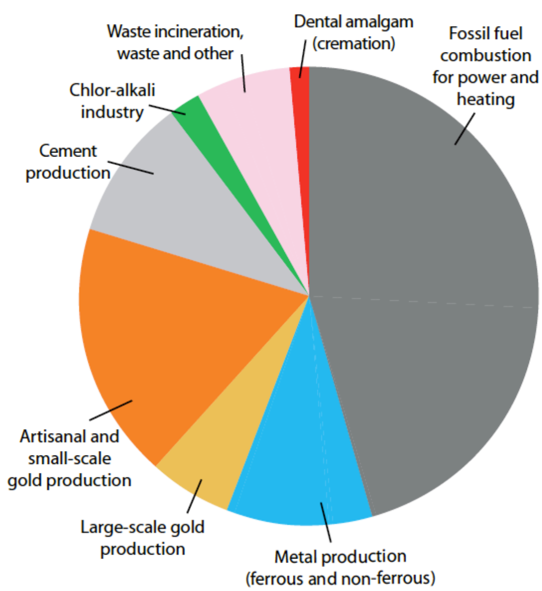
Source: Mercury Fate and Transport in the Global Atmosphere (Springer, 2009)

2.3 What are the sources of atmospheric emissions?

Emissions are often subdivided into ***unintentional*** and ***intentional*** releases (see Figures 5, 6 & 7).

- **Coal-fired power production, an unintentional release, is the single largest global source of atmospheric mercury emissions**, accounting for approximately 45% of the total quantified atmospheric emissions from anthropogenic sources (23, 25). Coal-plants emit mercury in its elemental and divalent forms, and also in association with particulate matter, with implications for global transport.
- Cement production, mining, combustion of other fossil fuels, iron and steel processing also contribute to unintentional mercury releases. Waste treatment contributes to emissions through incineration of municipal, medical and hazardous wastes and cremation (dental amalgams).
- **Mercury is released from intentional use and extraction including mercury mining, artisanal and small-scale gold and silver mining (ASGM), chlor-alkali production, production of mercury-containing products, and waste treatment.**
- There is a range of uncertainty for emissions from all sources (Figures 6 & 7).

FIGURE 5. Anthropogenic Mercury Emissions, 2005



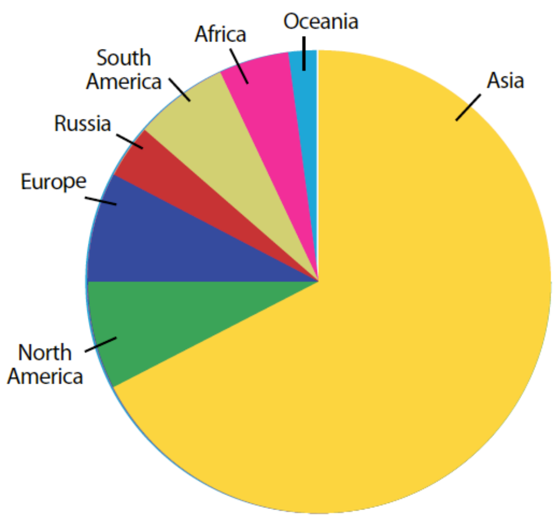


FIGURE 6. Uncertainty Factors for Hg Emissions (25)

Uncertainty of Hg emission estimates by sector.

Industrial source	Uncertainty (±%)
Stationary fossil fuel combustion	25
Non-ferrous metal production	30
Iron and steel production	30
Cement production	30
Waste disposal and incineration	As much as 5x
Mercury and gold production	?

Uncertainty of Hg emission estimates by continent.

Continent	Uncertainty (±%)
Africa	50
Asia	40
Australia	30
Europe	30
North America	27
South America	50

2.4 How is mercury transported in the atmosphere?

Mercury exists in a variety of forms in the atmosphere, which affects the distance it transports:

- In the atmosphere, mercury exists most abundantly in its **gaseous elemental form, Hg(0)**. Elemental mercury is emitted by natural sources and anthropogenic sources, including coal power plants.
- Elemental mercury **persists in the atmosphere between 0.5 and 1.5 years, allowing it to transport globally** (25). Through reactions, elemental mercury is often converted into divalent mercury, which is readily deposited out of the atmosphere and into ecosystems.
- Anthropogenic sources also emit mercury in its **divalent form (Hg(II))** and associated with **particulate matter (Hg(P))**.
- In contrast to Hg(0), **Hg(II) and Hg(P) have much shorter lifetimes in the atmosphere, on the order of days to weeks**. As a result they do not tend to be transported long distances, and instead contribute to local and regional pollution. Hg(II) and Hg(P) are removed, incidentally, through conventional scrubber technology on power plants.

