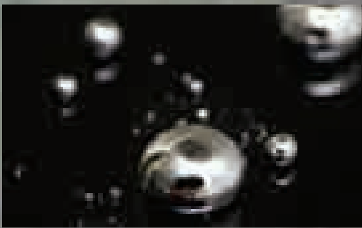

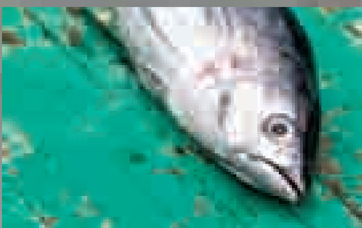

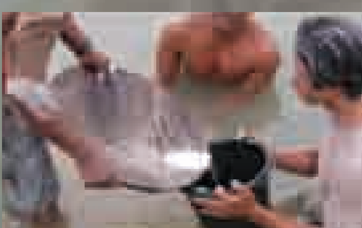

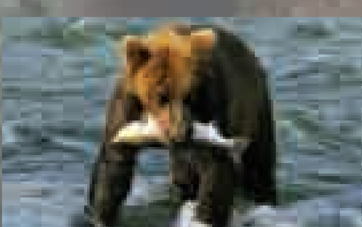

IPEN
INTERNATIONAL POPs ELIMINATION NETWORK

MERCURY-FREE: YOU, ME AND BABIES

An NGO Introduction to Mercury Pollution

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INTERNATIONAL POPs
ELIMINATION NETWORK

The International POPs Elimination Network (IPEN) is a global network of health and environmental organizations working in more than a hundred countries. The network was originally founded to promote the negotiation of a global treaty to protect human health and the environment from a class of toxic chemicals called Persistent Organic Pollutants (POPs). Then, following adoption by Governments of the Stockholm Convention on POPs, IPEN expanded its mission beyond POPs and now supports local, national, regional and international efforts to protect health and the environment from harms caused by exposure to toxic chemicals.

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List of Abbreviations and Acronyms

AAP	American Academy of Pediatrics
ALMR	Association of Lamp and Mercury Recyclers
AMDE	Atmospheric Mercury Depletion Event
APCD	Air Pollution Control Device
ASGM	Artisanal and Small-Scale Gold Mining
BAT	Best Available Techniques
BPOM	Indonesian Food and Drug Control Agency
CDC	United States Centers for Disease Control and Prevention
CFL	Compact Fluorescent Lamp
COP	Conference of Parties
CSO	Civil Society Organization
EMEA	European Agency for the Evaluation of Medicinal Products
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
FAO	United Nations Food Agriculture Organization
FDA	Food and Drug Administration
FGD	Flue Gas Desulfurization Systems
GAIA	Global Alliance for Incinerator Alternatives
GC	UNEP Governing Council
GEM	Gaseous Elemental Mercury
HCWH	Health Care Without Harm
HID	High-Intensity Discharge Lamp
IARC	International Agency for Research on Cancer
IPEN	International POPs Elimination Network
LCD	Liquid Crystal Displays
LED	Light-Emitting Diode
LNG	Liquid Natural Gas
MSDS	Material Safety Data Sheet
NGO	Non-governmental Organization
PAN	Pesticide Action Network
POP	Persistent Organic Pollutant
PTWI	Provisional Tolerable Weekly Intake
PVC	Polyvinyl Chloride
RGM	Reactive Gaseous Mercury
RoHS	Restrictions in the use of Hazardous Substances
S/S	Solidification/Stabilization
SCR	Selective Catalytic Reduction
TGM	Total Gaseous Mercury

Contents

1. Foreword

This is a booklet about the toxic environmental pollutant mercury. It provides information about mercury pollution and its harm to human health and the environment. The booklet also presents the major sources of mercury pollution and calls for civil society efforts at the local, national, and global level to work toward controlling human activities that release mercury into the environment. The booklet gives special attention to current intergovernmental discussions and negotiations aimed at establishing a global mercury-control treaty, and it encourages nongovernmental organizations (NGOs) and other civil society organizations (CSOs) to engage in the treaty process.

Mercury is a global pollutant. When mercury is released into the environment, it evaporates, travels on air currents, and then falls back to earth, sometimes near the original source and sometimes far away. When mercury enters the aquatic environment, microorganisms can transform it into methylmercury, a mercury compound that is more toxic at low doses than elemental mercury.

Methylmercury in the environment becomes part of the food chain. Small aquatic organisms ingest methylmercury from their surrounding environment. They, in turn, are eaten by fish and other larger aquatic organisms. As a result, the methylmercury biomagnifies, becoming increasingly concentrated as the pollutant works its way up the food chain. Marine mammals, birds, and other animals that consume fish can become highly polluted with methylmercury. Generally, higher concentrations are found in larger and older animals. People who regularly eat fish or fish-eating animals can also become sufficiently polluted with methylmercury that it harms their health. A mother passes on the mercury that has accumulated in her body to the developing fetus. Fetuses, as well as infants and children, are particularly susceptible to harm from mercury exposure.

The body of scientific knowledge about the harms to human health and the environment caused by mercury exposure has grown over the years, and many governments have already taken some steps to control—within their jurisdictions—industrial and other human activities that release mercury into the environment. However, because mercury is a global pollutant, no national government acting alone can protect its people and its environment from the harms caused by mercury pollution. Recognizing this, governments agreed in 2009 to start intergovernmental treaty negotiations with the aim of preparing a global, legally binding mercury-control treaty. The first meeting of the Intergovernmental Negotiating Committee to Prepare a Global Legally Binding Instrument on Mercury took place in Stockholm, Sweden, in June 2010. The objective of these negotiations is to reach agreement on final treaty text in time to adopt a new global mercury treaty at a diplomatic conference to be held in 2013.

This booklet has been produced to help encourage and enable organizations of global civil society to engage in local, national, and international activities aimed at controlling mercury pollution. It includes information they can use in programs and campaigns aimed at raising mercury awareness among their constituents and among the public at large. It identifies sources of mercury pollution and suggests what can be done to control those sources. The booklet also outlines the kinds of provisions a global mercury-control treaty must contain if it is to be successful in sufficiently minimizing mercury pollution to protect human health and the environment, and it encourages organizations of civil society in all countries to engage in advocacy efforts aimed at ensuring that governments adopt, ratify, and fully implement an effective and protective mercury-control treaty.

The booklet's intended audience is leaders and members of those NGOs and CSOs for whom the protection of public health and the environment from harms caused by mercury pollution is—or should be—a topic of concern. These include public health and environmental advocacy organizations, organizations of medical and health care professionals, organizations representing communities or constituencies potentially impacted by mercury exposure, trade unions, and others. It is the fourth in a series of booklets on chemical-safety topics for NGO audiences.[1] The other booklets in this series are:

- An NGO Guide to SAICM: The Strategic Approach to International Chemicals Management
- An NGO Guide to Persistent Organic Pollutants
- An NGO Guide to SAICM and Hazardous Pesticides

All these booklets were produced to encourage NGOs and CSOs to engage in campaigns, programs, and projects aimed at achieving a world in which exposure to toxic chemicals is no longer a significant source of harm to human health and to ecosystems.

This and other booklets in the series were prepared by the International POPs Elimination Network (IPEN). IPEN is a global network of more than 700 public-interest, nongovernmental health and environmental organizations working in more than 100 countries. The network was originally founded to promote the negotiation of a global treaty to protect human health and the environment from a class of toxic chemicals called persistent organic pollutants (POPs). Then, following adoption by governments of the Stockholm Convention on POPs, IPEN expanded its mission beyond POPs and now supports local, national, regional, and international efforts to protect human health and the environment from harms caused by exposure to all kinds of toxic chemicals.

We would like to thank Sweden's Environmental Protection Agency and Switzerland's Federal Office for the Environment and other IPEN donors for providing financial support that made the production of this booklet possible. The views expressed, however, do not necessarily reflect those of IPEN's donors.

We also thank those who have taken time to provide information for this booklet or to review it in part or in whole. Special thanks go to Eric Uram, Joe DiGangi, Alan Watson, and Peter Orris. Others who have contributed include Björn Beeler, Mariann Lloyd-Smith, Olga Speranskaya, Richard Gutierrez, Fernando Bejarano, Ravi Agarwal, Jindrich Petrlik, Eva Kruemmel, Fe de Leon, Manny Calonzo, Shahriar Hossain, Takeshi Yasuma, Lilian Corra, Yuyun Ismawati, Ahmed Jaafari, Gilbert Kuepouo, Valerie Denney, and others. Any and all mistakes in this booklet, however, are solely the responsibility of its author.

Jack Weinberg
October 2010

Notes

1 These booklets can be found in multiple languages on the IPEN website at http://www.ipen.org/ipenweb/documents/ipen_education.html.

2. Introduction to Mercury in the Environment

Mercury is a natural element whose chemical symbol is Hg. This abbreviation comes from the Greek word hydrargyrum, which means liquid silver. In its pure form, mercury is a silvery-white metal that is liquid at standard temperature and pressure. In different contexts, pure mercury is often called quicksilver, metallic mercury, or liquid mercury. Most commonly, however, pure mercury is called elemental mercury.

Because elemental mercury has high surface tension, it forms small, compact, spherical droplets when it is released into the environment. Although the droplets themselves are stable, the high vapor pressure of mercury compared with other metals causes the mercury to evaporate. In an indoor setting, mercury can quickly become an inhalation hazard. Outdoors, elemental mercury vaporizes and enters the atmosphere.[2]

Mercury is an element and it cannot be created by people, nor can it be destroyed. Mercury is released into the environment by volcanic eruptions, and it naturally occurs in the earth's crust, often in the form of mercury salts such as mercury sulfide. Mercury is present in very small quantities in uncontaminated soils at an average concentration of about 100 parts per billion (ppb). Rocks can contain mercury at concentrations between 10 and 20,000 ppb.[3] Many different kinds of human activities remove mercury from the earth's crust for some purpose, and this leads to releases of mercury into the general environment.

Elemental mercury can be produced for human use from an ore called cinnabar, which contains high concentrations of mercury sulfide. Elemental mercury can also be produced as a by-product from the mining and refining of metals such as copper, gold, lead, and zinc. Mercury can also be recovered by recycling operations and is sometimes removed from natural gas or other fossil fuels.

It has been estimated that approximately one-third of the mercury circulating in the global environment is naturally occurring and approximately two-thirds was originally released into the environment as a result of industrial and other human activities.[4] Besides volcanic eruptions, natural sources of mercury also include the weathering of rocks and soils. The amount of mercury that is circulating in the world's atmosphere, soils, lakes, streams, and oceans has increased by a factor of between two and four since the start of the industrial era.[5] As a result, levels of mercury in our environment are dangerously high.

Several kinds of human activities release mercury into the environment. Mercury is present in fossil fuels, metal ores, and other minerals. When coal is burned, much of its mercury content enters the environment. Mining and refining metal ores and the manufacture of cement also release mercury into the environment. Whenever people intentionally produce and use mercury, much of that mercury will eventually volatize into the atmosphere. The largest present intentional use of mercury is by artisanal and small-scale gold miners. Mercury compounds are also sometimes used as catalysts or feedstocks in chemical manufacturing and in other industrial processes. Finally, mercury and mercury compounds are present in numerous kinds of consumer and industrial products.

After mercury enters the air, it moves with the wind and eventually falls back to earth. In the air, mercury may travel either a short or long distance before falling back to earth; it may even fully circle the globe. A portion of the mercury that falls into the ocean or onto the land will re-volatilize; it will again travel with the wind and will again fall back to earth somewhere else. The mercury that falls on land and does not volatilize will likely bind to organic material. Some becomes trapped in peat or soils. The remainder eventually drains to streams and rivers and then to lakes and oceans. In the aquatic environment, elemental mercury will likely become bound to sediment and then transported on ocean or river currents. Some mercury remains dissolved in the water column. In aquatic systems, naturally present microorganisms can transform mercury into methylmercury, an organometallic compound that is more toxic at low doses than pure mercury. Methylmercury becomes part of the aquatic food chain; it bioaccumulates and biomagnifies, and it can then be transported by migratory species.

Mercury in the Atmosphere

Most mercury in the atmosphere is in the gaseous state, but some is attached to particulate matter. Gaseous mercury is mostly elemental mercury, but a small percentage has been oxidized into mercury compounds such as mercury chloride and mercury oxide.

Pure mercury vapor, also called gaseous elemental mercury (GEM), has very low water solubility and is very stable in the atmosphere, with an estimated residence time of between six months and two years. This stability enables elemental mercury to undergo long range transport and causes GEM concentrations to be fairly uniform in the atmosphere. The more industrially developed Northern Hemisphere, however, has higher atmospheric GEM concentrations than does the Southern Hemisphere.

Mercury compounds present in the atmosphere in a gaseous state are often referred to as reactive gaseous mercury, or RGM. RGM compounds are more chemically reactive than GEM ones and are mostly soluble in water. RGM is much less atmospherically stable than GEM, and rain and other forms of precipitation can remove it from the atmosphere. This is called wet deposition. RGM can also be removed from the atmosphere without precipitation through a process called dry deposition.

RGM remains in the atmosphere for only a fairly short time. Particulate-bound mercury also spends a relatively short time in the atmosphere and can also be fairly quickly removed by both wet and dry deposition.

Because GEM is a gas that is not highly water soluble, precipitation does not efficiently remove it from the atmosphere. There are various mechanisms, however, by which GEM becomes subject to deposition, and these remain an ongoing subject of investigation. Some studies relate GEM depositions to photochemical reactions in the surface layers of the atmosphere. Some indicate that dry deposition of GEM can occur on forest canopies and that this is an important sink for atmospheric GEM. Another study has found indications that under certain conditions, GEM can be removed from the atmosphere at the ocean boundary. [6,7,8]

A relatively new phenomenon called an atmospheric mercury depletion event (AMDE) has been reported in the literature. Research in the Canadian high Arctic found that each spring, during polar sunrise, the atmospheric mercury concentration dropped sharply and at the same time, ozone present in surface air was depleted. AMDEs have been demonstrated in both the Arctic and the Antarctic regions. These depletion events are likely caused by photochemical reactions in the low atmosphere between ozone and halogen compounds of largely marine origin, especially bromine oxides. In this process, ozone is destroyed and elemental mercury that is present in the atmosphere is oxidized

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and converted into reactive gaseous mercury compounds. It is estimated that approximately 300 metric tons of this reactive mercury is deposited annually in the Arctic due to AMDEs. The result, apparently, is a doubling or more of the amount of mercury depositions in the Arctic in excess to what would be expected in the absence of these springtime depletion events. Furthermore, these AMDE mercury depositions appear to be in the form of bio-available oxidized mercury compounds.[9,10,11] The discovery of the AMDE phenomenon helps further explain why Arctic peoples are disproportionately impacted by methylmercury exposure.

Investigations into the mechanisms by which the mercury contained in atmospheric GEM gets deposited onto land and water are ongoing.

Some Properties of Elemental Mercury

Property	Value
Atomic Weight	200.59
Atomic Number	80
Melting Point	-38.87°C
Boiling Point	356.58°C
Vapor Pressure at 25°C	2×10^{-3} mm Hg
Solubility in Water at 25°C	20–30 µg/L
CAS Registry Number	7439-97-6
Mass	13.5336 gm/cc

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3. Toxicological Effects of Mercury and Methylmercury

Knowledge that mercury is toxic goes back to at least the first century C.E. when the Roman scholar Pliny described mercury poisoning as a disease of slaves, noting that mines contaminated by mercury vapor were considered too unhealthy for Roman citizens.[12]

In popular culture, mercury poisoning has been associated with the Mad Hatter, a character that appears in the story *Alice's Adventures in Wonderland*. In the nineteenth century, workers in the English hat-making industry frequently suffered neurological symptoms such as irritability, shyness, depression, tremors, and slurred speech. Exposure to a mercury compound, mercuric nitrate—a chemical that was then widely used in making felt hats— caused these symptoms. Many believe that these poisoned workers were the source of the common English-language expression "mad as a hatter" and were the inspiration for the Mad Hatter character.[13]

Occupational exposure to mercury is not just a problem from the past. It remains a problem today for workers in many industries such as mercury mining; chlor-alkali production; the manufacturing of thermometers, fluorescent lamps, batteries, and other mercury-containing products; gold, silver, lead, copper, and nickel mining and refining; and the field of dentistry. The largest-scale exposures are suffered by the millions who work in artisanal and small-scale gold mining. These miners use elemental mercury to separate gold from waste rock¸ usually under uncontrolled or poorly controlled conditions. As a result, the miners, their families, and their communities are highly exposed.