Elemental mercury emissions transport over long distances via atmospheric and oceanic processes. **For this reason**, **remote areas may have mercury concentra-**

Figure 7. Range in Emissions Estimates by Sector, 2005 (25)

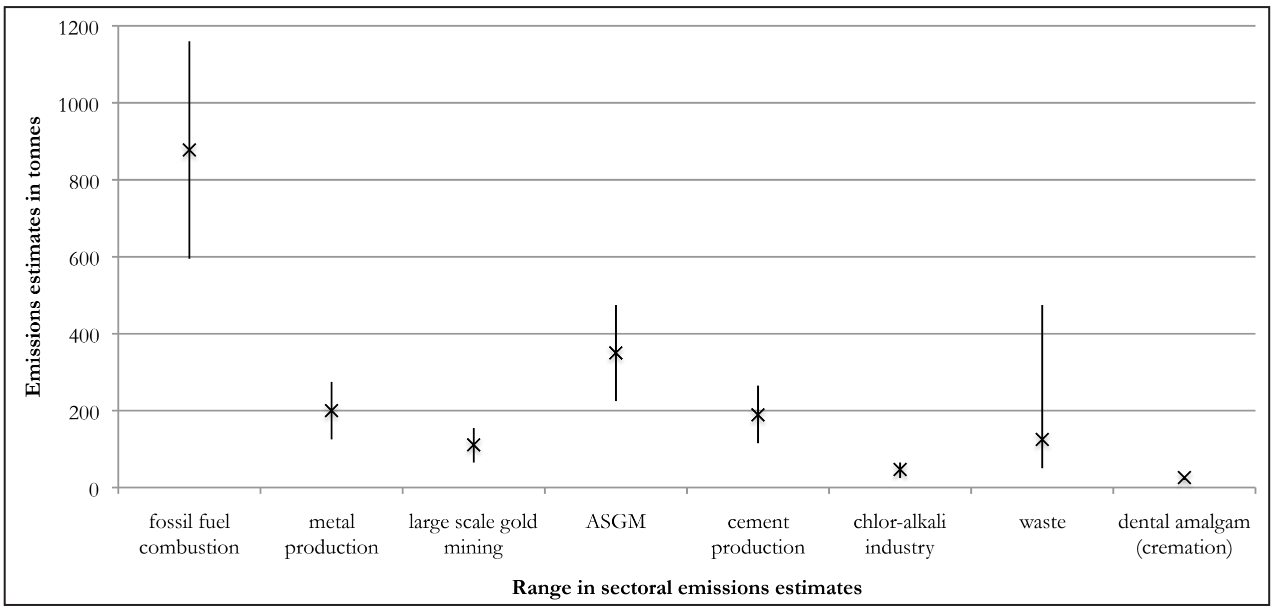
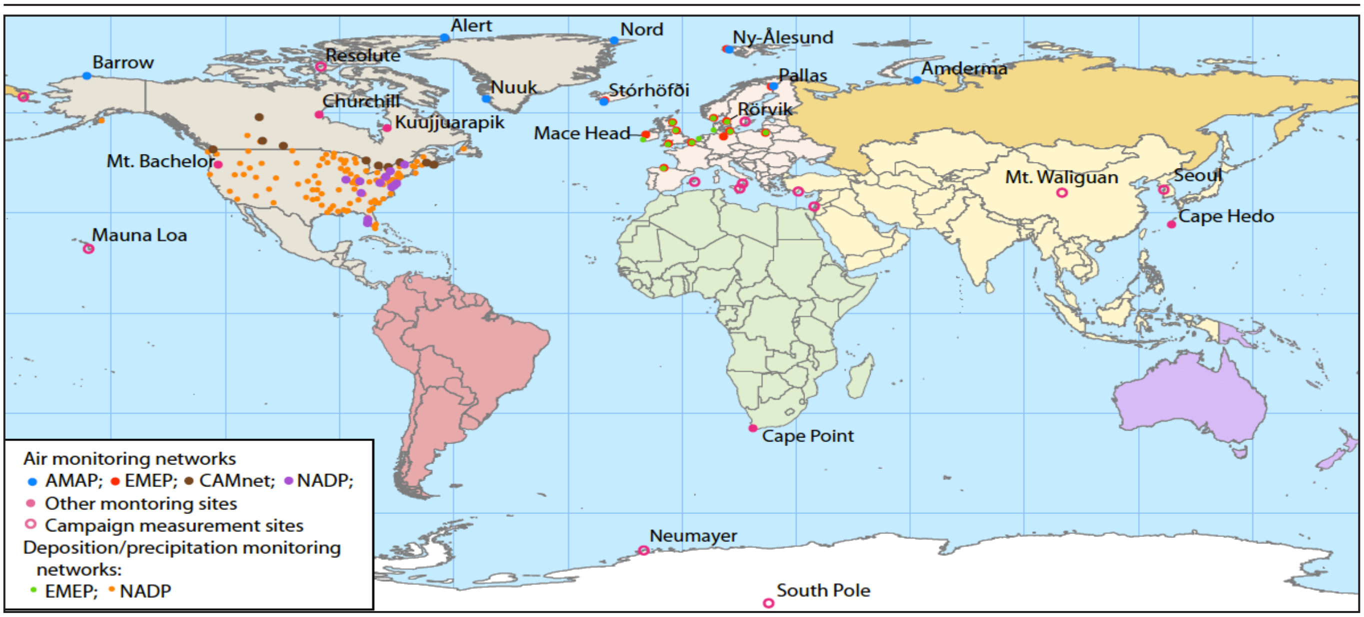