The nervous system is very sensitive to all forms of mercury. Methylmercury and metallic mercury vapors are especially harmful because mercury in these forms more readily reaches the brain. Exposure to high levels of metallic, inorganic, or organic mercury can permanently damage the brain and kidneys and has been shown to affect a developing fetus, even months after the mother's exposure. The harmful effects that can be passed from the mother to the fetus include brain damage, mental retardation, blindness, seizures, and the inability to speak. Children poisoned by mercury may develop problems in their nervous and digestive systems and kidney damage. Adults who have been exposed to mercury have symptoms such as irritability, shyness, tremors, changes in vision or hearing, and memory problems. Short-term exposure to high levels of metallic mercury vapors may cause effects such as lung damage, nausea, vomiting, diarrhea, increases in blood pressure or heart rate, skin rashes, and eye irritation.[14]

A guidance document prepared jointly by the World Health Organization (WHO) and the United Nations Environmental Program (UNEP) stated the following:

"The primary targets for toxicity of mercury and mercury compounds are the nervous system, the kidneys, and the cardiovascular system. It is generally accepted that developing organ systems (such as the fetal nervous system) are the most sensitive to toxic effects of mercury. Fetal brain mercury levels appear to be significantly higher than in maternal blood, and the developing central nervous system of the fetus is currently regarded as the main system of concern as it demonstrates the greatest sensitivity. Other systems that may be affected include the respiratory, gastrointestinal, hematologic, immune, and reproductive systems."[15]

3.1 Elemental Mercury and Inorganic Mercury Salts

People can be poisoned by pure elemental mercury by inhaling mercury vapors. Approximately 80 percent of inhaled mercury vapor is absorbed by the respiratory tract or through the sinuses and then enters the circulatory system to be distributed throughout the body.[16] Chronic exposure by inhalation, even at low concentrations, has been shown to cause effects such as tremors, impaired cognitive skills, and sleep disturbance in workers.[17] Elemental mercury vapors can be found in many industrial workplaces and can also be present in hospitals, dentist offices, schools, and homes where mercury-containing products are used. Exposure from inhaling these mercury vapors poses a significant risk.

On the other hand, elemental mercury in its liquid form differs from most inorganic and organic mercury compounds in that it is not easily absorbed into the body if someone ingests it or is exposed by skin contact. Animal data suggests that less than 0.01 percent of ingested elemental mercury is absorbed by the stomach and intestines. Cases of people being poisoned by swallowing metallic elemental mercury are rare.[18]

Inorganic mercury salts, on the other hand, can be highly toxic and corrosive. Acute exposures to inorganic mercury salts can cause corrosive damage to the stomach and intestines and can also cause significant kidney damage. If mercury salts are eaten or are in contact with the skin, the body can absorb them at a rate of about 10 percent of the amount ingested, which harms various organ systems including the central nervous system. The rate at which the body absorbs inorganic mercury salts is much greater than the absorption rate of elemental mercury but lower than the absorption rates of organic mercury compounds such as methylmercury, which, when ingested, are absorbed almost completely by the stomach and the intestines.[19]

3.2 Methylmercury

Methylmercury (CH_3Hg^{+}) is the form of mercury that is mainly responsible for mercury pollution in fish, shellfish, and the birds and mammals that eat them. When a person ingests methylmercury, the stomach and intestines absorb it much more completely than they absorb inorganic mercury.[20]

There appear to be a number of different ways in which mercury is transformed in the environment into methylmercury, and researchers are actively investigating these. One important process of biomethylation is carried out by bacteria that live in water with low levels of dissolved oxygen. In fresh and brackish water, this can occur in the sediments of estuaries and lake bottoms.[21] Methylmercury can also be formed in oceans when mercury falls from the atmosphere to the ocean surface and is transported to the ocean depths where naturally occurring bacteria decompose organic matter and, at the same time, also convert mercury to methylmercury.[22] Once in the environment, methylmercury bioaccumulates and biomagnifies as larger organisms eat smaller ones.

Methylmercury differs from metallic mercury in that when a person eats food contaminated with methylmercury, the stomach and intestines rapidly absorb it into the bloodstream. From there, it readily enters the brain of an adult, a child, or a developing fetus. In the brain, methylmercury accumulates and is slowly converted to inorganic (elemental) mercury.[23]

In 2000, the United States Environmental Protection Agency (U.S. EPA) asked the National Research Council of the National Academies of Sciences and Engineering to perform a study on the toxicological effects of methylmercury. The study found that the population at highest risk for methylmercury exposure is the children of women who consumed large amounts of fish and seafood during or immediately prior to pregnancy. It found that the risk to this population is likely to be sufficient to result in an increase in the number of children who must struggle to keep up in school and who might require remedial classes or special education.[24] It should be noted that studies have found that when children suffer these kinds of neurological deficits from exposure to pollutants, they are generally less successful in their later lives as measured by lifelong earnings. Such deficits not only harm exposed individuals and their families but can also have a cumulative impact on society through increased costs for schooling and care for affected individuals and by decreasing national productivity.[25]

Neurological Effects: The developing nervous system is more sensitive to the toxic effects of methylmercury than is the developed nervous system, although both the adult and fetal brain are susceptible.[26] Prenatal exposures interfere with the growth of developing neurons in the brain and elsewhere and have the potential to cause irreversible damage to the developing central nervous system. After exposures associated with chronic maternal fish consumption, infants might appear normal during the first few months of life but might later display deficits in subtle neurological end points such as deficits in IQ; abnormal muscle tone; and losses in motor function, attention, and visuospatial performance.[27]

The weight of evidence for developmental neurotoxic effects from exposure to methylmercury is strong. There is a strong data base including multiple human studies and experimental evidence in animals and in vitro tests. Human studies include evaluations of both sudden, high-exposure scenarios and chronic, low-level exposure.[28]

Heart Disease and High Blood Pressure: Researchers have found a correlation between consumption of methylmercury-contaminated fish and the risk of heart attack. A study of fishermen found that eating more than 30 grams (g) of fish per day doubled or tripled their risk of heart attack or cardiovascular death. Blood pressure elevations have also been observed in occupationally exposed men.[29]

Immune System Effects: Occupational studies suggest that mercury exposure can affect the immune system in humans. In vitro and animal studies have shown that mercury can be toxic to the immune system and that prenatal exposure to methylmercury can produce long-term effects on the developing immune system. Studies suggest that exposure to methylmercury can increase human susceptibility to infectious diseases and autoimmune disorders by damaging the immune system.[30]

Cancer: Two studies have found associations between mercury exposure and acute leukemia, but the strength of the findings is limited because of the small study populations and lack of control for other risk factors. Mercury exposure has also been associated with kidney tumors in male mice, and mercury has also been shown to cause chromosomal damage. On the basis of the available human, animal, and in vitro data, the International Agency for Research on Cancer (IARC) and the U.S. EPA have classified methylmercury as a possible (EPA Class C) human carcinogen.[31]

Reproductive Effects: The reproductive effects of methylmercury exposure have not been adequately evaluated in humans. However, an evaluation of the clinical symptoms and outcomes of more than 6,000 people exposed to methylmercury during a wheat-contamination incident in Iraq found a lowered rate of pregnancies (a 79 percent reduction), providing suggestive evidence of an effect of methylmercury on human fertility. Animal studies, including work in nonhuman primates, have found reproductive problems, including decreased conception rates, early fetal losses, and stillbirths.[32]

Effects on the Kidneys: Metallic mercury and methylmercury are both also known to be toxic to the kidneys. Kidney damage has been observed following human ingestion of organic forms of mercury at exposure levels that also cause neurological effects. Animal studies have also described methylmercury-induced toxicity to the kidneys.[33]

3.3 Environmental Impacts of Methylmercury

The ecological impacts of methylmercury pollution have been less well-studied than its human toxicity. We do know, however, that methylmercury accumulates in fish at levels that may harm the fish and animals that eat them. Birds and mammals that eat fish are generally more exposed to methylmercury than other animals in water ecosystems. Similarly, predators that eat fish-eating animals are at risk. According to an EPA report, methylmercury has been found in eagles, otters, and endangered Florida panthers, and analyses conducted for the report suggest that some highly exposed wildlife species are being harmed by methylmercury. Effects of methylmercury exposure on wildlife can include death, reduced fertility, slower growth, and abnormal development and behavior patterns that can affect survival. In addition, the levels of methylmercury found in the environment may alter the endocrine system of fish, and this may impact their development and reproduction.[34,35]

In birds, mercury exposure can interfere with reproduction when concentrations in eggs are as low as 0.05 milligrams (mg) to 2.0 milligrams per kilogram (kg). The eggs of certain Canadian species are already in this range, and mercury concentrations in the eggs of several other Canadian species continue to increase and are approaching these levels. Mercury levels in Arctic ringed seals and beluga whales have increased by two to four times over the last 25 years in some areas of the Canadian Arctic and Greenland.[36] There are also indications that predatory marine mammals in warmer waters may be at risk. In a study of Hong Kong's population of hump-backed dolphins, mercury was identified as a particular health hazard.[37]

Recent evidence also suggests that mercury is responsible for a reduction of microbiological activity vital to the terrestrial food chain in soils over large parts of Europe and potentially in many other places in the world with similar soil characteristics.[38]

Rising water levels associated with global climate change may also have implications for the methylation of mercury and its accumulation in fish. For example, there are indications of increased formations of methylmercury in small, warm lakes and in many newly flooded areas.[39]

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4. Mercury Pollution

Minamata disease is a serious and often deadly illness caused by exposure to high levels of methylmercury. It is associated with hot spots of acute mercury pollution from certain industrial processes and mercury-contaminated wastes. Mercury pollution, however, also causes harm to human health and the environment at locations far from industrial or other local mercury sources. In all regions of the world, fish and shellfish from ponds, streams, rivers, lakes, and oceans are commonly contaminated by methylmercury in concentrations that can cause significant health deficits to the people who eat them, especially people who depend on fish and shellfish as a major source of protein.

4.1 Acute Mercury Pollution and Minamata Disease

The most famous example of acute mercury contamination occurred in fishing villages along the shore of Minamata Bay, Japan. Chisso, a chemical company located near the bay, used mercury sulfate and mercury chloride as catalysts in the production of acetaldehyde and vinyl chloride. Wastewater from the plant was discharged into Minamata Bay and contained both inorganic mercury and methylmercury. The methylmercury originated mainly as a side product of the acetaldehyde production process.[40] Methylmercury accumulated in the fish and shellfish in the bay and in local people who ate the fish and shellfish. The result was a form of mercury poisoning that is now known as Minamata disease.[41]

Minamata disease patients complained of a loss of sensation and numbness in their hands and feet. They could not run or walk without stumbling, and they had difficulties seeing, hearing, and swallowing. A high proportion died. The disease was first diagnosed in 1956. By 1959, a strong case had been made that the disease was caused by the high concentrations of methylmercury that were present in the fish and shellfish in the bay.

Mercury discharges from the Chisso plant into the bay were continuous from the time the factory started using the acetaldehyde-production process in 1932 until 1968, when the factory discontinued this production method. Production of vinyl chloride using a mercury catalyst continued at the plant until 1971, but after 1968 the wastewater was diverted to a special pond.[42]

According to a recent review in an environmental health journal, the Minamata victims needed to overcome legal and political rigidities that demanded convincing documentation before there was adequately serious consideration given to their plight. This was compounded by failures in the scientific community, whose understanding of the cause of methylmercury-induced health effects was impaired by a reliance on narrow case definitions and uncertain chemical speciation. The article's authors point out that although methylmercury was known to be capable of producing developmental neurotoxicity as early as 1952, it took another 50 years for researchers to understand the vulnerability of the developing nervous system to heavy metals such as methylmercury. Additionally, normal uncertainties of the kind associated with virtually all new environmental health research delayed for years the achievement of a scientific consensus as to the cause of the people's symptoms. This, in turn, caused long delays before the pollution source was finally stopped, and it caused even longer delays in reaching decisions to compensate the victims.[43]

Although most victims at first had a difficult time securing compensation, by the end of 2009, 2,271 victims had been officially certified and more than 10,000 people had received financial compensation. Other exposed people were still fighting for adequate compensation.[44] In May 2010, more than 50 years after the disease was first diagnosed, the Government of Japan adopted additional redress measures for unrecognized Minamata disease sufferers and promised further efforts. Then Japanese Prime Minister Yukio Hatoyama participated in the 54th annual Minamata commemoration ceremony and apologized for the government's inability to prevent the spread of the disease in the country's worst industrial pollution case. In his speech, he expressed hope that Japan will actively contribute to creating an international treaty for preventing future mercury poisoning and proposed naming it the Minamata Treaty.[45] In June 2010, at the first meeting of the Intergovernmental Negotiating Committee to Prepare a Global Legally Binding Instrument on Mercury, the delegation from the Government of Japan repeated this proposal and offered to host the Diplomatic Conference that will follow the negotiations and adopt the new treaty.

A second outbreak of Minamata disease occurred in 1965 in Japan in the Agano River basin in the Niigata Prefecture. A different chemical company, producing acetaldehyde using a mercury sulfate catalyst and a similar process, dumped its wastewater into the Agano River. The Japanese government certified 690 people as patients in this outbreak of the disease.

Another example of Minamata disease occurred in the early 1970s in Iraq when an estimated 10,000 people died and 100,000 were severely and permanently brain damaged from eating wheat that had been treated with methylmercury.[46] Another example is the poisoning of Canadian aboriginal people at Grassy Narrows, which was caused by mercury discharges from a chlor-alkali plant and pulp and paper mill in Dryden, Ontario, between 1962 and 1970.[47]

Less well-known and less dramatic cases of acute mercury pollution continue to occur. According to Masazumi Harada, the leading world expert on Minamata disease: "Rivers in the Amazon, Canada, and China have been affected by mercury poisoning, but as with Minamata disease, there are few patients who look severely ill at first glance: People are clearly affected by mercury, but the mercury is found in small amounts in patients' bodies, or they are still in the initial stages of the disease."[48]

4.2 Mercury-Contaminated Fish

Acute mercury pollution, however, is just one part of a much bigger picture. Widespread mercury pollution at levels of concern can be found in oceans, lakes, rivers, ponds, and streams in all parts of the world.

As indicated earlier, mercury enters water bodies mainly by falling directly from the air and through drainage from mercury-contaminated soils. Upon entering the aquatic environment, a significant fraction of the mercury is transformed into methylmercury by microorganisms that are naturally present in these ecosystems. The microorganisms are then eaten by small aquatic organisms that are, in turn, eaten by fish and shellfish. These then are eaten by larger fish, birds, mammals, and people.

Methylmercury starts at the bottom of the food chain and then accumulates and biomagnifies as larger organisms eat smaller ones. As a result of this biomagnification, the concentration of methylmercury in some fish species can be at levels in the range of a million times (10^6) greater than the background concentration of the mercury in the water that the fish inhabit.[49]

Mercury pollution of water bodies is very widespread. Water bodies located downwind or downstream of heavy mercury-polluting sources such as large coal-fired power plants, cement kilns, mines, waste dumps, chlor-alkali facilities, pulp and paper mills, and other large industrial sources often have particularly high levels of mercury contamination. However, even in the Arctic region at locations far distant from any significant mercury-polluting sources, researchers have found a number of communities where people's dietary intake of mercury exceeds established national guidelines, and they have found evidence of resulting harm to children's nervous systems and related behavioral effects.[50] A study by the United States Geological Survey (USGS) sampled predatory fish in streams at 291 locations spread throughout the United States. The researchers found that mercury was present in every fish they sampled, and 27 percent of the samples exceeded the U.S. EPA human-health criterion of 0.3 micrograms of methylmercury per gram wet weight.[51]

Many governments provide recommendations, guidelines, or legal limits for the maximum amount of mercury and/or methylmercury that should be allowed in fish that are to be sold on the market. However, not all guidelines established are enforceable, and many NGOs argue that they are too permissive to adequately protect public health. In some cases, the fishing industry has successfully beaten back efforts by government agencies to establish stricter standards with arguments that doing so would hurt sales.

The Codex Alimentarius Commission—a body established by the United Nations Food and Agriculture Organization and the World Health Organization to set internationally recognized food safety standards—has set guideline levels of 0.5 micrograms of methylmercury per gram in non-predatory fish and 1 microgram of methylmercury per gram in predatory fish. The U.S. Food and Drug Administration (FDA) has set an action level of 1 microgram of methylmercury per gram in both fish and shellfish – substantially higher than the USEPA human-health criterion. The European Community allows 0.5 micrograms of methylmercury per gram in fishery products (with some exceptions). Japan allows up to 0.4 micrograms of total mercury per gram in fish or 0.3 micrograms of methylmercury per gram of fish.[52] The Canadian Food Inspection Agency's guideline for the commercial sale of fish is 0.5 micrograms of total mercury per gram of fish wet weight, and Health Canada has established a guideline of 0.2 micrograms of total mercury per gram wet weight for frequent consumers of fish.[53]

In general, large predatory fish have the highest levels of methylmercury in their tissues; larger fish and older fish tend to be more contaminated than smaller fish and younger fish. Methylmercury in fish is bound to tissue protein rather than fatty tissue. Therefore, trimming and skinning mercury-contaminated fish ***does not*** reduce the mercury content of the fillet portion. Nor is the methylmercury level in fish reduced by cooking.[54]

A guidance document jointly prepared by the U.S. EPA and FDA states that nearly all fish and shellfish contain traces of mercury, and that some fish and shellfish contain levels that may harm a fetus or young child's developing nervous system. The risk, of course, depends on the amount of fish and shellfish eaten and the levels of mercury they contain. The guidance document advises pregnant women, nursing mothers, women who may become pregnant, and young children to completely avoid eating fish species that typically contain unacceptably high levels of mercury such as shark, swordfish, king mackerel, and tilefish. It further advises that they eat no more than 12 ounces (340 grams) per week of fish and shellfish that are lower in mercury. On average, this means they should eat no more than two fish meals per week. The guidance document finally suggests they check local advisories about the safety of locally caught fish and, if no reliable advice is available, limit themselves to only one meal per week of locally caught fish.[55]

The guidance document, nonetheless, suggests that fish and shellfish not be completely eliminated from the diet. It notes that, mercury aside, fish and shellfish are a very nutritional food source: They contain high-quality protein and other essential nutrients, are low in saturated fat, and contain omega-3 fatty acids that are important for nutrition.[56] Health experts often recommend choosing fish to eat that are low in mercury and high in omega-3 fatty acids.