Figure 8. Atmospheric Mercury Monitoring Stations (25)



tions three to five times above preindustrial levels, despite limited local emissions. In areas with high levels of local emissions, mercury concentrations may be elevated 10 times or more above baseline, largely due to divalent and particulate mercury emissions (27).

However, while long range transport is important, there are locations where Hg(0) is easily transformed into Hg(II) and rapidly deposited. In these locations, regional inputs are more important than global inputs leading to local hotspots of mercury accumulation (28).

Mercury may have disproportionate effects on **the Arctic**, which is particularly noteworthy given the Arctic does not emit significant amounts of mercury. The Arctic Monitoring and Assessment Programme has released detailed information on mercury in the Arctic:

- Mercury arrives in the Arctic via long-range environmental transport. **Models estimate most natural deposition in the Arctic originates from the ocean while most anthropogenic deposition originates from East Asia (Figure 9)**.
- **Traditional diets within some Arctic populations put these populations at greater risk to high mercury exposure (4, 20).**
- Arctic ecosystems may play an important role acting as a global sink for mercury, through Atmospheric Mercury Depletion Events (AMDEs). However, much of this mercury is rapidly re-volatilized; for this reason, its importance of these events to Arctic foodwebs remains unclear.

Figure 9. Model Estimates for Emissions Contributions to Arctic Deposition by Region (4)