Unfortunately, fish-consumption advice can be confusing and hard to follow. There is great variability in levels of mercury in fish depending on the species, the location where the fish was caught, its size, the time of the year, and other considerations. Choices are further complicated by the fact that in highly industrial countries, the fish at the market or on the restaurant menu is likely to have been shipped in from half a world away. Nonetheless, in wealthy countries, most women and children can choose if they wish to limit their fish consumption to no more than two fish meals per week and still maintain a nutritious diet by replacing fish with other protein-rich foods. However, there are many people in the world for whom restricting fish consumption may not be a realistic option.

In industrial countries such as the United States, Canada, and others, some Indigenous Peoples and some poor people catch their own fish and shellfish (and in some cases, fish-eating birds and mammals) and rely on these foods as their main sources of protein. They often cannot afford, or may otherwise lack access to, good alternative nutritious foods. In the developing world, even larger numbers of people depend on fish. People living on islands, in coastal regions, along inland waterways, and others often have traditional diets that are highly dependent on fish for nutrition. The U.N. Food Agriculture Organization (FAO) estimates[57] that fish provide more than 2.9 billion people with at least 15 percent of their average per capita animal protein intake. Additionally, fish, on average, provide 50 percent or more of animal protein consumption for people in some small-island developing states and also in Bangladesh, Cambodia, Equatorial Guinea, French Guiana, the Gambia, Ghana, Indonesia, and Sierra Leone. The FAO reports that fish provide nearly 8 percent of animal protein consumption in North and Central America, more than 11 percent in Europe, about 19 percent in Africa, and nearly 21 percent in Asia. (Summary fish consumption figures for South America were not provided.) The report also notes that actual consumption is likely considerably higher than the figures provided because official statistics do not record the contribution of subsistence fishing.

Even considering the negative health impacts of eating large amounts of mercury-contaminated fish and shellfish, there are many people for whom severely restricting their fish consumption may be a bad choice or may be no choice at all. Some cannot reduce their fish consumption without facing hunger or starvation. For others, the main available substitute foods that would replace fish are high in sugars and low in protein. Restricting fish consumption in favor of such foods can lead to increases in obesity, diabetes, heart disease, and other diseases. For communities whose access to nutritious alternative foods is limited, the health benefits of fish consumption may, on balance, outweigh the health risks associated with mercury exposure. Members of these communities will continue to suffer the health consequences of exposure to methylmercury until international action is successful in significantly reducing mercury contamination in fish. This, in turn, is not likely to occur without the adoption and effective implementation of a comprehensive mercury-control treaty. In addition, many Indigenous Peoples and others have important cultural and social reasons for continuing to eat their traditional foods.

Mercury Impacts on Arctic Peoples

People living in the Arctic region, especially Indigenous People, are particularly vulnerable to mercury exposure. Their climate does not allow them to grow grains or vegetable, which are often dietary staples in other parts of the world. Because they often live in remote locations, store-bought food tends to be prohibitively expensive, especially healthy, perishable foods. They therefore have little choice but to survive on a diet that is not only heavy in fish, but also in mammals and birds that eat fish. The lives of Arctic Indigenous Peoples living in the far northern regions of highly industrial countries are similar in many ways to the lives of most people in the developing world.

Inuit People live in the coastal Arctic in Northern Canada, Greenland, Alaska (U.S.), and Chukotka (Russia). The staple of their traditional diet is sea mammals. A study of mercury exposure in Inuit preschool children living in Nunavut, Canada, found that nearly 60 percent of them ingest mercury in amounts that exceed the provisional tolerable weekly intake (PTWI) level for children established by the World Health Organization in 1998. This PTWI is 1.6 micrograms of methylmercury per kilogram of body weight per week. The average mercury intake for all the children participating in the study was 2.37 micrograms of methylmercury per kilogram of body weight per week. Of this mercury intake, 33.37 percent came from eating the muktuk (blubber and skin) of beluga whales, 25.90 percent came from eating narwhal muktuk,14.71 percent came from eating ringed seal liver, 10.60 percent came from eating fish, 6.02 percent came from eating caribou meat, and 4.59 percent from eating ringed seal meat. These sources made up more than 95 percent of the children's total mercury intake.[58]

Other Arctic Indigenous Peoples are also disproportionally impacted by exposure to methylmercury. Villages populated by indigenous Athabascan peoples are located throughout the North American Arctic, mostly along the great rivers. Trapping, hunting, and fishing remain crucial to their subsistence livelihoods. In the summer, families often leave the village for large fish camps.[59] The traditional livelihood of the Sami Peoples of Norway, Sweden, Finland, and the Kola Peninsula of Russia includes semi-nomadic reindeer herding, coastal fishing, fur trapping, and sheep herding.[60] There have been suggestions that polar sunrise atmospheric mercury depletion events, which result in the deposition of large quantities of bio-available mercury compounds on the Arctic tundra, amplify the presence of mercury in the tundra food web. This, together with aquatic methylmercury pollution, contributes to significant methylmercury accumulations in the traditional foods of these and other Arctic peoples.[61]

4.3 Mercury-Contaminated Rice

A number of recent studies have looked at mercury pollution in some inland regions of China where most inhabitants eat little fish but live in areas where considerable mercury is released into the environment. [62] The researchers noted that rice paddy soil is a suitable environment for the kind of bacteria that transform mercury into methylmercury. They therefore considered the possibility that methylmercury produced in the paddy soil might be taken up by the rice plants. The study looked at rural people who mainly eat local agricultural products and concluded that 95 percent of the total methylmercury exposure among these people came from rice.

For most people studied, exposure to methylmercury from eating rice was low compared with what is currently thought to be a tolerable weekly intake, and the researchers concluded these people probably face low risk. However, some of the people studied were in an area near mercury mines. Their exposure to methylmercury from eating rice greatly exceeded what is thought to be the tolerable weekly intake, and they were considered to be at a potential health risk.

The authors noted that rice does not contain certain micronutrients that are present in fish—micronutrients that enhance neurodevelopment and that may possibly counterbalance some of the harm caused by mercury exposure. The authors concluded that current methylmercury exposure guidelines based on fish consumption may be inadequate to protect people whose exposure to methylmercury comes from a rice-based diet. They therefore called for more research on the health impacts on pregnant women who are exposed to low doses of methylmercury by eating rice.

The study's authors highlight the urgency of this concern by noting that rice is the main staple food of more than half the world's population. In Asia alone, more than 2 billion people get up to 70 percent of their daily dietary energy from rice and its by-products. The authors therefore conclude that related research should be urgently conducted not only in China but also in other countries and regions, such as India, Indonesia, Bangladesh, and the Philippines, that produce a significant percentage of the global rice and where rice is a staple food.[63]

Notes

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5. How Mercury Gets Into the Environment

Mercury enters the environment in several different ways. Some mercury enters the environment by natural processes such as volcanic eruptions, geothermic activities, and the weathering of mercury-containing rocks. Most of the mercury currently in the global environment, however, entered as a result of human activity. Human activities that release mercury into the environment are called anthropogenic sources of mercury. Once mercury is present in the aquatic or terrestrial environment, it can volatilize and reenter the atmosphere.

Anthropogenic sources of mercury fall into one of three broad categories:

Intentional sources: These sources arise when an intentional decision is made to create a product that contains mercury or to operate a process that uses mercury. Examples of products that contain mercury or a mercury compound include fluorescent lamps, some thermometers, batteries and switches, and other similar products. A non-industrial process that uses mercury is small-scale gold mining, in which elemental mercury is used to capture gold from mixtures of crushed rocks, sediments, soils, or other particles. Examples of industrial processes include chemical manufacturing plants that use mercury compounds as catalysts, especially in vinyl chloride monomer production and some chlor-alkali plants that use pools of elemental mercury as a cathode in electrolysis.

Unintentional sources: These sources arise from activities that burn or process fossil fuels, ores, or minerals that contain mercury as an unwanted impurity. Examples include coal-fired power plants, cement kilns, large-scale metal mining and refining, and fossil fuel extraction for coal, oil, oil shale and tar sands. Incinerators and landfills that are used to dispose of mercury-containing end-of-use products and wastes also release mercury into the environment and are categorized by some as unintentional sources.

Remobilization activities: These sources arise from human activities that burn or clear forests or that flood large areas. The biomass and organic surface soils in forests often contain mercury that has fallen out from the air. Burning or clearing forests—especially boreal or tropical forests—releases large quantities of this mercury back into the air.[64] Large dam projects flood vast areas, and this allows for mercury trapped in biomass and surface soils to become more readily converted into methylmercury and enter the aquatic food chain.[65] Smaller dams that cause fluctuating upstream water levels can also be a problem. Methylmercury can be produced by bacteria that flourish on shorelines that are alternately exposed to air and covered with water as small dams open and close their floodgates.[66]

Researchers have tried to estimate the total amount of mercury released into the environment from different categories of anthropogenic sources. The data available to these researchers, however, is both incomplete and inexact. It is particularly difficult to distinguish between a natural source of mercury (that enters the environment from volcanic activity or the weathering of rocks) and the remobilization and reemission of mercury that originally entered the environment from an anthropogenic source and was subsequently deposited into the water or onto land.

Because of this difficulty, most published estimates of natural sources of mercury in the atmosphere actually include in their totals the reemissions of mercury that had previously entered the environment as a result of human activities.[67] This inflates many of the published estimates of the amount of mercury in the global environment from natural sources, and it unintentionally fosters the impression that the mercury released into the environment by volcanoes and by the weathering of rocks are larger contributors to total global atmospheric mercury than they actually are. If the reemissions of mercury that originally entered the environment as a result of human activities could be counted as contributing to the total of all global atmospheric mercury emissions, then estimates of total anthropogenic mercury emissions into the atmosphere would likely be considerably higher than currently published estimates.

It is also difficult to calculate the percentage of global mercury pollution coming from different anthropogenic sources. The 2008 the United Nations Environment Programme (UNEP) "Global Atmospheric Mercury Assessment"[68] identifies various human activities that release mercury into the environment and provides emission data for many of them. This emissions data is frequently cited as an indicator of the proportion of global mercury pollution that comes from these different sources. So, for example, it is frequently repeated that burning fossil fuels—primarily coal—is the largest source of mercury pollution and accounts for 45 percent of all global mercury emissions from anthropogenic sources, that artisanal and small-scale gold mining (ASGM) is the second largest source of mercury pollution and accounts for an estimated 18 percent of global emissions, and so on.[69]

These and other estimates of mercury emissions from various sources, however, can be misunderstood.. This is because reported atmospheric emissions estimates are based only on measurements of mercury released directly into the air and do not take into account mercury releases into wastes, soils, and water even though much of this mercury will subsequently volatilize and enter the air. Nor do these emission estimates take into account other unmeasured mercury releases associated with the source. Actual mercury releases from a source may be much higher than the reported mercury emissions from the source.

Emission Estimate Data May Be Misunderstood

The reported percentage of global air emissions that come from a particular source is often used as an indicator of how much of the world's mercury pollution comes from that source. So, for example, when we read that burning fossil fuels accounts for 45 percent of all global mercury air emissions from anthropogenic sources, it is natural to conclude that 45 percent of the global mercury pollution problem comes from burning fossil fuels. But this may be a misleading conclusion for a number of reasons:

1. There are some sources of mercury air emission for which there is little data or no data. The contribution to global mercury air emissions from these sources may be greatly underestimated.

2. It is easier to measure the amount of mercury emissions to the atmosphere from some sources than for others. The contribution to global mercury air emissions from hard to measure sources may be underestimated.

3. Some mercury sources such as mercury in products have a complicated life cycle. It may be difficult to fully incorporate the mercury air emissions that occur at all points in the product life cycle into the emissions estimates associated with these sources.

4. Some mercury sources release large quantities of mercury to soils, water and wastes. Mercury releases to these media do not generally count as contributing to total global air emissions However, mercury that is released to media other than air will frequently contaminate aquatic ecosystems and contribute to total global

mercury pollution. Additionally, much of the mercury released to these media will, at a later time, volatilize and enter the air. It may be difficult to fully incorporate such secondary air emissions into global air emissions estimates associated with the original source.

One extreme example of an underestimated source is vinyl chloride monomer (VCM) production. There appear to be no available data on mercury air emissions from VCM production. Therefore, global mercury air emissions from VCM production are counted as zero in UNEP's estimated total anthropogenic mercury emissions to the atmosphere of 1,930 metric tons.[70] And yet, more mercury is used in vinyl chloride monomer production than is used in most other intentional sources. There are good common sense reasons to assume that VCM production is a major contributor to global mercury pollution. However, if one were to use UNEP's global air emissions estimates as an indicator, one could reach the obviously false conclusion that VCM production contributes zero percent to the world's total mercury pollution.

The conclusion that artisanal and small-scale gold mining contributes 18 percent of anthropogenic mercury emissions is based on UNEP estimates that the total of all anthropogenic mercury emissions to the atmosphere is 1,930 metric tons per year and that ASGM activities globally generate 350 metric tons of these mercury emissions. However, the report that provides this data also estimates that ASGM activities consume 806 metric tons of mercury per year.[71] One must therefore give consideration to the fate of the rest of the mercury consumed by ASGM activities (the missing 456 metric tons).

A portion of this total may be recovered. (But most mercury recovered in ASGM activities would be reused by miners and would likely not show up in estimates of mercury consumption from the sector). A very large fraction of the 850 tons of mercury consumed by ASGM activities is almost certainly released into the environment. Most of what is not included in the official air emissions estimate is released into water, onto land, into wastes, or is just not accounted for. Much will later be reemitted from the water or land into the air, although it may not all be counted as air emissions. This suggests that the portion of global mercury pollution coming from ASGM activities is likely considerably more than the frequently cited 18 percent figure suggests.

Similarly, reported air emissions associated with most other sources that intentionally use mercury are relatively small compared with the amount of mercury these sources are estimated to consume as shown in the following table from UNEP's "Technical Background Report to the Global Atmospheric Mercury Assessment":

Comparing estimated global mercury consumption with estimated global mercury atmospheric emissions by source category[72]

Source Category	Estimated Global Mercury Consumption in Metric Tons	Estimated Global Mercury atmospheric Emissions in Metric Tons
ASGM	806	350
Vinyl Chloride Monomer Manufacture	770	00
Chlor-Alkali Plants	492	60
Batteries	370	20
Dental Amalgam	362	26
Measuring and Control Devices	350	33
Lighting	135	13
Electrical Devices	200	26
Others	313	29
Total	3,798	557

When mercury is consumed, it is reasonable to assume that it goes somewhere. To be sure, in some cases, a portion of the consumed mercury is later recovered or recycled or is responsibly disposed of. These amounts can and should be quantified. In general, however, mercury that has been consumed and then not accounted for should be assumed to contribute to total global mercury pollution.

Of the 1,930 metric tons that UNEP estimates to be the annual total of all anthropogenic mercury emissions to the atmosphere, an estimated 65 percent of the total (approximately 1,250 metric tons) comes from just three sources that do not intentionally use mercury: 45 percent from fossil fuel combustion, 10 percent from metal production (excluding gold), and 10 percent from cement production.[73] In contrast, UNEP estimates that only 557 metric tons of mercury emissions are released to atmosphere from sources that intentionally use mercury. However, the products and processes that intentionally use mercury are reported to consume an estimated 3,800 metric tons of mercury per year. This suggests that only 15 percent of the mercury consumed by these intentional sources is released to the atmosphere. What is the fate of the remaining 85 percent? Much of it certainly enters the environment and contributes to global mercury pollution.

For example, when a battery, a fluorescent bulb, or some other mercury-containing product goes into a dump or landfill, much of its mercury content is released over time to the air and to other environmental media. When burned or incinerated, the mercury content can be released more quickly as it is difficult to catch even with modern filters.

Chlor-alkali plants and VCM (vinyl chloride monomer) manufacturing also certainly release much more mercury into the environment than official air emission estimates suggest.

Most of the mercury consumed by intentional sources almost certainly ends up in the environment, and much of it ends up circulating through the global atmosphere. The only way to make sense of the reported data on anthropogenic mercury emissions is to conclude that environmental releases of mercury from intentional sources are a much larger contributor to total global mercury pollution than UNEP's emissions data alone might suggest. Additionally, since much of UNEP's data comes from government sources and reflects the ways most governments gather data on mercury air emissions and other releases to the environment, NGOs would do well to critically examine the mercury emission and release data supplied and used by their national governments.

Notes

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6. Mercury Supply

Virtually all products or processes that contain or use mercury or mercury compounds are dependent on access to a supply of elemental mercury.

6.1 Mercury Mining

Since ancient times, people have mined a naturally occurring red or reddish brown ore called cinnabar, which contains high quantities of mercury sulfide. The first reported large-scale cinnabar mine began operation more than 3,000 years ago in the Peruvian Andes. As far back as 1400 B.C.E., cinnabar ore was excavated from mines near the present day town of Huancavelica, Peru. The ore was crushed to make a red pigment known as vermillion. Cinnabar mining began at the site long before the rise of the Inca civilization and continued into modern times. Vermillion was used by the Incas and other ancient civilizations in the region to cover the human body for ceremonial purposes and also to decorate gold objects such as burial masks.[74] Vermillion produced from cinnabar was also known in ancient China and India. It was used in ancient Rome to color the faces of triumphant generals.[75]

Elemental mercury can be produced from cinnabar by heating the ore in the presence of air and then condensing elemental mercury from the vapor.* Knowledge of this process dates back to at least 200 B.C.E., and ancient Greeks, Romans, Chinese, and Hindus all knew how to produce elemental mercury this way.[77] There is also suggestive evidence that the Incas learned to produce elemental mercury this way before their first contact with Europeans.[78]

The world's largest known reserves of cinnabar ore are located at the Almadén mine in Spain. Mining and refining operations began at that location more than 2,000 years ago. Mercury from the Almadén mine was used by the ancient Phoenicians and Carthaginians and later by the Romans to amalgamate

* The chemical equation for the reaction that takes place is $HgS + O_2 \rightarrow Hg + SO_2$.

and concentrate gold and silver. The Roman author Pliny was the first to provide a detailed description of this process in his book, *Natural History.*[79]

Data is available on the operations of the Almadén mine and other mines over the past five centuries. Since the year 1500 C.E., approximately one million metric tons of elemental mercury has been produced from cinnabar and other ores mined at Almadén and at other locations. Half that amount—500,000 tons—had already been produced before 1925. Shipments of mercury from Spain for use in silver or gold mining in the Spanish colonies in America continued for 250 years. Most of the mercury went to locations in present day Mexico.[80]

Gold and Silver Mining in Earlier Centuries

The largest use of mercury during the sixteenth to eighteenth centuries was for the production of silver and gold in Latin America, and this use released enormous quantities of mercury into the global environment. Most of this silver and gold was shipped back to Spain and Portugal, where it became a major contributor to rapid economic expansion in Western Europe.

The nineteenth century saw a large boom of mercury mining in North America for use by gold rush miners in California and then northern Canada and Alaska. This gold production was an important contributor to economic expansion in North America. Nineteenth-century gold booms also occurred in Australia and in other countries. Large quantities of mercury from the gold and silver mining of earlier centuries remain in the environment and continue to be a source of harm.[81,82]

Operations that mine mercury ores and refine them into elemental mercury release a large amount of mercury vapors into the air and are thus also a direct and significant source of mercury pollution. One study found atmospheric mercury concentrations around an abandoned mercury mine in China to be several orders of magnitude higher than regional background sites.[83] A study of human exposure to mercury from eating rice grown in a district near mercury mines and smelters found high exposure, even when compared with districts near zinc smelters and heavy coal-based industries.[84] Researchers in California measured significant amounts of mercury leaching into a creek flowing past a long-abandoned mercury mine site. This and preliminary results from other mine sites indicate that inoperative mercury mines are major sources of mercury pollution to water bodies, and they also, in turn, remain continuing sources of atmospheric mercury emissions as well.[85]

In recent years, most of the primary mercury mines in the world have closed due to falling demand for elemental mercury. There have also been environmental pressures to close mines. The last mercury mine in the United States closed in 1990, a large mercury mine near Idrija, Slovenia, closed in 1995, and the Almadén mine in Spain stopped mining and processing primary mercury ores in 2003. At present, there are no primary mercury mines operating in North America or Western Europe, and none are expected to restart. Most other mercury mines in the world have also closed, including a major mine in Algeria that appears to have stopped operations at the end of 2004.[86,87]

According to the USGS, most primary mercury mining currently takes place in only two countries: China and Kyrgyzstan. In 2009, Chinese mines produced an estimated 800 metric tons of mercury and Kyrgyz mines produced an estimated 250 metric tons.[88] According to the Chinese Government, mercury exports from China are very low and most of its mercury production is used domestically.[89] The Khaidarkan mining complex in Kyrgyzstan, on the other hand, produces mainly for the export market.[90] The USGS estimates total 2009 mercury mine production in all other countries to be 130 metric tons combined.[91]

6.2 Producing Elemental Mercury as a By-Product in Nonferrous Metals Refining

Elemental mercury is also sometimes produced as a by-product when various metal ores are refined. Mercury is found in trace quantities in most nonferrous metal ores such as zinc, copper, lead, gold, silver, and others. Until recently, the mercury content of these ores would be released into the environment as part of the waste streams generated during mining and refining. In recent years, however, some refiners have started to recover mercury from their wastes and produce elemental mercury for sale on domestic or international markets. [92]

Many producers who have decided to do this have been required to do so in order to comply with national, state, or provincial laws or regulations. In other cases, producers may be required to comply with laws or regulations governing mercury waste disposal and may have determined that it is less costly to recover elemental mercury from their wastes and sell it than it would be to dispose of their mercury wastes in compliance with approved disposal methods.

For example, approximately 35 pollution-control systems that remove mercury from zinc smelter flue gases are now in operation worldwide.[93] A handful of large-scale gold mining operations in South America and North America recover elemental mercury from their wastes and sell this mercury. According to one very cautious estimate, approximately 300 to 400 metric tons of mercury was recovered globally in 2005 by refiners of zinc, gold, copper, lead, and silver.[94] This estimate does not include a large contract between the Russian Federation and the Khaidarkan mercury mining and refining facility in Kyrgyzstan. Under this contract, existing stockpiles of mercury-contaminated wastes from a large zinc smelter and other Russian sources are to be transported to Kyrgyzstan for refining. It has been estimated that approximately 2,000 metric tons of elemental mercury are to be extracted from these wastes and then sold.[95]

6.3 Elemental Mercury from Natural Gas

Natural gas also contains trace quantities of mercury that is released into the environment when the gas is burned. In some areas—including countries bordering the North Sea, Algeria, Croatia, and others—the mercury concentrations in the gas are particularly high, and processors in these areas often remove mercury from their gas. It is estimated that 20–30 metric tons of mercury are recovered yearly from natural gas wastes in the European Union.[96] Data does not appear to be available on mercury recovered from natural gas in other regions.

Producers of liquid natural gas (LNG) remove mercury from natural gas before cooling it. Otherwise, the mercury present in the gas will damage the aluminum heat exchangers used in natural gas liquefaction plants. This typically requires reducing the mercury content of the natural gas to below 0.01 micrograms of mercury per normal cubic meter of natural gas. Based on a review of marketing materials from manufacturers of equipment to remove mercury from natural gas, it appears that the main reason this equipment is purchased is to protect the downstream equipment of liquefaction and chemical production plants. Outside of Western Europe, it appears these technologies are not widely used to remove mercury from natural gas sold for use in residential heating and cooking or commercial and industrial furnaces and boilers.[97] Little is known about the effects of this mercury on ordinary natural gas consumers or its contribution to total global atmospheric mercury pollution.

One supplier of equipment to remove mercury from natural gas to protect liquefaction equipment suggests that in its recent analytical experience, mercury levels in natural gas have ranged from less than detectable to 120 micrograms of mercury per normal cubic meter. The supplier provides a typical case example from a facility at an unnamed location, but one clearly outside the European Union. At this facility, the incoming gas mercury content ranged from 25 micrograms to 50 micrograms of mercury per normal cubic meter of natural gas while the mercury content in the outgoing gas was reduced to below detection limits. The mercury is removed from the natural gas with proprietary adsorbents. The adsorbents are then regenerated, and elemental mercury is removed in what the technology company claims is a form that can be sold on the market. [98] However, outside of Western Europe, salable elemental mercury that is recovered by these technologies does not appear to be reflected in internationally available mercury-supply data.

6.4 Mercury Recycling and Recovery

Most of the elemental mercury that is recovered by recycling comes from industrial processes that use mercury or mercury compounds. In some cases, the mercury that is recovered is reused by the industry. In some cases, it goes onto the market. And in some cases, agreements have been reached to remove the recovered mercury from the market and place it in permanent storage.

The largest source of recycled or recovered mercury is the chlor-alkali industry. This industry produces chlorine gas and alkali (sodium hydroxide) by a process that applies electrolysis to saltwater. Some chlor-alkali plants use a mercury-cell process in which mercury is used as the electrolysis cathode.[99] Mercury-cell chlor-alkali plants consume large quantities of mercury and are very polluting. Fortunately, the trend in recent years has been to phase out many of these mercury-cell plants in favor of other processes that do not use mercury.

A single mercury-cell plant may contain hundreds of tons of elemental mercury for use in production and may have even more mercury in its warehouses to replenish lost mercury. When a mercury cell is decommissioned, much of this mercury can be recovered. Under a voluntary agreement, mercury-cell chlor-alkali plants in Western Europe are being slowly phased out with an agreed-upon completion date of 2020. A 2004 study that examined closures of European chlor-alkali mercury cells concluded that between 1980 and

2000, nearly 6,000 tons of mercury was recovered from decommissioned mercury cells. The study estimated that in 2004, approximately 25,000 tons of mercury inventories were associated with then-operating chlor-alkali plants, about half of them in Western Europe.[100] In April 2010, a European industry association stated that there were 39 mercury-cell chlor-alkali plants still operating in 14 European countries which, taken together, contain 8,200 metric tons of elemental mercury.[101]

Operating mercury-cell chlor-alkali plants also sometimes recover mercury from their waste streams. It is estimated that in 2005, worldwide, between 90 and 140 metric tons of mercury were recovered from operating mercury-cell chlor-alkali plants.[102]

The other type of manufacturing that uses and recycles large quantities of mercury is the production of vinyl chloride monomer to produce polyvinyl chloride, in which mercuric chloride is used as a catalyst. This process is not used in most countries. However, four such facilities are believed to be operating in the Russian Federation, and more than 60 are operating in China. It is not known whether similar facilities are operating in other countries.[103]

In the Chinese plants, the catalysts used in one year are estimated to contain 610 metric tons of mercury. In 2004, the industry estimated it recycled nearly half of the mercury originally contained in its catalysts (290 tons), but it provided no information on the fate of the other half.[104]

Elemental mercury can be recovered by properly managing mercury-containing products at the end of their life, such as mercury-containing thermometers, dental amalgam, switches, fluorescent lamps, and other similar items. It can also be recovered from mercury-contaminated wastes generated at plants that manufacture mercury-containing products, that use mercury in their production processes, or that burn or process mercury-contaminated fuels or minerals.

6.5 The Need to Reduce Mercury Supply

Between 1991 and 2003, the price of mercury stabilized at its lowest real level in a century, to between USD $4 and $5 per kilogram.[105] More recently, mercury prices have dramatically gone up. At the time of this writing, the spot price for a flask of mercury on the London market is between USD $1,250 and $1,450.[106] This translates into a price per kilo of mercury of between

USD $36 and $42, which is a significant increase over recent low prices. The reasons for this rise in the price of mercury are unclear. The rise may reflect a reduction in mercury supply based on mercury mine closures and actions by some governments to restrict mercury exports. It may reflect an increase in mercury demand by artisanal and small-scale gold miners as the price of gold rises to new heights. It may also reflect hording by mercury traders who anticipate that a global mercury-control treaty will soon be adopted that will restrict future mercury supplies. Most likely, all three of the above factors are at play.

High mercury prices will discourage some uses of mercury and will make it easier to implement substitutes and alternatives that eliminate or minimize the use of mercury. Therefore, the objectives of a global mercury-control treaty are best served if the mercury price is high enough to discourage mercury demand. However, some features of mercury-control regimes could have the consequence of creating new or expanded sources of mercury. As governments impose stricter controls on mercury emissions and on the disposal of mercury-contaminated products and wastes, it creates incentives for metals refiners, recyclers, and others to recover elemental mercury from waste streams and fossil fuels and to bring this newly recovered mercury onto the market. At the same time, a global mercury-control treaty may also contribute to decreased global mercury demand by eliminating, phasing out, or reducing numerous current uses of mercury. Finally, although there may currently be some hording of mercury stocks by traders in anticipation of future supply shortages, this is likely no more than a short-term phenomenon. For these reasons, mercury prices could again fall in the absence of specific interventions to ensure that the global mercury supply is and remains restricted relative to the global demand.

To help address this, the European Union has adopted a regulation that will enter into force in March 2011. This regulation bans exports from the E.U. of metallic mercury, cinnabar ore, mercury chloride, mercury oxide, and mixtures of metallic mercury with other substances. The regulation also bans the primary production of elemental mercury from cinnabar ores in all E.U. countries. It additionally classifies as waste all metallic mercury recovered from mercury-cell chlor-alkali plants as well as mercury obtained from nonferrous mining and smelting operations and the cleaning of natural gas. The classification of this mercury as waste means that mercury derived from these sources in E.U. countries cannot be sold or used but must be disposed of in a way that is safe for human health and the environment.[107]

The United States has also passed a law that addresses mercury exports. This law will become effective in 2013. It will prohibit, with some exceptions, exports of elemental mercury from the U.S., and it will require the establishment of a designated facility for the long-term management and storage of mercury generated within the United States.[108]

These actions by the E.U. and the U.S. go in a very positive direction. A new global mercury-control treaty should build on these measures and impose progressive global restrictions on mercury supply relative to demand. The treaty should ban all primary mercury mining and the production of elementary mercury from cinnabar ores. It should ban or restrict commercial sales of mercury recovered from chlor-alkali plants, metals mining and refining, industrial catalysts, natural gas cleaning, and other sources. Additionally, the treaty should include measures that will provide financial and technical support for the establishment of national or regional permanent safe storage or environmentally sound disposal facilities in all regions for both elemental mercury and also mercury-containing wastes.

Notes

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7. Intentional Sources: Mercury in Products

A number of common products contain mercury or mercury compounds. During the manufacture of these products, mercury is often released into the air (both inside and outside the workplace) and is also often released as a contaminant in solid and liquid waste streams. During their ordinary use, mercury-containing products often break or otherwise release their mercury content into the environment. And then, at the end of their useful life, only a fraction of all mercury-containing products goes to recyclers that recover their mercury content. Frequently, these end-of-life products go to incinerators, landfills, or dumps. Depending on the air pollution control measures that are used, incinerators can rapidly release the mercury content of end-of-life products into the air. Landfills and waste dumps also release much of the mercury content of these products into the air, but tend to do so a little more slowly. In one way or another, much of the mercury content of products eventually finds its way into the environment.

7.1 Mercury in Medical Devices

Mercury-containing devices have long been used in hospitals and health care settings. These include fever thermometers, blood pressure measuring devices (sphygmomanometers), and esophageal dilators.

When such devices break, the mercury they contain can vaporize and expose health care workers and patients. Mercury from breakages can contaminate the immediate area of the spill as well as the facility's wastewater discharges. Such equipment breakages are common. Hospitals using mercury fever thermometers frequently report that they replace multiple thermometers per year for each hospital bed. One survey reported that in a 250-bed hospital, 4,700 mercury-containing fever thermometers were broken in a single year.[109]

Each mercury fever thermometer contains between 0.5 g and 3 g of mercury[110] while a mercury blood pressure device generally contains between

100g and 200g of mercury.[111] An esophageal dilator is a long, flexible tube that is slipped down a patient's throat into the esophagus for certain medical procedures. Although they are not as common as fever thermometers and blood pressure measuring devices, each dilator can contain as much as a kilogram of mercury.[112]

Good and affordable alternatives to mercury-containing fever thermometers, blood pressure measuring devices, and esophageal dilators are now widely available in many countries, and efforts are underway to phase out mercury-containing health care devices.[113] The international NGO network Health Care Without Harm (HCWH) plays a leading role in many of these efforts.[114] Together with the World Health Organization, HCWH is leading a global initiative to achieve the virtual elimination of mercury-based thermometers and sphygmomanometers and to substitute accurate, economically viable alternatives for them by 2020. This initiative maintains a joint WHO/HCWH website and is recognized as a component of UNEP's Global Mercury Partnership program.

In 2007, the European Parliament approved legislation that will prohibit the sale within the E.U. of new mercury fever thermometers and will also restrict sales of other mercury-containing measuring devices.[115] Several European countries including Sweden, the Netherlands, and Denmark have already banned the use of mercury thermometers, blood pressure devices, and a variety of other equipment. In the United States, thirteen state governments have legislated bans on mercury thermometers, and thousands of hospitals, pharmacies, and medical-device purchasers have voluntarily switched from mercury-containing devices to digital thermometers and to aneroid and digital blood pressure devices.[116] In the Philippines, the Department of Health issued a 2008 administrative order calling for the gradual phaseout of mercury thermometers in all health facilities nationwide.[117] In Argentina, the Minister of Health signed a resolution in 2009 that instructs all hospitals and health care centers in the country to purchase mercury-free thermometers and blood pressure devices.[118]

In most developing countries and countries with economies in transition, however, the move away from mercury-containing medical devices generally has been slower. In some places, there is limited awareness of the need to make this change. However, even as awareness of the need to phase out mercury-containing devices in health care grows, three important barriers to change remain:

- Distrust of the available mercury-free alternatives by some health professionals
- An inadequate market supply of accurate and affordable mercury-free devices
- A lack of national, regional, or global standard-setting and device-certification programs to ensure that devices available on the national market meet accepted accuracy and performance criteria

As a long-term strategy, the World Health Organization supports a move toward bans on the use of mercury-containing medical devices and replacing them with effective mercury-free alternatives in all countries. In the short term, the WHO encourages countries that have access to affordable alternatives to develop and implement plans to reduce the use of mercury equipment and replace it with alternatives. In the interim, the WHO also encourages hospitals to develop mercury cleanup, waste-handling, and storage procedures.[119] A global mercury-control treaty can help speed up and complete the full elimination of mercury-containing medical devices worldwide.

7.2 Mercury-Containing Switches

Several kinds of electrical switches contain mercury. These include tilt switches, float switches, thermostats, relays that control electronic circuits, and others.[120] In 2004, for example, new switches, thermostats, and relays sold in the United States contained approximately 46.5 metric tons of elemental mercury.[121] Good alternatives are available for virtually all of these.

Two European Union directives that entered into force in 2005 and 2006 ban the sale in European countries of switches and thermostats that contain mercury: WEEE (Waste Electrical and Electronic Equipment) and RoHS (Restrictions in the Use of Hazardous Substances).[122] Several U.S. state governments also enacted bans on mercury-containing switches and thermostats. In response to these measures, many manufacturers have replaced these switches with mercury-free alternatives. As a result, the number of mercury-containing switches sold in North America and Western Europe has been rapidly declining. Less information is available on trends in the use of mercury-containing switches in developing countries and countries with economies in transition.