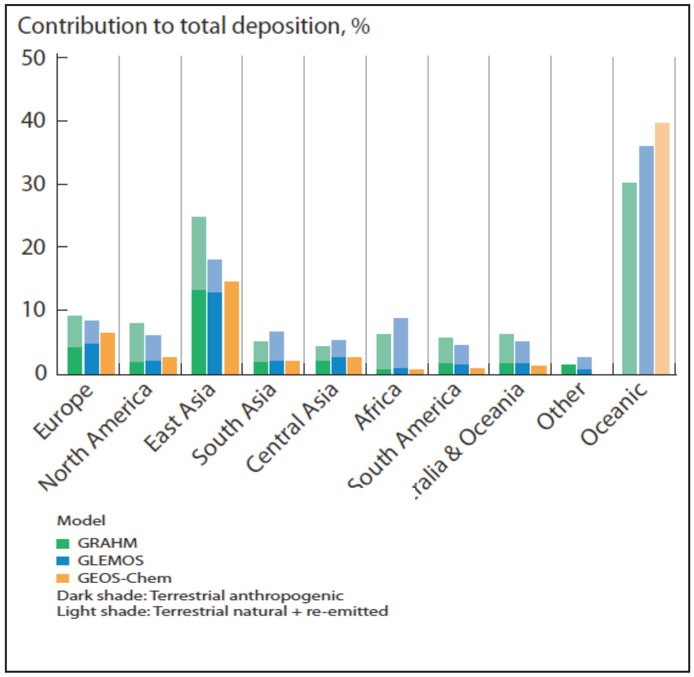
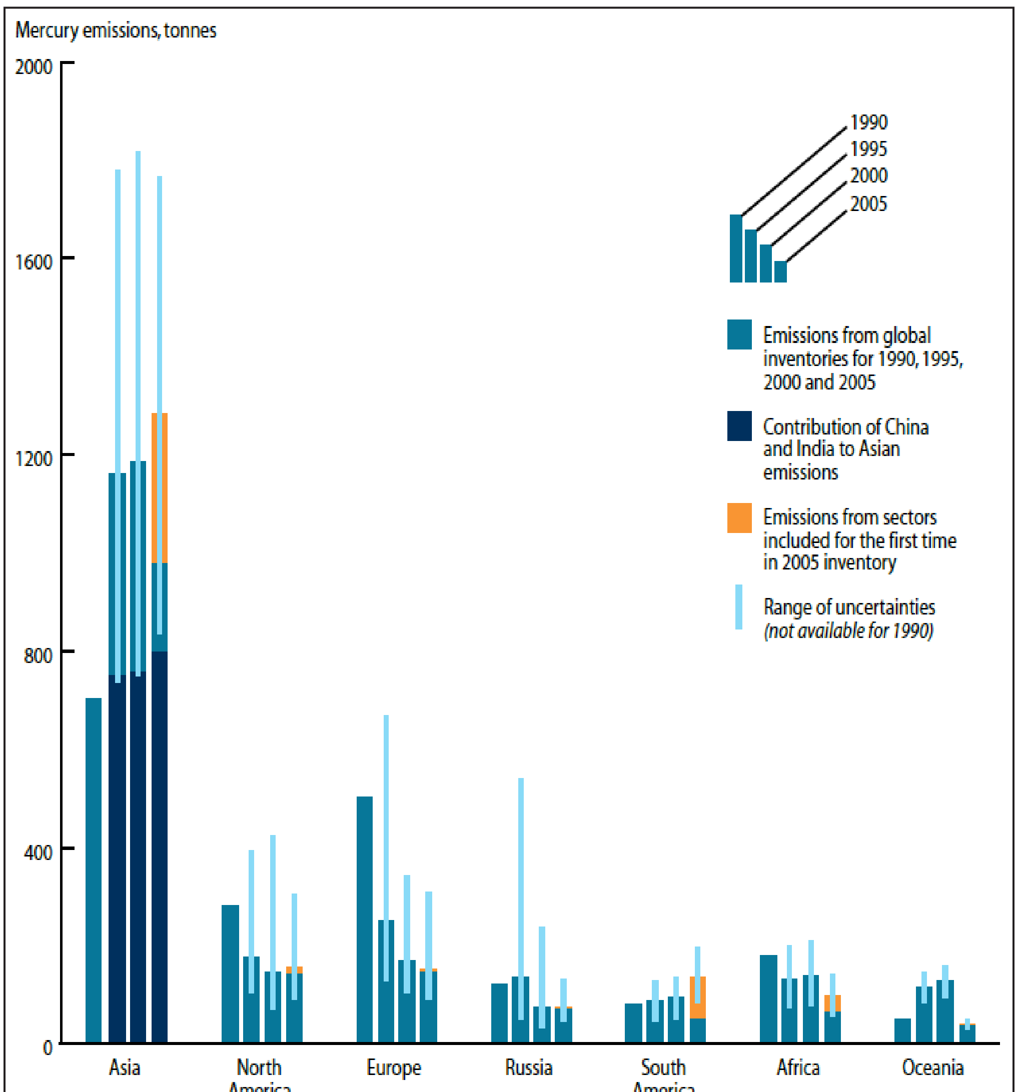


Figure 10. Regional Mercury Emissions Trends, 1990-2005 (25)



2.5 How will ecosystems respond to emissions reductions?

Ecosystem responses to mercury abatement vary depending on the type of ecosystem, location specific hydrology, water quality, soil cover, trophic structure, temperature and the timing and delivery of deposition into waterbodies (27). For these reasons, proximate ecosystems can vary significantly in their mercury concentrations. Together, several factors affect a given ecosystem's sensitivity to mercury loading:

- The topography of nearby terrestrial ecosystems, including the watershed size and watershed-to-surface water ratios, affect the residence time of mercury in the soil. This in turn alters the speed of mercury loading in waterbodies and later conversion to MeHg.
- Larger watersheds with less surface water likely retain larger amounts of mercury in the soil, although this effect is perhaps small (29).
- Wetlands, lake sediments and anoxic bottom waters are significant sites of MeHg conversion as these ecosystems have longer water residence times, allowing greater opportunity for greater conversion.
- Land use change, through conversion of forested areas, may also increase mercury loading in waterbodies; however, runoff in agriculturally converted areas may lead mercury to be associated with particulate matter, decreasing its bioavailability.

Although scientific research suggests mercury concentrations in ecosystems and fisheries should decline with reduced mercury emissions, the timing and extent of the ecosystem response is uncertain. The effect mercury abatement has on methylation rates in ecosystems is particularly important for the ongoing global negotiations on mercury.

One study, which added enriched mercury isotopes into a watershed, found methylmercury deposited directly into the lake was readily bioaccumulated in fish. However, mercury deposited into the watershed was stored, with little uptake in fish. Although this study found a rapid initial decline in fish mercury concentrations, on the order of years, full recovery was delayed as watersheds continued to export mercury to the lake. In addition, contaminated peat and upland soils could take centuries to decline entirely (30).

A second study suggests that ecosystem responses to input reductions may occur over two phases: first a relatively fast 20-60% reduction in mercury levels in predatory fish over a few decades, but then a long-tailed reduction over decades and even centuries to reach a more complete reduction (31). For this reason, ecosystem responses to mercury abatement may not be linear and remain uncertain.

3 Demand for Mercury Used in Products & Processes

Issue 3. Introduction

Mercury is an excellent material for many products and processes because of its unique combination of characteristics: it is a liquid at room temperature, acts as a good electrical conductor, has a high density and high surface tension, and is toxic to microorganisms. For these reasons, mercury is used in a number of products and processes globally, despite clear reasons for concern (Figure 11). Although mercury is also used for ASGM, this issue is treated separately in the following section (Issue 4: ASGM).

3.1 Which products contain mercury?

- Mercury is used in measuring devices (manometers, thermometers), electrical and electronic switches, fluorescent lightbulbs, dental amalgam fillings, batteries, biocides (in the paper industry), antiseptics (in pharmaceuticals), catalysts, pigments and dyes, detergents, and explosives.
- Mercury compounds are used in a wide variety of health and beauty products, including pesticides, biocides, pharmaceuticals, and cosmetics, despite their known human toxicity.
- In some cases, substitutes have been implemented, however, mercury continues to be intentionally used in some products.

Figure 11. Global Mercury Demand by Sector (31)

Global mercury demand (2005)	Metric tonnes
Small-scale/artisanal gold mining	650-1,000
Vinyl chloride monomer (VCM) production	600-800
Chlor-alkali production	450-550
Batteries	300-600
Dental use	240-300
Measuring and control devices	150-350
Lighting	100-150
Electrical and electronic devices	150-350
Other (paints, laboratory, pharmaceutical, cultural/traditional uses, etc.)	30-60
Total	**3,000-3,900**

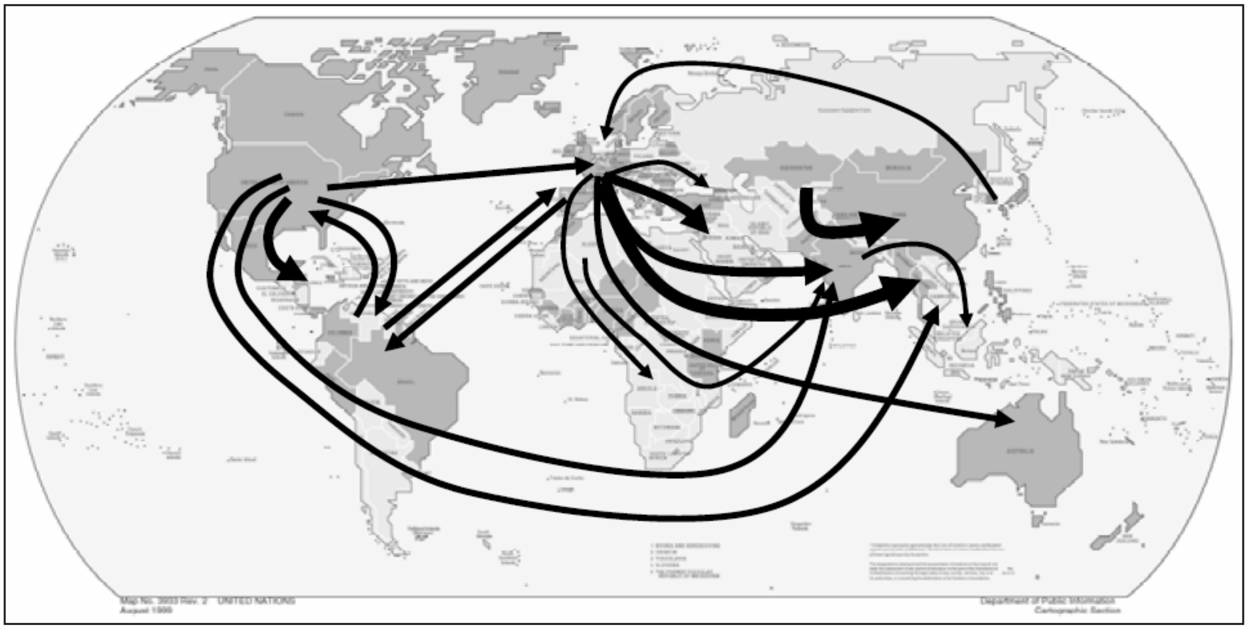
3.2 Which industrial processes use mercury?