Tilt switches: These are switches that contain small tubes with electrical contacts at one end. When the end of the tube with the electrical contacts is tilted down, mercury flows to that end and closes the circuit. When that end of the tube is tilted up, the circuit is broken.[123]

Tilt switches have been commonly used in automobiles to control lamps in trunks and at other locations. Each switch contains, on average, 1.2 g of elemental mercury. It was estimated that in 2001, automobiles on the road in the United States contained 250 million mercury tilt switches.[124] In recent years, almost all automakers have discontinued placing tilt switches in new vehicles. Sweden banned tilt switches in automobiles in the early 1990s. European auto manufacturers responded by discontinuing virtually all use of mercury tilt switches in 1993. American automakers followed in 2002.[125] And it appears that virtually all automakers in the world have now discontinued their use. Many older vehicles, however, still contain mercury switches that, unless removed and properly disposed of, will release their mercury into the environment when the vehicles are scrapped.

Tilt switches have also been used in many other products, although their use has become less prevalent in recent years. These products include washing machines, clothes dryers, freezers, clothes irons, space heaters, television sets, furnace fan limit control switches, security and fire alarm systems, children's novelty shoes with blinking lights, and many others.[126] Tilt switches are also used in industrial applications where a single switch might contain as much as 3.6 kg of elemental mercury.[127] Very sensitive mercury switches are sometimes used in gyroscopes and artificial horizons, especially in aerospace and military applications.[128]

Float Switches: These are commonly used to operate pumps and control the level of a liquid. A float switch is a round or cylindrical float with a switch attached to it. The switch operates a pump and turns the pump on or off when the float rises above or sinks below a certain height.[129] An individual float switch may contain as little as 100 mg of mercury or as much as 67 g. Small float switches are used in sump pumps that prevent basement flooding. Larger ones are used in municipal sewer systems, as controls for irrigation pumps, and for many industrial applications. Alternatives for mercury-containing float switches are readily available at similar prices.[130]

Thermostats: These are used in homes and elsewhere to control heating and cooling devices. Until recently, most thermostats contained mercury. Mercury thermostats have bimetal coils that contract and expand with room temperature. When the coil contracts or expands, it activates a mercury switch that opens or closes a circuit to make a furnace, heat pump, or air conditioner turn on or off. The average total amount of mercury in a residential analog thermostat is approximately 4 g. Industrial thermostats may contain much more mercury.[131]

In recent years, many manufacturers have replaced mercury-containing thermostats with mercury-free electromechanical or digital thermostats. In the U.S., for example, the mercury content of new thermostats sold in 2004 (13.1 metric tons) was not much different from the mercury content of new thermostats sold in 2001 (13.25 metric tons). By 2007, however, there had been a nearly 75 percent reduction in the mercury content of new thermostats sold (down to 3.5 metric tons).[132] Mercury-containing thermostats have largely been replaced with electronic thermostats that are programmable and that pay for themselves very quickly in the energy savings they provide the customer. Care must be taken to ensure that when electronic thermostats are installed as a replacement for mercury thermostats, the older thermostats are properly managed.

Mercury-Containing Relays: These are devices that open or close electrical contacts to control the operation of other devices. Relays are often used to turn on and off large current loads by supplying relatively small currents to a control circuit. Mercury-containing relays include mercury displacement relays, mercury wetted reed relays, and mercury contact relays.[133]

Relays are widely used in many different products and applications. The global market for relays in 2001 was USD $4.658 billion in revenues. The largest users of relays are the telecommunications, transportation, and industrial automation industries. Relays can be found in notebook computers and computer power supplies, copiers, battery chargers, heaters and ovens, industrial furnaces, street lamps and traffic signals, surgical equipment and X-ray machines, aircraft, voltmeters and ohmmeters, machine tool controls, mining equipment, pool heaters, dry-cleaning equipment, circuit boards, programmable logic controllers, and many other applications.[134] In the United States in 2004, new relays entering the market contained 16.9 metric tons of mercury.[135]

There are many types of mercury-containing switches and relays besides those described above. These include pressure and temperature switches, flame-sensor switches, reed switches, vibration switches, and others. Most of the easily available information about mercury-containing switches comes from North America and Western Europe, where such switches are largely being replaced by mercury-free alternatives. There is not good information about whether similar trends have begun in other regions.

Much of the mercury that is contained in switches in existing products and equipment will eventually enter the environment unless measures are taken to recover this mercury. Unfortunately, the present trend is for highly industrial countries to ship their electronic wastes to low-wage areas in the developing world, where most waste-processing facilities are poorly run and managed and often create local pollution problems. A global mercury treaty could help rectify this problem by speeding up the global phaseout of mercury-containing switches and relays and requiring or promoting better management of electronic products and equipment at the end of their useful life.

7.3 Mercury in Batteries

The main use of mercury in batteries is to prevent a buildup of hydrogen gas that can cause the battery to bulge and leak. Mercury has also been used as an electrode in mercuric oxide batteries. In the United States, as recently as the early 1980s, battery manufacturing was the largest single domestic use of mercury; it consumed more than 900 metric tons of mercury per year. By 1993, many battery manufacturers were selling mercury-free alkaline batteries for most applications, and by 1996, this became the national standard for most battery applications following the adoption of a federal law regulating mercury-containing batteries. Western European countries put similar restrictions in place. Globally, however, mercury continued to be widely used in battery production; batteries reportedly accounted for about one-third of total global mercury demand in the year 2000.[136]

According to a European Union report, the total mercury content in batteries sold in both the U.S. and in E.U. countries in 2000 was 31 metric tons. In the same year, the mercury content of batteries sold in the rest of the world was 1,050 metric tons.[137] A more recent estimate in the UNEP report "Summary of Supply, Trade and Demand Information on Mercury" suggests that global mercury content of new batteries sold in 2005 had declined to somewhere between 300 and 600 metric tons.[138]

The batteries that have the highest mercury content are mercuric oxide batteries, which are 40 percent mercury by weight. These batteries have been valued for having a high-energy density and a flat voltage curve and have been used in applications such as hearing aids, watches, calculators, electronic cameras, precision instruments, and medical devices.[139] We have not, however, been able to find any evidence that small mercuric oxide batteries are still being produced anywhere in the world. On the other hand, large mercuric oxide batteries are still produced for use in military and medical applications and in industrial equipment where a stable current and a long service life are considered to be essential. According to a European Commission report, in the year 2007, mercuric oxide batteries containing between 2 and 17 metric tons of mercury were sold in E.U. countries.[140]

Mercury-containing batteries other than mercuric-oxide batteries use mercury to inhibit gas formation inside the battery and to prevent leakage. Most alkaline batteries on the world market no longer contain mercury. The main exception is alkaline button cell batteries.

Button cell batteries are small batteries used in hearing aids, watches, toys, novelties, and other small, portable devices. Many of these batteries contain mercury. The four major button battery technologies are zinc air, silver oxide, alkaline manganese, and lithium. Lithium button batteries do not contain mercury. On the other hand, zinc air, silver oxide, and alkaline manganese button batteries typically contain from 0.1 percent to 2.0 percent mercury by weight. Many of these batteries enter commerce through the sale of products with the battery already embedded. As an example, in 2004, 17 million Spider Man toys were distributed in breakfast cereals sold in the U.S. It is estimated that this single promotional campaign brought 30 kilograms of mercury into circulation.[141]

Zinc Air Button Batteries: The majority of these are sold for use in hearing aids, a demanding use that requires a high-energy battery. These batteries generally have a useful life of only a few days, and hearing aid users buy multiple replacement batteries at a time. Reliable, mercury-free zinc air button batteries are on the market in some countries at prices equivalent to their mercury-containing counterparts.[142]

Silver Oxide Button Cell Batteries: These batteries are used mainly in watches and cameras, but also may be used in miniature clocks, electronic games, calculators, and other products that require a flat discharge profile. Three Japan-based companies—Sony, Seiko, and Hitachi—have offered mercury-free silver oxide button batteries in a variety of sizes for several years. Recently, companies in Germany and China have also begun to produce them. Mercury-free silver oxide button batteries from some producers are the same price as their mercury-containing counterparts, while batteries from some other producers are slightly more costly to purchase. It appears that mercury-free silver oxide button batteries are rapidly gaining market share.[143]

Alkaline Manganese Button Cell Batteries: This is the battery type of choice for toys and novelties that contain button cells and is also used in many other products such as cameras, calculators, digital thermometers, and remote controls. It has been estimated that China used more than 900 metric tons of mercury in 2004 in the manufacture of alkaline manganese button cells. These are the least costly of the button cell battery types, and popular sizes are available in bulk quantities at prices of USD $0.10 per battery or less.

There at least five Chinese manufacturers who offer mercury-free alkaline manganese button cell batteries in a variety of sizes. These include New Leader, Super Energy, Chung Pak, Pak Ko, and Shenzhen Thumbcells. These companies sell the batteries mainly to original equipment manufacturers for use in end products. According to one researcher, ingredients such as bismuth, indium, and organic surfactants can be used to replace the mercury in alkaline manganese button cell batteries with little or no technical difficulty.[144]

Lithium Miniature Batteries: These batteries are shaped more like a coin than a button and have no added mercury. Timex uses lithium batteries in 95 percent of its watches, and lithium batteries also are common in electronic games, calculators, car-lock systems, garage door openers, and greeting cards. Some have suggested lithium batteries could make a good alternative to mercury-containing button cells in many applications. However, doing so would require that products be redesigned to accommodate a different physical battery shape because lithium batteries are typically flatter and wider than button cells. Lithium batteries also have a much higher operating voltage than button cells, which may make them unsuitable for many current applications.[145]

Mercury is released into the environment from batteries during manufacture and at the end of the battery's useful life. Information on mercury emissions and releases that result from the manufacture of mercury-containing batteries is not available, but the quantities could be substantial. However, the main way that mercury-containing batteries release mercury into the environment almost certainly occurs at the end of their useful life. In most countries, the recycling rate for batteries, especially button cell batteries, is very low, with most batteries ending up in incinerators, landfills, or waste dumps. These, in turn, sooner or later release much of the mercury content of the batteries to the environment.

There has been real progress in recent years toward replacing mercury-containing batteries with mercury-free alternatives, especially for batteries entering the Western European and North American markets. National advocacy can speed up substitution in other regions, but only a global mercury-control treaty can help move the world toward a complete phaseout of all mercury-containing batteries.

7.4 Mercury in Fluorescent Lamps

Mercury is used in a variety of lamps and contributes to their efficient operation and life expectancy. Fluorescent and other mercury-containing lamps are generally much more energy efficient and longer lasting than incandescent and other equivalent forms of lighting.[146]

Fluorescent lamps—including both fluorescent tubes and compact fluorescent lamps (CFLs)—have, by far, the largest market share of all mercury-containing lamps. Fluorescent lamps generally contain less mercury than do other mercury-containing lamps, and the average mercury content of each individual fluorescent lamp has been decreasing. Nonetheless, because of their large market share, it has been estimated that fluorescent lamps represent approximately 80 percent of the total mercury used in lighting.[147]

A fluorescent lamp is a phosphor-coated glass tube that contains mercury and has electrodes located at both ends. When voltage is applied, the electrodes energize the mercury vapor in the tube, and this causes it to emit ultraviolet (UV) energy. The phosphor coating absorbs the UV energy and emits visible light. Mercury is an essential component of all fluorescent lamps.[148]

Nonetheless, under many circumstances, the use of compact fluorescent light lamps to replace incandescent bulbs will actually reduce total mercury releases into the environment. Why is this?

Coal contains mercury that is released into the environment when the coal is burned. Most countries depend on coal-fired power plants for a high proportion of the electricity they use. As a result, measures that decrease electricity usage can decrease mercury emissions from coal-fired power plants.

In Some Countries, the Use of Mercury-Containing Fluorescent Lighting May, in the Short Term, Contribute to Reducing Global Mercury Pollution

Fluorescent tubes and compact fluorescent lamps often contain a relatively small amount of mercury and are very energy efficient compared with incandescent bulbs. When large numbers of people use fluorescents in place of incandescent bulbs, this will, in general, greatly reduce total electricity demand. In most cases, this substitution can reduce mercury emissions from power plants by an amount that is greater than the amount of mercury contained in the fluorescent lamps themselves. This can be demonstrated with an example based on data from the United States. It should be noted, however, that for some developing countries and countries with economies in transition, some conclusions based on the conditions that prevail in highly industrial countries may not apply.

Consider a 14-watt CFL that is used to replace a 60-watt incandescent bulb. Both the 14-watt CFL and the 60-watt incandescent bulb produce approximately the same amount of light. In the United States, the average life of such a CFL is approximately 20,000 hours. Over this average life, the CFL will consume 280 kilowatt hours (kWh) of electricity. Over that same period, a 60-watt incandescent bulb will consume 1,200 kWh of electricity. By substituting a 14-watt CFL for a 60-watt incandescent bulb, under the conditions that prevail in the United States, one can save, on average, 920 kWh of electricity usage over the life of the CFL.

In the United States, an average coal-fired power plant emits approximately 0.0234 mg of mercury into the air for each kilowatt hour of electricity it generates. If we assume that a home in the U.S. gets all of its electricity from an average American coal-fired power plant, we find that replacing a 60-watt incandescent bulb with a 14-watt CFL reduces power plant mercury emissions by an average of 21.5 mg (and also reduces emissions of greenhouse gases, sulfur dioxide, nitrogen oxide, and other pollutants).

Because the average 14-watt CFL sold in the U.S. generally contains 5 mg of mercury or less, its use reduces total mercury emissions by approximately 16.5 mg of mercury, even if we assume that all the mercury in the CFL eventually enters the environment. (With 21.5 mg mercury conserved minus the 5 mg mercury contained in the CFL, you end up with a 16.5 mg reduction in mercury emissions.)[149,150] Under these conditions, when fluorescents replace incandescent bulbs on a large scale, total reductions in mercury emissions can be significant.

On the other hand, conditions in some countries can be quite different. In Russia, for example, it appears that fluorescent lamps contain more mercury than is the case in the United States, with many lamps in Russia containing between 20 mg and 500 mg of mercury. Russian experts estimate that the total of all mercury currently contained in fluorescent lamps in use in Russia is approximately 50 metric tons. Given their burnout rate, it is estimated that these lamps are responsible for the release of approximately 10 metric tons of mercury into the environment each year.[151]

In Russia and in many other countries, voltage regulation of the power supply is inconsistent, and electricity consumers experience numerous sharp power spikes. As a result, the life expectancy of fluorescent lamps in Russia tends to be shorter than in countries that have a more stable electrical power supply.[152]

These and other considerations influence both the benefits and the costs associated with a conversion from incandescent bulbs to fluorescent lamps. For example, the mercury content of coal varies from country to country and region to region as does the amount of mercury released per kilowatt hour of production from the average coal-fired power plant. Also, the proportion of the electrical supply derived from coal-fired power plants varies from place to place. Some countries have relatively good systems for ensuring that fluorescent lamps are collected at the end of their useful life and managed in ways that minimize mercury releases into the environment while some other countries have no such systems in place. There are also differences between countries in the relative cost of fluorescent lamps. Finally, it is possible that in countries where electricity prices are relatively low, where the cost of fluorescent lamps is very high, and where fluorescent lamps tend to have a shortened life span, conversion from incandescent to fluorescents may result in a net cost to consumers rather than a net savings.

In the end, experts in different countries and regions may reach different conclusions about the desirability of phasing out incandescent bulbs for fluorescent lamps in their countries. A number of factors may go into such decision making. On the one hand, experts will consider climate change and the importance of measures to reduce electricity demand on power plants fired by coal or other fossil fuels, and they will consider power plant emissions of mercury and other toxic pollutants. On the other hand, experts may also consider the mercury content of the fluorescents on their national markets and mercury emissions that occur at the point of lamp manufacture and at the point where the mercury was mined and refined. They may also give consideration to the more immediate health and safety concerns associated with bringing mercury-containing products into homes and workplaces and the likelihood that people will just dump burned-out lamps. Other considerations may include the average operating life of fluorescent lamps in the country and the relative cost to consumers of incandescent bulbs versus fluorescents.

Finally, those who support the phaseout of incandescent bulbs and replacing them with fluorescent lamps recognize that this is not a satisfactory permanent solution but only a short-term or midterm measure. The longer-term goal is the development and widespread use of lamps that provide good lighting and that are energy efficient, mercury free, long lasting, inexpensive, and nontoxic.

The use of fluorescents poses its own problems. Fluorescents release hazardous mercury vapors into the indoor environment when they break. Also, if we take into account all the mercury pollution associated with the life cycle of fluorescents, we need to consider not only the mercury content of the lamp and the pollution caused at the end of its useful life but also the mercury pollution associated with mining the mercury that goes into the lamp and the mercury pollution associated with producing the lamp.

Fortunately, new energy-efficient lamps that contain no mercury are being developed. The most promising is light-emitting diode (LED) technology. LED lighting is becoming commercially available but is still relatively expensive. As with all new technologies, however, costs can be expected to come down over time. Vendors claim that commercially available LED bulbs now coming onto the market contain no mercury, provide 77 percent energy savings over incandescent bulbs, last 25 times as long, are cool to the touch, and offer full brightness from the moment they are turned on (unlike fluorescents).[153] Eventually, LED bulbs or other new technologies will almost certainly replace both incandescent bulbs and fluorescent lamps. There is still, however, insufficient information available about the environmental and health impacts of LED bulbs, so this needs further investigation.

In the short-term to midterm, replacing incandescent bulbs with long-lived fluorescent lamps appears to be environmentally beneficial in many countries. Nonetheless, all fluorescent tubes and compact fluorescent lamps (CFLs) are not the same. In 2004, most fluorescent tubes sold in the U.S. contained less than 10 mg of mercury, but a full 12.5 percent of them contained more than 50 mg. Two-thirds of all CFLs sold in the US in 2004 contained less than 5 mg but some contained more than 10 mg.[154] The average mercury content of size T12 fluorescent tubes manufactured in China in 2006 was between 25 mg and 45 mg, for size T5 tubes it was 20 mg, and for CFLs it was 10 mg.[155] In India, the most popular CFLs contain between 3.5 mg and 6 mg of mercury, but some contain more, and the government is preparing standards.[156]

In Western Europe, the E.U. Parliament and Council have established a directive that restricts the use of mercury in electrical and electronic equipment. It requires the mercury content of CFLs to be below 5 mg per lamp and the mercury content of general-purpose fluorescent tubes to be below 10 mg per tube.[157] In some other countries, however, the average mercury content of fluorescents may be much higher.

In addition, knowing the mercury content of a fluorescent lamp does not tell the full story of its contribution to global mercury pollution. Some lamp manufacturers, such as many of those in China, source their mercury from small, highly polluting primary mercury mining and refining operations. Some factories that produce lamps have poor pollution controls and release large quantities of mercury vapors to the indoor or outdoor air. Some generate large quantities of poorly managed mercury-contaminated solid and liquid waste streams. On the other hand, some other lamp manufacturers create minimal amounts of pollution and source their mercury from well-controlled recycling operations that recover mercury that would otherwise enter the environment.

The lack of a functional system to ensure the environmentally sound management of spent mercury-containing lamps, especially in developing countries, poses serious threats to waste workers and their communities, who often retrieve waste lamps from mixed trash disposed in dump sites or landfills and recycle them in uncontrolled conditions. In the Philippines, for example, government data indicates that 88 percent of households and 77 percent of commercial establishments disposed of their waste fluorescents as domestic waste. The investigative work of the EcoWaste Coalition, a member of IPEN, on the informal recycling of CFLs in dump sites has caught the attention of policy makers who now see the need to put in place an effective mechanism for the collection and recovery of end-of-life lamps, including the imposition of extended producer responsibility (EPR) to curb inappropriate disposal.

This problem is not unique to countries with developing economies. The Association of Lamp and Mercury Recyclers (ALMR) in the United States estimates that only about 23 percent of all lamps get recycled (30 percent of commercial and industrial but only 5 percent of residential).[158] Recycling rates in the E.U. are much higher. The European Community's Waste Electrical and Electronic Equipment directive provides for free take-back of end-of-life electrical equipment including fluorescents and for the establishment of collection facilities and collection systems for electronic wastes from private households.[159] Canada is also beginning to implement its own Canada-Wide Standard requiring the development of an Extended Producer Responsibility scheme for a growing list of consumer goods.[160]

Many different kinds of systems are used to manage and process end-of-life fluorescent lamps. These include lamp crushers and other kinds of fluorescent lamp recycling systems. No comprehensive data appears to be available on several factors related to these systems: the amount of atmospheric emissions released from different kinds of lamp crushing or recycling systems, the work-place occupational mercury exposures, the mercury ground and water pollution at the plant site, off-site mercury waste transfers, and how much pure elemental mercury different systems are able to recover. It appears, however, that while some may be relatively good, some other lamp crushing and recycling systems may be highly polluting and may cause significant occupational and/or community mercury exposures.

A mercury-control treaty can include measures that will limit the mercury content of fluorescent lamps; require cleaner lamp-production processes; increase the availability of safe, nonpolluting lamp recycling facilities; and expedite the development of high-quality, mercury-free lighting alternatives that are energy efficient, affordable, and nontoxic.

7.5 Other Mercury-Containing Lamps

In addition to fluorescent lamps, a number of other kinds of lamps on the market also contain mercury. Many of them are considered high-intensity discharge lamps (HID). This name is commonly used for several types of lamps, including metal halide, high-pressure sodium, and mercury vapor lamps.

HID lamps operate similarly to fluorescent lamps. They use a gas-filled tube that contains a metallic vapor at a relatively high pressure. They have two electrodes, and when an arc is established between them, it produces extremely high temperatures and visible radiant energy. These lamps have very long lives, and some of them put out much more light than typical fluorescent lamps. They require a relatively long warm-up period to achieve full light output and even a momentary loss of power causes the warm-up to start again—a process that can take several minutes. Different kinds of high-intensity lamps use different gas combinations in the arc stream—generally it's xenon or argon and mercury—and this affects the lamp's color characteristics and overall efficiency.[161]

Metal halide lamps: These lamps use metal halides such as sodium iodide in their arc tubes and produce light in most regions of the spectrum. Metal halide lamps provide high efficiency, good color rendition, and long service life and are commonly used in stadiums, warehouses, department and grocery stores, and industrial settings. They are also used for bright blue-tinted car headlights and for aquarium lighting. The amount of mercury used in individual metal halide lamp lamps ranges from more than 10 mg to 1,000 mg. Seventy-five percent of metal halide lamps contain more than 50 mg of mercury; one-third of them contain more than 100 mg of mercury.[162]

Ceramic metal halide lamps: These were recently introduced to provide a high-quality, energy-efficient alternative to incandescent bulbs and halogen lamps. They are mainly used for accent lighting and retail lighting. They differ from standard metal halide lamps in that the arc tube is made of ceramic. These lamps contain less mercury than standard metal halide lamps and also provide better light quality and better color consistency at a lower cost. More than 80 percent of these lamps contain less than 10 mg of mercury and the rest contain less than 50 mg of mercury.[163]

High-pressure sodium lamps: These lamps are a highly efficient light source, but tend to look yellow and provide poor color rendition. They were developed as energy-efficient sources for exterior, security, and industrial lighting applications and are widely used in street lighting. High-pressure sodium lamps give off a yellow to orange color light and, because of their poor color-rendering, are used mainly for outdoor and industrial applications where high efficiency and long life are priorities. Virtually all high-pressure sodium lamps contain between 10 mg and 50 mg of mercury.[164]

Mercury vapor lighting: This is the oldest technology of the high-intensity discharge lamps. The arc produces a bluish light that renders colors poorly, so most mercury vapor lamps have a phosphor coating to alter the color and somewhat improve color rendering. Mercury vapor lamps have a lower light output and are the least efficient of the high-intensity discharge lamps. They are mainly used in industrial applications and for outdoor lighting because of their low cost and long life. Most contain between 10 mg and 50 mg of mercury, but 40 percent contain more than 50 mg of mercury, and 12 percent contain more than 100 mg of mercury.[165]

Cold-cathode fluorescent lamps: These are a variation on fluorescent tubes but have a small diameter. Cold-cathode lamps are used for backlighting in liquid crystal displays (LCDs) for a wide range of electronic equipment, including computers, flat-screen TVs, cameras, camcorders, cash registers, digital projectors, copiers, and fax machines. They are also used for backlighting instrument panels and entertainment systems in automobiles. Cold-cathode lamps operate at a much higher voltage than conventional fluorescent lamps. This eliminates the need for heating the electrodes and increases the efficiency of the lamp 10 to 30 percent. They can be made of different colors, have high brightness, and long life. Their mercury content is similar to that of other fluorescent lamps.

Neon lights: These are gas-discharge bulbs that commonly contain neon, krypton, and argon gasses at low pressure. Like fluorescent bulbs, each end of a neon light contains a metal electrode. Electrical current passing through the electrodes ionizes the neon and other gases, causing them to emit visible light. Neon emits red light; other gases emit other colors. For example, argon emits lavender and helium emits orange-white. The color depends on the mixture of gases and other characteristics of the bulb. Neon lights are usually made by artisans in small workshops and are widely used in advertising, commercial displays, and decoration. Red neon lights do not contain mercury, but other color neon lights can contain between approximately 250 mg and 600 mg of mercury per bulb.[166]

Mercury short-arc lamps: These are spherical or slightly oblong quartz bulbs with two electrodes that are only a few millimeters apart. The bulb is filled with argon and mercury vapor at low pressure. Wattage can range from less than 100 watts to a few kilowatts. The light created is extremely intense, and these lamps are used for special applications, such as search lights, specialized medical equipment, photochemistry, UV curing, and spectroscopy. A variation of this lamp is the mercury xenon short-arc lamp, which is similar but contains a mixture of xenon and mercury vapor. These lamps typically contain between 100 mg and 1,000 mg of mercury. Many contain more than 1,000 mg of mercury.[167]

Mercury capillary lamps: These provide an intense source of radiant energy from the ultraviolet through the near infrared range. They require no warming-up period for starting or restarting and reach near full brightness within seconds. Mercury capillary lamps come in a variety of arc lengths, radiant powers, and mounting methods. They are used in making printed circuit boards and other industrial applications. They are also used for UV curing—widely utilized in the silk-screen process, CD/DVD printing and replication, medical manufacturing, bottle/cup decorating, and coating applications. These lamps contain between 100 mg and 1,000 mg of mercury.[168]

7.6 Mercury in Measuring Devices

Mercury expands and contracts evenly with changes in temperature and pressure. This characteristic has made mercury useful in scientific, medical, and industrial devices that measure temperature and pressure.

The European Union has adopted a directive restricting some measuring devices that contain mercury. All mercury fever thermometers are banned from the market in E.U. countries. Other mercury-containing measuring devices intended for sale to the general public are also banned including manometers, barometers, sphygmomanometers (blood pressure measuring devices), and the other kinds of mercury thermometers. An exemption has been given to antique devices more than 50 years old, and the E.U. commissioned further study on the availability of reliable, safe, technically and economically feasible alternatives for mercury-containing devices for use in the health care field and in other professional and industrial applications.[169] A number of U.S. state governments have also adopted bans or restrictions on some mercury-containing measuring devices.[170] In response, a number of manufacturers have been moving away from these devices and have been increasing their production of high-quality, cost-effective, mercury-free alternatives.

Thermometers and sphygmomanometers are the most common mercury-containing measuring devices. Thermometers are used in a variety of applications such as fever thermometers as well as other types of thermometers used in homes and in industrial, laboratory, and commercial applications. A thermometer may contain between 0.5 g and 54 g of mercury. In the U.S., for example, the mercury content of all thermometers sold in 2004 was approximately two metric tons. A sphygmomanometer contains between 50 g and 140 g of mercury. The mercury content of all sphygmomanometers sold in the U.S. in 2004 was approximately one metric ton.[171]

Because sphygmomanometers and some other mercury-containing measuring devices are open to the air, mercury is lost over time through volatilization. As a result, mercury must occasionally be replenished in these devices. Increasingly, the standard to which these instruments are recalibrated is from a non-mercury device, which indicates the accuracy and durability of non-mercury, electronic devices.

Other mercury-containing measuring devices include the following:

- **Barometers** measure atmospheric pressure. (Each may contain 400 g to 620 g of mercury.)
- **Manometers** measure differences in gas pressure. (Each may contain 30 g to 75 g of mercury.)
- **Psychrometers** measure humidity. (Each may contain 5 g to 6 g of mercury.)
- **Flow meters** measure the flow of gas, water, air, and steam.
- **Hydrometers** measure the specific gravity of liquids.
- **Pyrometers** measure the temperature of extremely hot materials. (They're primarily used in foundries.)

The mercury content of all manometers sold in the U.S. in 2004 was a little more than one metric ton. All the other measuring devices listed above that were sold in the U.S. in 2004, when taken together, contained 0.1 metric tons of mercury.[172]

7.7 Mercury in Dental Amalgam

Dental amalgam is a material used by dentists to fill dental caries, or cavities, caused by tooth decay. Dental amalgam fillings are also sometimes called silver fillings because they have a silver-like appearance. The amalgam is a mixture of metals that contains elemental mercury and a powdered alloy composed of silver, tin, and copper. By weight, approximately 50 percent of dental amalgam is elemental mercury. This technology is more than 150 years old.[173] In the past, dentists mixed amalgam on-site, using bulk elemental mercury and metal powders. Today, many dentists purchase dental amalgam in capsules that come in different sizes. The mercury content of each capsule can vary from 100 mg to 1,000 mg of mercury.[174]

A mercury amalgam dental filling releases mercury vapors in very small quantities, and these vapors can be absorbed into a person's bloodstream. It has been estimated that a person with amalgam dental fillings absorbs, on average, between 3 and 17 micrograms of mercury vapor into his or her blood each day. This is a small exposure, but it is much larger than the average human exposure that comes from the mercury content of the outdoor air we breathe.[175]

Studies of possible harms caused by mercury exposure from dental amalgam have come to widely differing conclusions. Some studies have found evidence suggesting that mercury from dental amalgam may lead to various health impairments including nephrotoxicity, neurobehavioral changes, autoimmunity, oxidative stress, autism, and skin and mucosa alterations. Evidence has also been cited that suggests a link between low-dose mercury exposure with the development of Alzheimer's disease and multiple sclerosis. The authors of a scientific review article that supports this view argue that some other studies of dental amalgam have substantial methodical flaws and that mercury levels in the blood, urine, or other biomarkers do not reflect the mercury load in critical organs. The authors state that there have been various trials in which the removal of dental amalgam has permanently improved chronic complaints in a relevant number of patients. This review article concludes that "dental amalgam is an unsuitable material for medical, occupational, and ecological reasons."[176]

Other authoritative studies, however, have reached different conclusions. For example, the U.S. Food and Drug Administration (FDA) reviewed the available scientific evidence to determine whether the low levels of mercury vapor associated with dental amalgam fillings are a cause for concern. Based on this review, the FDA concluded that dental amalgam fillings are safe for adults and for children ages 6 and older.[177] Following this review, in 2009, the FDA updated its regulations governing dental amalgams. The new FDA regulations classify dental amalgams as posing a moderate risk. The FDA recommends warning patients who have mercury allergies about the use of dental amalgam.

It also recommends that packaging materials for dental amalgam include statements to help dentists and patients make informed decisions. The statements should contain information about the scientific evidence on the benefits and risks of dental amalgam, including the risks of inhaled mercury vapor.[178]

In response to both health and environmental concerns associated with dental amalgams, its use has been declining in the U.S. and Western Europe. (Trends in the rest of the world are not clear.) In 2007, the Norwegian Minister of the Environment issued a directive prohibiting the use of mercury in dental materials.[179] In 2009, Sweden followed suit, prohibiting the use of dental amalgam for children and restricting its use for adults to cases where there is a particular medical reason for its use and where other treatments have been judged insufficient.[180] Based on available evidence, Austria, Germany, Finland, Norway, the United Kingdom, and Sweden have advised dentists to specifically avoid mercury-containing amalgam fillings during pregnancy.[181]

In the United States, the use of mercury dental amalgams has been declining. Between 2004 and 2007, the mercury content of dental amalgams used in the U.S. declined nearly 50 percent from 27.5 metric tons in 2004 to 15 metric tons in 2007.[182]

When dentists' use mercury amalgam fillings, mercury-containing wastes are generated that enter sewer systems and solid-waste streams. There is, however, a growing trend for many dentist offices to capture and recycle mercury wastes generated in their practices, and some national dental associations have established guidelines on best management practices for amalgam waste.[183]

In many countries, it is a common practice to cremate people after they die. In a crematorium, dental amalgam is vaporized and released into the air. There are no good statistics on how much mercury is released into the air globally from cremations. According to one 1995 estimate relating to cremations in the United States, approximately 500,000 people were cremated and this released approximately 1.25 metric tons of mercury into the air.[184] Cremation is very common in a number of countries, and this practice is growing rapidly in some others. In some cases, dental amalgams are removed prior to cremation to prevent mercury emissions. However, there has been cultural resistance to this practice. Emission controls on crematoria can also reduce mercury releases, but these can greatly increase costs.

There is a strong case for phasing out the use of dental amalgam and replacing it with safer alternatives. In doing so, we need adequate evaluations of proposed substitutes in order to ensure that we avoid alternatives with negative health or environmental impacts of their own.

7.8 Mercury-Containing Pesticides and Biocides

Both inorganic and organic mercury compounds have been used as pesticides for a number of applications. The compounds have been used in seed treatments, to control algae and slime in cooling towers and pulp and paper mills, as additives in marine paints and water-based paints and coatings, in tree-wound dressings, in protection for seed potatoes and apples, for fabric and laundry uses, and others.[185]

In Australia, the pesticide Shirtan, which contains 120 g of mercury per liter in the form of methoxy ethyl mercury chloride, is still registered for use as a fungicide to control pineapple disease in sugarcane crops.[186] The Pesticide Action Network (PAN) lists 79 mercury-containing pesticides in its pesticides database.[187]

The Rotterdam Convention on Prior Informed Consent identifies the pesticide uses of elemental mercury and mercury compounds in its Annex III list of chemicals that cannot be exported to a country without the receiving country's prior informed consent. The convention identifies 44 mercury compounds whose use as a pesticide has been restricted by governments. The identified pesticide compounds include inorganic mercury compounds, alkyl mercury compounds, alkyloxyalkyl mercury compounds, and aryl mercury compounds. The Annex also lists mercury compound formulations in the form of liquids, wettable powders, granular materials, latex paints, formulation intermediates, and soluble concentrates.[188]

Many mercury-containing pesticides have been banned and restricted because of their toxicity to people, their ability to contaminate food and feed, and their toxicity to aquatic organisms. The most serious cases of mercury pesticide toxicity have been associated with the use of mercury compounds as seed treatments that have been widely used to protect seeds against fungus infestations.