Mercury is used in a number of industrial processes including chlor-alkali production and vinyl chloride monomer production (VCM).

Chlor-alkali production, used to make chlorine and caustic soda, creates significant demand for mercury. If the mercury cell process is used, mercury is released to the atmosphere and nearby waterways. When chlor-alkali plants close or are converted, large amounts of mercury can be released to the environment if not carefully managed. Emissions from existing mercury process plants in Western Europe and the U.S. have been reduced via regulation, as well as voluntary efforts. Many other countries, including Brazil, have taken action to reduce emissions; however, these plants appear to be relea sing more mercury than comparable European plants (32). Roughly three-quarters of the entire global chlorine production capacity exists in Western Europe and North America.

Vinyl chloride monomer (VCM) production is a process used to create polymers particularly polyvinyl chloride (PVC). The use of mercury in VCM is particularly concerning as it is not clear how much of the mercury is lost during the process (32). The process has been phased out in Europe and the United States. However, China demands >600 metric tonnes of mercury per year as an input to the VCM process, representing an estimated 80-90% of the world's VCM production. Demand for PVC in China is increasing, with mercury use in VCM nearly doubling between 2002 and 2004 from 350 tonnes to 610 tonnes of mercury (32).

FIGURE 12. Mercury Trade Shipments, 2004 (31)



3.3 How much mercury is traded?

There is significant trade in mercury and mercury-containing products, some of which is illegal, uncontrolled and/or unregulated. Global trade in mercury products is likely in the range of $100-150 million annually (32).

Global demand for mercury has declined from more than 9,000 metric tonnes annually in the 1960s, to just under 7,000 metric tonnes in the 1980s, and less than 4,000 metric tonnes since the late 1990s. In 2005, global demand for mercury was 3,000-3,900 metric tonnes per year (32).

While demand for mercury has been declining in developed countries, there is evidence that **mercury demand remains relatively robust in many lower income economies and supply is shipped from many developed countries (Figures 12 & 13)**:

- In South and East Asia, demand continues for mercury use in products, vinyl chloride monomer (VCM) production and ASGM.
- In Central and South America, demand for mercury continues for ASGM.
- Significant quantities of mercury are shipped from Western Europe (the EU plus Switzerland) to Asia, Africa, and Australia.
- The United States also exports mercury to Central America and Asia. Figure 12 shows different sizes of arrows representing larger and smaller volumes of mercury moving between regions during 2004.

FIGURE 13. Global Mercury Demand & Supply by Region, 2005 (31)

Elemental mercury, 2005	Regional demand (metric tonnes)	Regional supply (metric tonnes)
East and Southeast Asia	1,600-1,900	900-1,300
South Asia	300-500	100-200
European Union (25 countries)	400-480	400-800
CIS and other European countries	150-230	800-1,200
Middle Eastern States	50-100	0-50
North Africa	30-50	0-50
Sub-Saharan Africa	50-120	0-50
North America	200-240	300-500
Central America and the Caribbean	40-80	20-100
South America	140-200	100-200
Australia, New Zealand and Oceania	20-40	0-50
TOTAL	**3,000-3,900**	**3,000-3,800**

4 Artisanal & Small-Scale Gold Mining

Issue 4. Introduction

Mercury has been used in the process of gold and silver mining since Roman times. **Today, high gold prices, combined with difficult socio-economic situations in some communities, has led to increased use of mercury for small-scale mining, particularly in the southern hemisphere.** These practices largely occur within the informal sector and are unregulated, making information on scale, impacts and solutions difficult to ascertain (33).