The first commercial mercury-based seed treatment formulation was a liquid called Panogen (methylmercury guanidine). It was developed in Sweden in

1938 and came into wide use by the late 1940s. Later, a dust formulation of ethylmethyl mercury called Ceresan was developed and widely used in treating small grains. Seed treatments using organomercury compounds were highly effective and were so inexpensive that many treating stations would apply them for no cost or little cost when a farmer brought in seed to be cleaned. Widespread use of mercury-containing fungicides continued until the 1970s, when restrictions began after several incidents of poisoning from people eating treated grain directly or eating meat from animals that had consumed treated grain. The use of organic mercury fungicides has been banned in many countries, but they may remain in use for certain applications in some others.[189]

A severe case of pesticide poisoning, sometimes called the Basra Poison Grain Disaster, occurred in 1971 in the Iraqi port of Basra. A shipment of 90,000 metric tons of American barley and Mexican wheat intended for use as seed grain arrived in the port. The grain had been treated with methylmercury as an antifungal to prevent rot. It was supposed to go to farmers and had warnings printed on the bags in English and Spanish. However, these languages were not widely understood in the port city, and a large quantity was sold locally as food.[190] It is estimated that as a result of mercury poisoning, 10,000 people died and 100,000 were severely and permanently brain damaged.

Some other applications of mercury as a pesticide or biocide that may still be in use include the following:

- **Paint additives:** Phenyl mercuric compounds and mercuric acetate are sometimes added to paints as fungicides to prevent the growth of mold and mildew. These paints are no longer used in the United States and Western Europe, but may still be used in other regions.
- **Pulp and paper mills:** Phenyl mercury acetate is sometimes added to pulp in the paper-making process as a fungicide or slimicide. Because paper pulp is warm and rich in nutrients, fungi and slime molds can grow on the pulp and clog the machinery unless they are controlled. Large quantities of phenyl mercury acetate have been used for this purpose. This can contaminate both the pulp mill's discharge water and also the paper products themselves. Phenyl mercury acetate has also been added to pulp stored for shipping. There is little information available on whether this mercury application is still used.

- **Topical antibiotics:** Mercurochrome and Tincture of Merthiolate and some other topical antibiotics contain mercury and are used for both human and animal treatments for dressing wounds. These antibiotics are still in use, especially for veterinary applications.

7.9 Mercury in Laboratories and Schools

Elemental mercury as well as mercury compounds, mercury-containing reagents, and mercury-containing devices are frequently found in both school and professional laboratories.

There have been numerous serious incidents of poisoning from mercury contamination in high schools. One prominent case occurred in 2006 at St. Andrew's School in Parañaque, Philippines. Students there found and began playing with 50 g of mercury intended for a science experiment. As a result, around 24 of the students, mostly aged 13, went to the hospital for close monitoring for mercury poisoning. The school remained closed for months while local and international experts cleaned up and decontaminated the building.[191] In February 2010, one of the students filed a civil case against his teacher and the school for the lifelong illness brought upon by mercury poisoning.[192]

Shortly thereafter, the Philippine Department of Education issued Memorandum No. 160, which reiterated the call of the Department of Health to phase out mercury and mercury-containing devices in health care facilities and institutions. It also called for a review of existing safety measures in science laboratories to ensure that mercury is excluded from the commonly used chemicals in school laboratory work. Ban Toxics, an NGO based in the Philippines and a member of IPEN, was instrumental in getting the Philippine Department of Education to issue this order.[193]

Another prominent incident occurred in 2009 at the Agua Fria High School in Arizona in the United States. Teachers there were using mercury for a lesson on density. Two students found a large bottle of mercury on a shelf near their desks, opened it, started playing with the mercury, and took some home. In the end, mercury contamination was found not only in the school but also on a school bus, in several homes, and on many students' personal items. Several hundred students and staff members were exposed, the cleanup cost the school district USD $800,000, and the school superintendent resigned.[194]

The stories above are just two high-profile examples of a type of mercury exposure that is all too common. High schools have no need to do experiments and demonstrations that use mercury. This practice should be prohibited. If a school, laboratory, or other facility has a history of using mercury, accumulated mercury may still be present in floor drains or sink traps even after the practice has been discontinued, and this may be a cause for concern.[195]

Some laboratory uses of mercury may be appropriate when professional chemists or advanced students of chemistry in college laboratories perform them. However, we can and should eliminate or significantly reduce the use of mercury in labs because good alternatives can effectively replace most uses of elemental mercury, mercury compounds, and mercury-containing devices. For example, laboratories sometimes use a mercury-filled apparatus to maintain an inert atmosphere over a reaction and to provide pressure relief. Similar laboratory equipment filled with mineral oil are available, and labs should use these instead.[196] Labs can avoid most other mercury-containing equipment and devices as well. Some laboratories use zinc-mercury amalgam as a reducing agent but, again, good alternatives are usually available.[197] Mercury is also often present in lab chemicals and reagents, many of which have good substitutes.

Some hospital labs and other laboratories have decided to go virtually mercury free. Those who wish to do this should read container labels, material safety data sheets (MSDSs), and inserts that come with reagents. These will identify intentionally added mercury compounds in the reagents. However, MSDSs will generally not identify unintended mercury in the lab chemicals if the quantity is below 1 percent. This is because manufacturers are often not required to list the hazardous components of a product if they are present in concentrations below a certain level. Labs and hospitals, however, can ask sales representatives and product manufacturers about mercury in their products and can request a certificate of analysis or other data on the mercury content of laboratory products.[198]

7.10 Mercury in Cosmetics

Cosmetic products such as creams, lotions, and soaps are sometimes marketed with the promise that their use will lighten the color of skin or remove dark spots. These products often contain mercury in the form of mercury chloride and/or ammoniated mercury. Both of these compounds are carcinogenic. Skin-lightening cosmetics that do not contain mercury often contain hydroquinone ($C_6H_6O_2$), which is also highly toxic.[199]

In general, the more of the pigment melanin one has in his or her skin, the darker it is. Cosmetics that contain mercury compounds or hydroquinone initially cause the skin to lighten by inhibiting the production of melanin. In the longer term, however, these products make the skin blotchy, which in turn may cause the person to use more of it in an attempt to smooth out the color. Mercury-containing cosmetics have been banned in many countries, but they often remain available as under-the-counter items. They appear to be particularly popular in many Asian and African countries.[200]

One study suggests that many women in African countries use these products regularly, including 25 percent of women in Mali, 77 percent of women in Nigeria, 27 percent of women in Senegal, 35 percent of women in South Africa, and 59 percent of women in Togo. In a 2004 survey, 38 percent of women in Hong Kong, Korea, Malaysia, the Philippines, and Taiwan indicated that they use skin-lightening products. Many women use these products for long periods, sometimes for as long as 20 years.[201]

In 1999, the Kenya Bureau of Standards issued a public notice to inform and educate consumers about the harmful effects of mercury, hydroquinone, and the hormonal preparations and oxidizing agents that are contained in some cosmetic products on the market. In 2004, the Indonesian Food and Drug Control Agency (BPOM) issued a warning against 51 beauty-care products containing mercury. Many were imports, but in 2006, the police seized 200 boxes of cosmetic products containing mercury from a small manufacturing company in West Jakarta. In 2005, New York City's Department of Health and Mental Health issued a health alert recommending that New Yorkers immediately cease using all skin-lightening creams and soaps that list mercury as an ingredient as well as any cosmetic products that do not have a list of ingredients on the label.[202]

A study conducted by NGOs in the IPEN network found mercury in several skin-lightening products sold in Mexico. Of seven products analyzed, four contained detectable quantities of mercury, with one of them containing 1,325 parts per million (ppm). All the tested products came with a list of their ingredients, but none listed mercury as an ingredient.[203]

A Chicago newspaper tested skin-lightening creams sold in local stores and found that six of them contained mercury at levels that violated U.S. federal law. These six came from China, India, Lebanon, and Pakistan, and some were sold in stores specifically catering to these immigrant communities. Five of the creams contained more than 6,000 ppm mercury and one of them, manufactured in Pakistan, contained nearly 30,000 ppm mercury. This product was a white cream labeled as Stillman's Skin Bleach Cream. The store owner was reported as saying that he carried this cream because the product is so popular in Pakistan.[204]

So far in 2010, the Food and Drug Administration of the Philippines has banned 23 imported skin-lightening products that the agency described as "imminently injurious, unsafe, or dangerous" for containing impurities and contaminants beyond regulatory limits. For mercury, the allowable threshold is 1 ppm.

A 2000 European Union directive stipulates that mercury and its compounds may not be present as ingredients in cosmetics, including soaps, lotions, shampoos, and skin-bleaching products (except for phenyl mercuric salts for the conservation of eye makeup and products for removal of eye makeup in concentrations not exceeding 0.007 percent weight to weight).[205]

Although many jurisdictions have laws prohibiting the use of mercury-containing skin creams and soaps, most have had difficulties enforcing these laws.

Few jurisdictions prohibit the use of small amounts of mercury compounds in eye-makeup products such as mascara, and mercury is still widely found in these products. Mercury compounds are used in eye-makeup products as a germ killer and preservative, and they make the products last longer.[206] Though some manufacturers have removed mercury from some mascara products in response to consumer demand, most jurisdictions still allow the sale of makeup products that contain added mercury compounds. One exception is the U.S. state of Minnesota, where a law that took effect in 1998 totally banned all intentionally added mercury in cosmetics, including mascara and eye liners.[207]

7.11 Mercury in Medicine

Doctors have often used mercury compounds as medicines.

Calomel

Physicians have used mercurous chloride (Hg_2Cl_2), or calomel, since at least the sixteenth century to treat malaria and yellow fever. A preparation called worm chocolate or worm candy was given to patients infested with parasitic worms.[208] Through the nineteenth and early twentieth century, many physicians continued to use calomel as a purgative, cathartic, and liver stimulant.[209] Parents frequently gave teething powders containing calomel to infants.[210]

Doctors continued to recommend the use of calomel into the 1950s in the United States, the United Kingdom, and elsewhere for treating childhood teething and constipation. Mercury exposure from ingesting calomel often caused a common infantile and childhood illness called acrodynia, or pink disease. As late as 1950, acrodynia accounted for more than 3 percent of admissions to children's wards in London hospitals. Official statistics record that 585 children died of pink disease between 1939 and 1948 in England and Wales.[211] Calomel was not removed from the British Pharmacopoeia until 1958. The 1967 edition of the *United States Dispensatory and Physicians' Pharmacology* lists calomel as a medicine and not as a poison. After the childhood use of calomel was discontinued, pink disease virtually disappeared.[212]

Western Pharmaceutical Use of Calomel

Physicians in the western medical tradition prescribed the use of calomel and other mercury compounds to their patients well into the twentieth century. The following is an excerpt on the pharmacological uses of calomel from the 1911 edition of the *Encyclopedia Britannica*:

> "Calomel possesses certain special properties and uses in medicine. . . . Calomel exerts remote actions in the form of mercuric chloride. The specific value of mercurous chloride is that it exerts the valuable properties of mercuric chloride in the safest and least irritant manner, as the active salt is continuously and freshly generated in small quantities. . . .
>
> "Externally the salt [calomel] has not any particular advantage over other mercurial compounds. . . . Internally the salt is given in doses—for an adult of from one half to five grains. It is an admirable aperient [laxative], acting especially on the upper part of the intestinal canal, and causing a slight increase of intestinal secretion. The stimulant action occurring high up in the canal (duodenum and jejunum), it is well to follow a dose of calomel with a saline purgative a few hours afterwards. . . .
>
> "The salt [calomel] is often used in the treatment of syphilis, but is probably less useful than certain other mercurial compounds. It is also employed for fumigation; the patient sits naked with a blanket over him, on a cane-bottomed chair, under which twenty grains of calomel are volatilized by a spirit-lamp; in about twenty minutes the calomel is effectually absorbed by the skin." [213]

Mercurochrome

The antiseptic mercurochrome is still sold in pharmacies in many countries and is applied to cuts and wounds to prevent infections. This antiseptic is marketed under many other names including Merbromine, sodium mercurescein, Asceptichrome, Supercrome, Brocasept, and Cinfacromin. The commercial product usually contains 2 percent of the mercury/bromine compound merbromine ($C^{20}H^{9}Br^{2}HgNa^{2}O^{6}$) mixed with water or alcohol.

Mercurochrome is no longer sold in the U.S. retail market because of concerns about its mercury toxicity, but bulk quantities of merbromine can still be purchased from U.S. chemical supply houses. This mercury-containing antiseptic is still widely sold and used for both human and veterinary applications in Australia and in most other countries.

Mercury in Traditional Medicines

Cinnabar (a naturally occurring mineral that contains mercury sulfide) has been used in traditional Chinese medicine for thousands of years as an ingredient in various remedies. It is sometimes also called zhu sha or China Red. According to the Pharmacopoeia of China, forty cinnabar-containing traditional medicines are still in use there. One study suggests that because cinnabar is insoluble in water and poorly absorbed in the gastrointestinal tract, it exhibits less toxicity than other forms of mercury, although long-term users may suffer kidney disorders. Nonetheless, the study's authors indicate that the rationale for the continuing inclusion of cinnabar in traditional Chinese medicines remains to be fully justified.[214] An Internet site selling zhu sha as a medicinal makes the claim that it tranquilizes the mind and treats irritability, insomnia, and dreaminess as well sore throat and canker.[215]

In the past, calomel was also used in traditional Chinese medicine, but these uses have largely been replaced by safer therapies. No calomel-containing oral Chinese remedy is today listed in the Pharmacopoeia of China.[216]

There is a long tradition of ingesting mercury for medicinal purposes in Indian Ayurveda practice and in tantric and Siddha alchemy. The Vagbhatta, which is from the sixth century C.E., recommends internal uses of mercury for therapeutic ends. The Italian traveler Marco Polo, who visited India in the late thirteenth century, reportedly met yogis who lived long and healthy lives because they consumed a drink made of mercury and sulfur. Indian traditional medicines called kajjali and rasasindoor, which contain mixtures of mercury and sulfur, are still used to treat diabetes, liver disease, arthritis, and respiratory diseases.[217]

Reportedly, mercury capsules known as azogue are still sold in Mexico in religious stores for use as a remedy for indigestion or gastroenteritis blockages (empacho).[218]

Thiomersal

Thiomersal, which goes by the name thimerosal in North America, is a mercury-containing compound that is used to prevent bacterial and fungal growth. Other names for this compound include Merthiolate, mercurothiolate, ethylmercurithiosalicylic acid, and sodium 2-ethylmercuriothio-benzoate. The chemical formula for thiomersal is $C_9H_9HgNaO_2S$.[219]

Thiomersal is widely used in vaccines and may also be used in some other medical applications such as skin tests, eye and nose drops, and multiple-use solution containers such as those used for contact lenses. It also may be used in tattoo inks.[220] In the United States, manufacturers of contact lens solutions voluntarily discontinued the use of thiomersal in these products before 2000. This practice, however, may continue in other countries.

Thiomersal is sometimes present in waste streams from hospitals, clinical laboratories, and pharmaceutical industries, and this may lead to the need for environmental cleanups.[221]

The use of thiomersal in childhood vaccines has become a subject of controversy.

Thiomersal in Vaccines

Some vaccines do not contain thiomersal. These include many single-dose vaccines and vaccines for which the thiomersal might interfere with the vaccine's efficacy. In some vaccines, thiomersal is used during the production process but is not added to the final product. These vaccines typically contain trace amounts of thiomersal of less than 0.5 micrograms per dose. Some other vaccines contain thiomersal that has been added to the final product to prevent contamination with microorganisms. These vaccines typically have thiomersal concentrations of between 10 micrograms and 50 micrograms per dose.[222]

Thiomersal is sometimes added to vaccines during manufacture to prevent microbial growth. However, with changes in manufacturing technology, the need to add preservatives during the manufacturing process has decreased. Thiomersal is added to multi-dose vials of vaccines to prevent the vaccines from becoming contaminated with pathogens when multiple needles are inserted into the same container. For example, there is a case from before vaccines contained preservatives in which vaccinated children died after being injected with a vaccine contaminated with living staphylococci bacteria. A British Royal Commission investigated the incident and recommended that biological products in which the growth of a pathogenic organism is possible should not be issued in containers for repeated use unless there is a sufficient concentration of antiseptic (preservative) to inhibit bacterial growth. The use of a preservative in multi-dose vaccines is now the internationally accepted practice.[223]

In the late 1990s, in response to a new legislative mandate and parental concerns, the U.S. Food and Drug Administration began an investigation of thiomersal in vaccines. The FDA found that by the age of 6 months, an infant in the U.S. might have received as much as 187.5 micrograms of mercury from thiomersal-containing vaccines.* In 1999, in response to these findings, the U.S. Centers for Disease Control and Prevention (CDC) and the American Academy of Pediatrics (AAP) issued a joint precautionary statement. They asked pharmaceutical companies to remove thiomersal from vaccines as quickly as possible and, in the interim, they asked doctors to delay the birth dose of hepatitis B vaccine in children who were not at risk for hepatitis.[225] This statement was based on precaution and evidence that methylmercury and many other mercury compounds were documented neurotoxins. At the time, however, there had been few if any relevant studies of ethyl mercury and no studies that indicated harm to infants caused by exposure to thiomersal in vaccines.