4.1 What is the scale of ASGM globally?

It is estimated that ASGM for livelihood purposes involves more than 100 million people on all continents and in 55 countries. Of this, it is estimated 10-30 million people are miners, including 4.5 million women and 1 million children. **ASGM produces ~20-30% of the world's gold production**. Although ASGM can be conducted without mercury, speed and simplicity make mercury-use the most common method (33).

- Currently, mercury amalgamation is used as the major artisanal technique for gold extraction in South America, China, Southeast Asia and Africa. **Countries with significant operations include China (200-250 tonnes released) and Brazil, Columbia, Peru, Bolivia, Venezuela, Tanzania, and Zimbabwe (10-30 tonnes each) (33; Figure 16)**.
- As a consequence of poor practices, recent estimates suggest mercury amalgamation in ASGM results in the discharge of 650 to 1000 tonnes of mercury annually, representing approximately one-third of all global, anthropogenic mercury releases. Thus, ASGM may be the single largest intentional-use source of mercury pollution in the world (34). Almost all mercury used in ASGM is eventually released (34).
- It is estimated that as much as 300 tonnes of mercury per annum are volatilized directly to the atmosphere, while 700 tonnes are discharged in mine tailings into soil, rivers and lakes. In addition to domestic pollution impacts, both air emissions and tailings discharge contaminate international waters and air (34).
- Although the sale and use of mercury for ASGM is officially banned in Brazil, China and several other countries, this ban is clearly difficult to enforce in the rural areas where ASGM occurs – especially since these activities often occur in the informal sector.

4.2 What are the impacts of ASGM?

During one of the steps of the gold purification process, gold amalgam is heated, releasing mercury vapor (Figure 14). Occupational hazards from ASGM are significant. **Miners and community members may breathe air with Hg concentrations above 50 µg/m3, which is 50 times the WHO maximum public exposure guideline.** As a result, miners can exhibit mercury-poisoning symptoms including tremors (34).

Figure 14. ASGM Techinques Using Hg

In addition to occupational hazards, ASGM generates thousands of dispersed, polluted sites, often presenting serious, long-term environmental health hazards to populations living near and downstream of mining regions (35). As a result of ASGM practices, mercury is found in surrounding soils, plants, sediments, waterways, and especially mine tailings at extraction sites and at trading posts.

Recent scientific research suggests most mercury pollution from ASGM occurs locally (~60%) with a smaller proportion contributing to the global mercury pool (~30%), although this research was based on historic mining periods (34).

4.3 What are the potential actions to address mercury use in ASGM?

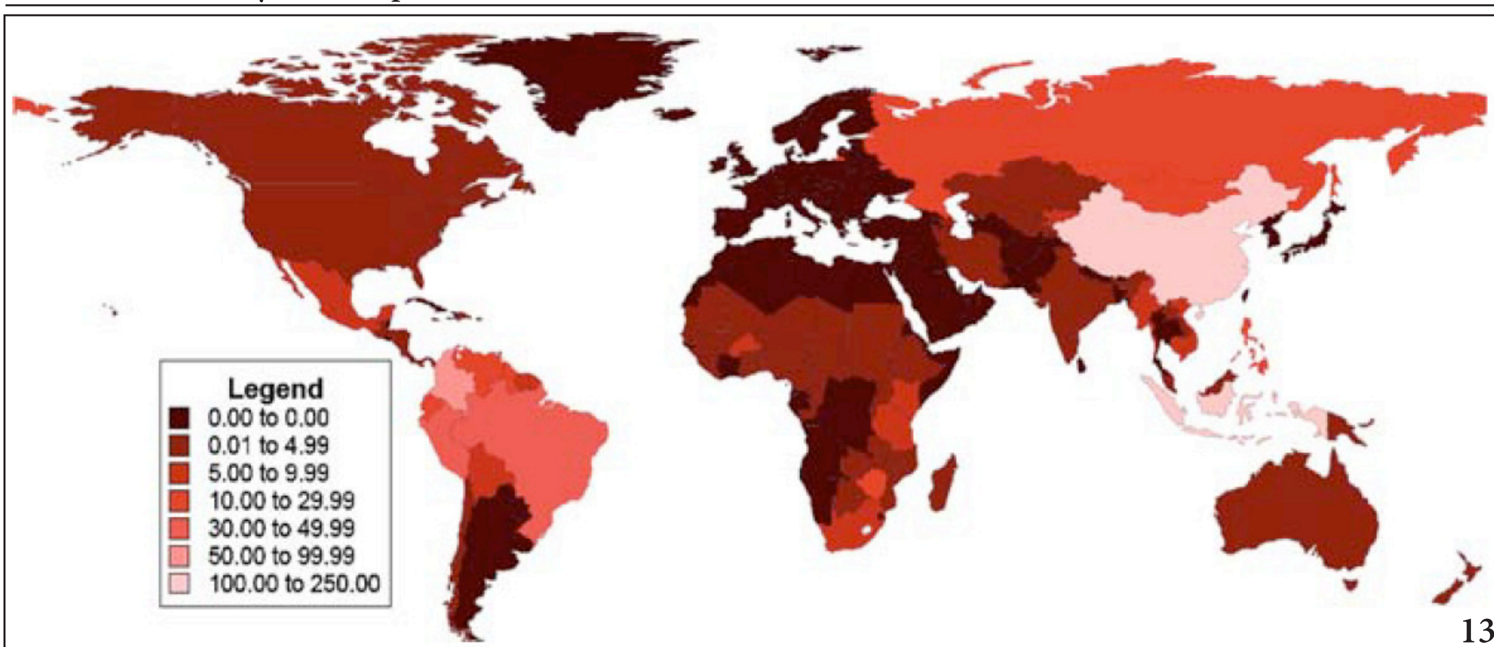
ASGM continues due to a combination of high-gold prices, access to mercury and persistent poverty (35). In addition, the practice takes place largely within the informal sector, making regulation difficult. The impacts of mercury pollution are complex, time-delayed and difficult for miners to see, impeding efforts to reduce hazardous practices (34). Finally, many miners are unacquainted with cost-effective hazard reduction techniques (36). Nevertheless, mercury releases and health hazards may be reduced by:

- educating miners and families about hazards and alternative techniques
- **promoting capture devices, such as retorts, which can reduce mercury emissions up to 95% (35; Figure 15)**
- developing facilities where miners can take concentrated ores for the final refining process
- banning the use of mercury by artisanal miners, which may encourage central processing facility use; however, enforcing bans can be difficult.

For all these actions, widespread adoption of mercury-free or reduced risk gold-mining practices **will require substantial investment in terms of technology and training (37)**. Trade regulation may also be necessary as much of the mercury that is used for ASGM enters the country legally for other purposes, including use in products and processes (33).

Figure 15. Using a Retort

Figure 16. Mercury Consumption for ASGM



• Conclusion

Options for actions on mercury

There are several actions available to reduce global mercury releases:

- controlling mercury emissions through end-of-pipe technologies (e.g. scrubbers on coal power plants)
- reducing consumption of raw materials and products that generate mercury releases
- substituting products or processes for those that do not use mercury
- reducing mercury use in ASGM

Unintentional atmospheric emissions: mercury releases through coal combustion can be reduced with existing scrubber technology used for sulfur dioxide and nitrogen oxides; these scrubbers also remove Hg(II) and Hg(P). However, mercury specific scrubbers are required to remove Hg(0). The use of particular control techniques depends on the type of coal being combusted, as this alters the relative amount of Hg(0) and Hg(II).

Mercury use in processes: mercury releases and occupational exposures may be reduced through strict mercury accounting procedures, management measures to keep mercury from being dispersed, filtering exhaust air and proper disposal of mercury wastes. Several prevention or alternative technologies already exist with more in development.

Mercury in products: substituting non-mercury products and managing the waste stream may reduce mercury releases and exposures.

ASGM: mercury releases and exposures can be reduced through the use of capture devices, including retorts. Actions may focus on technology transfer, including building central processing facilities. Bans on mercury may also be pursued. All actions on ASGM will require technical and institutional support to ensure success.

• Data Gaps

A number of countries have data gaps in their national mercury release inventories or lack inventories altogether. Missing data may include: information on uses and emissions, sources of releases, levels in the environment and prevention and control options for mercury and mercury compounds.

Many countries could also benefit from developing a national action plan for mercury.

Some data needs include:

- National inventories on use, consumption and releases of mercury.
- Monitoring of levels of mercury in various media and biota and assessment of the impacts of mercury on humans and the environment.
- Information on transport, transformation, cycling, and fate of mercury in various compartments.
- Evaluation tools for human and ecological risk assessments.
- Information on possible mercury exposure prevention and reduction measures.
- Public awareness-raising on the potential adverse impacts of mercury and proper handling and waste management practices, particularly for mercury use in ASGM.
- Capacity building and physical infrastructure for safe management of mercury as a hazardous substance, potentially on a regional basis.
- Information on trade in mercury and mercury-containing materials.

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