In 1999, the European Agency for the Evaluation of Medicinal Products (EMEA) also issued a statement about thiomersal in childhood vaccines. The EMEA concluded that there was no evidence of harm to children caused by the level of thiomersal in the vaccines then being used. The EMEA, however, also called for precautionary action such as promoting the general use of vaccines without thiomersal and other mercury-containing preservatives and working towards the elimination of these preservatives by manufacturers.[226]

Since 1999, controversy about thiomersal in vaccines has continued and escalated. Many parents believe that infant exposure to thiomersal in vaccines contributes to autism and other brain-development disorders. This appears to have been driven in part by dramatic increases in the incidence of autism in the 1980s and 1990s. In addition, a growing awareness that mercury is a serious neurotoxin has made many parents question why any mercury should be injected into their infants. Parents' groups and others cite studies in the literature that they claim support or suggest a connection between thiomersal and autism. These claims, however, are disputed.[227]

The medical community broadly rejects the conclusion of a connection between thiomersal and childhood neurological disorders. In 2004, the U.S. Institute of Medicine's Immunization Safety Review Committee issued a report examining the hypothesis that vaccines are causally associated with autism. It concluded that the body of evidence favors rejection of a causal relationship between thimerosal-containing vaccines and autism.[228] Also in 2004, the European Medicines Agency Committee for Human Medicinal Products concluded that the latest epidemiological studies show no association between vaccination with thiomersal-containing vaccines and specific neurodevelopmental disorders.[229] The position of the U.K.'s Commission on Human Medicines is that there is no evidence of neurodevelopmental-adverse effects caused by the levels of thiomersal in vaccines except for a small risk of hypersensitivity reactions such as skin rashes or local swelling at the site of injection.[230] The World Health Organization's Global Advisory Committee on

* The infant could receive as much as 75 micrograms from three doses of the diphtheria–tetanus–pertussis vaccine; 75 micrograms from three doses of the Haemophilus influenzae type b vaccine, and 37.5 micrograms from three doses of the hepatitis B vaccine.

Vaccine Safety has concluded that there is currently no evidence of mercury toxicity in infants, children, or adults exposed to thiomersal in vaccines.[231]

The importance of vaccination for the prevention of disease is well documented. Concerns about the side effects of vaccinations have, in some developed countries, resulted in a reduction in the vaccination rate, and this has contributed to outbreaks of measles and other diseases in addition to an increase in serious complications. There are, therefore, important concerns within the public health community and elsewhere that controversies about thiomersal in vaccines could have serious consequences for children's health.

Many industrial countries appear to be moving toward the use of single-dose vaccines and are phasing out thiomersal in vaccines. Doing this globally may take time because of challenges associated with replacing multiple-dose vaccines with single-dose vaccines. There are also challenges with changing the formulation of a licensed vaccine. Replacing thiomersal with a mercury-free alternative during production or not adding thiomersal to the final product will generally require research and development and will also require a new licensing process with a series of preclinical and clinical trials.[232] Still, progress has been made.

According to a fact sheet from a European NGO coalition, the National Central Laboratory of the Danish Health System has not used thiomersal in vaccines for children since 1992. Sweden's Children's Vaccine Program has not used mercury-based preservatives in vaccines since 1994. And the U.K. Department of Health announced in 2004 it would no longer use thiomersal in infant vaccines.[233] In the United States, almost all routinely recommended vaccines for infants are available only as thiomersal-free formulations or in formulations that contain less than 1 micrograms of thiomersal per dose. The only exception is inactivated influenza vaccine, which is mainly available for pediatric use in the U.S. in a formulation that does contain thiomersal. However, some other formulations of this vaccine that contain either no thiomersal or only a trace of thiomersal are also available.[234]

The situation in the developing world is quite different, with little apparent momentum in most countries toward phasing out thiomersal from vaccines. In many countries, it is difficult or impossible to mobilize the resources necessary to immunize all infants and children, and this has raised questions about diverting resources to the phaseout of thiomersal vaccines. Substitution of thiomersal-containing vaccines with mercury-free alternatives might be particularly problematic in countries where domestically manufactured vaccines contain thiomersal and are far less costly than imported thimerosal-free substitute vaccines.[235]

Another important consideration is whether vaccines used for immunization are supplied in single-dose vials or multiple-dose vials. In many cases, it is important for multi-dose vials to contain a preservative like thiomersal to protect against contamination from the multiple needles entering the vial. The use of a preservative is less important when a single-dose vial is used. The WHO argues that supplying vaccines in single-dose vials would require a significant increase in production capacity and would come with a high cost. The WHO also indicates that single-dose vials require significantly larger cold storage space and they increase transportation needs. Because the WHO has determined that many developing countries have insufficient production capacity and insufficient infrastructure for vaccine transportation and storage under cold-chain conditions, it has concluded that additional costs and burdens make single-vial dose vaccines unfeasible for the majority of countries.[236,237]

Even though the WHO and some others make a strong case against moving to eliminate thiomersal in the developing world, many NGOs and civil society organizations are uncomfortable with this as a long-term perspective. They are aware that the global medical community has often been slow to recognize harms to human health from low-dose exposures to other toxic substances. For example, as recently as the 1960s, the medical community did not yet have studies or data clearly showing that children with blood lead levels as high as 50 micrograms per deciliter were suffering harmful lead poisoning. Today, it is recognized that children with blood lead levels of 5 micrograms per deciliter or less suffer harmful effects. With this historical perspective in mind, some find it difficult to take comfort in assurances from the medical community that there is no known association between thiomersal-containing vaccines and neurodevelopmental harms to children.

As many highly industrial countries move toward phasing out thiomersal from childhood vaccines, it is difficult for many NGOs and others to accept the double standard that this should not also be a goal for developing countries. Possible ways forward might include research into effective mercury-free preservatives that replace thiomersal and assistance to vaccine manufacturers in developing countries to enable them to produce good, low-cost, mercury-free vaccines. A global mercury-control treaty could be a vehicle to promote these and other measures.

7.12 Mercury in Cultural Products, Traditional Medicines, and Jewelry

Mercury is widely used in cultural and religious practices. In Hindu practice, mercury is contained in Parad, a material from which religious relics are made. It is used in the rituals of several religions in Latin America and the Caribbean including Candomblé, Espiritismo, Palo Mayombé, Santería, Voodoo, and Yoruba Orisha. It is also used in medicines and jewelry and for other cultural practices.[238]

People may keep mercury in containers, such as pots or cauldrons, to purify the air. In some cultures, people sprinkle mercury on the floor of a home to protect its occupants. Some use it with water and a mop to spiritually clean a dwelling. And some add mercury to oil lamps and candles to ward off evil spirits; to bring good luck, love, or money; or to hasten other spells. People also keep mercury in amulets, ampoules, vials, or pouches that they carry or wear around the neck.[239]

Parad is an amalgamation of mercury and other metals that is used to make relics for worship in the Hindu tradition. It is traditionally made of silver and mercury, but it is now often made of mercury and tin, with trace amounts of other metals. One study found the mercury content of Parad to be almost 75 percent. Various religious objects are made of Parad and sold in markets in India including beads worn around the waist or neck, cups used to ritually drink milk (*amrit*), statues that represent Gods (*Shivlings*), and other objects. India has many Shiva temples which have Parad Shivlings. A study by Toxics Link, an Indian NGO, found that mercury leaches from Parad into milk, and this may expose those who follow the tradition of drinking milk from a Parad cup or drinking milk in which a Parad relic has been soaked.[240], [241]

Mercury has also been used in western works of art. The most famous of these is the Calder Mercury Fountain in the Fundación Joan Miro museum in Barcelona, Spain. The Spanish Government commissioned the American artist Alexander Calder to build this fountain as a monument to the Almadén mercury mine for display at the 1937 World's Fair. Instead of using water, the fountain pumps and circulates approximately five metric tons of pure elemental mercury. The fountain is placed behind glass to protect viewers from touching the mercury or breathing its fumes.[242]

Mercury jewelry that may have been originally produced for use as amulets or charms sometimes finds its way onto the general market. For example, mercury-containing necklaces thought to come from Mexico began to show up in schools in the U.S. and possibly elsewhere. One report describes necklaces with a beaded chain, cord, or leather strand and a glass pendant containing between three grams and five grams of mercury. The mercury is visible as a silvery clump of liquid rolling around in a hollow glass pendant. The glass pendants came in various shapes, such as hearts, bottles, saber teeth, and chili peppers, and sometimes the pendants also contained brightly colored liquid along with the mercury.[243], [244]

Notes

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8. Intentional Sources: Mercury in Mining and Industrial Processes

There are three major mining and industrial processes that intentionally use mercury and release large quantities into the environment. These are artisanal and small-scale gold mining (ASGM), the use of mercury catalysts in chemicals production, and mercury-cell chlor-alkali plants.

8.1 Mercury Use in Artisanal and Small-Scale Gold Mining

Mercury is released into the environment from both large-scale and small-scale gold mining. However, most of the mercury emissions from large-scale gold mining are the result of mercury impurities in the gold ores themselves. On the other hand, small-scale gold miners purchase and use elemental mercury, which is then released into the environment during the mining and refining process. Of all the intentional uses of mercury, artisanal and small-scale gold mining appears to be, by far, the largest global source of mercury pollution. This practice also does serious harm to miners and their families, and it seriously degrades local and regional ecosystems.

Artisanal gold miners tend to work as individuals or small groups in remote locations where the ores that contain gold are found. After concentrating the gold through separation techniques such as panning, the miners mix the remaining combination of gold, soils, sands, or sediments with elemental mercury to concentrate the gold and create a mercury/gold amalgam. The miners then press the excess mercury from the amalgam so they can separate out the gold-rich amalgam relatively quickly. The miners heat the amalgam, which drives off the mercury, leaving behind fairly pure gold. This process keeps the miner in control of the gold until he (or she) decides to sell it. It also keeps costs to a minimum, and the miner can take the profit at any time.

Setting up an artisanal gold mining operation requires minimal expertise and investment. With gold prices rising to USD $1,250 per ounce and with mercury prices still relatively low, artisanal gold mining is attractive, especially where there is high poverty and unemployment and particularly among people who have suffered economic or environmental disasters. Small-scale gold mining is practiced in 55 countries. UNEP estimates that between 10 and 15 million people worldwide are directly engaged in small-scale gold mining, and another 85 to 90 million people are indirectly dependent upon it. Small-scale miners produce between 20 percent and 30 percent of all gold that is mined—approximately 500 to 800 metric tons of gold per year. These mining operations are frequently illegal or unregulated, and the miners are typically poor and often have little or no awareness of the hazards posed by mercury exposure.[245] In some countries, most gold mining is done by artisanal and small-scale miners. For example, in the Philippines, 75 percent of all mined gold is done by individuals and small operators.

It is estimated that artisanal and small-scale gold mining operations consume between 650 and 1,000 metric tons of mercury each year. Some of this mercury is released directly into the air, especially if the mercury is not properly stored or recovered during separation from the amalgam. The rest is lost through spills, careless handling, and by other means, and the mercury ends up contaminating soils or is released directly into water systems. Mercury-contaminated soils can also run off into water systems. The result is widespread mercury contamination in ecosystems surrounding artisanal and small-scale mining activities. The elemental mercury that is present in contaminated soils or in water systems can subsequently volatilize into the air and contribute to global atmospheric mercury.[246,247]

Some small-scale mining operations use a process called whole-ore amalgamation. The miner crushes and grinds the ore in a mill and adds mercury to the mixture. Often, only a small fraction of this mercury binds to the gold present in the mixture. The churning action of the mill releases the rest of the mercury into the environment. As the mill's action crushes the ore, it also reduces the size of elemental mercury droplets within the mill. They get smaller and smaller and are then flushed from the mill by the water flowing through it. Whole-ore amalgamation appears to be the most polluting of all gold mining processes and can cause the most severe human exposures and environmental contamination. However, miners widely use this method because mercury is inexpensive compared with the price of gold, and this process produces saleable gold (and an immediate payday) with the least manpower. There are several alternative practices that can reduce mercury use and pollution by concentrating the gold in the ore before adding mercury, but some of these techniques require more time, skill, and investment. When used, however, these techniques can capture more gold while using less mercury.[248]

Another common practice is to pan for gold. Water in a pan is used to gather the heavier particles contained in soil, sand, or sediment while allowing lighter materials to be washed away. The miner then adds mercury to these heavier particles to separate out their gold content.

Miners often use a shovel or a metal pan over an open fire to heat amalgam and recover gold. When they do this, it releases mercury vapors directly into the air that the miners, their families, or others nearby can inhale. But miners can use a simple process called retorting to reduce the amount of mercury vapor that is lost. The retort captures mercury vapors, cools them, recovers the elemental mercury, and allows the miner to reuse it. A retort (which can be any number of devices made from glass bowls, pottery, or other available materials) collects and cools the mercury vapor as it escapes from the amalgam during heating, allowing it to condense back into a liquid state. A field assessment by the United Nations Industrial Development Organization found that effective retorts can be produced for as little as USD $3.20. These can capture more than 95 percent of the mercury vapor and allow it to be recycled and reused. Unfortunately, because of the relatively low cost of elemental mercury, low awareness of the hazards from mercury vapors, and insufficient information about retorts, few small-scale miners use them.[249]

Health surveys have found high levels of mercury in many miners: Some miners have been exposed to levels of mercury more than 50 times higher than World Health Organization public-exposure limits. At one site, nearly half of all miners exhibited unintentional tremors, a typical symptom of mercury-induced damage to the central nervous system. Miners' families often live nearby the locations where amalgam is heated. Miners also carry mercury home with them on their contaminated clothes. As a result, miners' families are also frequently exposed.[250] It is reported that in in Indonesia, and likely elsewhere, health care officials often have low awareness about mercury poisoning, and they may interpret tremors and other symptoms of mercury exposure as malaria or dengue fever.[251]

Mercury contamination at artisanal gold mining sites is often ignored because these sites are frequently in remote areas far from the public's notice. Even when there is a desire to monitor these sites, it may be difficult to do so because of the unavailability of mobile equipment and local environmental laboratories.

In August 2010, in Lampung, Indonesia, one medium-size gold mining company that had previously used the mercury amalgamation process was cleaning up a pond containing mercury-contaminated mine tailings as it prepared to switch over to a cyanide process. During this time, it rained, and the company opened the pond and released the tailings into the river. This killed many fish. People in the area collected the dead fish floating on the water, took them home, and fed them to their families. As a result, approximately 200 people were hospitalised for mercury poisoning. The company was fined and obliged to cover the health costs of the villagers.[252]

There is no quick or easy way to eliminate or minimize mercury emissions from small-scale gold mining. Solutions often are dependent on the region, area, or even locality where the mine is located. Many countries have attempted to outlaw the practice, but the usual result is the creation of illegal mining operations. It has been reported that in a country where the practice of heating amalgam outdoors to recover gold was outlawed, some miners began heating the amalgam inside their homes and seriously exposed their entire families to mercury vapors. In Kalimantan, Indonesia, in 2007, a number of people were heating amalgam inside homes and gold shops without proper ventilation. An intervention by the UNIDO Global Mercury Project helped to remedy this with the installation of ventilation hoods.[253]

A global mercury-control treaty can make important contributions to reducing mercury releases from small-scale gold mining. It can control the mercury supply and trade, which will raise the price and restrict the availability of elemental mercury to small-scale miners. This will discourage inefficient mining practices such as whole-ore amalgamation. Retorts and other technologies that capture gold using less mercury or no mercury, on the other hand, will become much more attractive to miners. A mercury treaty can also help mobilize resources to provide better services and training to small-scale miners and their communities and to promote the adoption of less polluting and more sustainable practices. It can promote assistance to local governments in the mining areas and can help make financial support opportunities available to groups of miners willing to undertake cooperative operations that use non-mercury technologies or less polluting practices. The eventual phaseout of the use of elemental mercury in mining practice should remain a long-term goal.

The achievement of this goal, however, may need to be linked to successes in other poverty-reduction programs and in some cases, displaced miners and their families may need access to supplemental livelihood opportunities.

8.2 Mercury in Chlor-Alkali Production

Chlor-alkali plants are industrial processes that use electrolysis to produce chlorine gas or other chlorine compounds, alkali (also known as caustic soda or sodium hydroxide) or sometimes potassium hydroxide, and hydrogen gas. Some older chlor-alkali plants still use what is called a mercury-cell process, which is very polluting and releases large quantities of mercury into the environment.

These plants employ an electrolytic process in which electricity in the form of direct current (DC) is passed between electrodes that are in contact with a saltwater (brine) solution. The positively charged electrode called the anode is graphite or titanium; the negatively charged electrode called the cathode is a large pool of mercury that may weigh several hundred tons. When electrical current is passed across the electrodes, it creates chlorine gas at the anode, which is vented and collected. This also creates a sodium-mercury amalgam at the cathode. Subsequently, a reaction between the metallic sodium in this amalgam and water is induced to produce sodium hydroxide and hydrogen gas, which are both also removed for use.*

Mercury-cell plants were the main commercial process used for the production of chlorine and sodium hydroxide beginning in the 1890s and lasting until the middle of the twentieth century. Some mercury cells are still in operation throughout the world, but most have been replaced with alternative electrolytic or other processes that do not use mercury. These alternative processes use what are called diaphragm cells or membrane cells. A major reason that many mercury-cell plants have been shuttered or converted to non-mercury processes is regulatory pressures based on findings that these plants produce substantial mercury emissions, that they also produce mercury wastewater discharges and mercury-contaminated solid wastes, and that areas around chlor-alkali plants have become highly contaminated with mercury.[255] Another reason for replacement is that diaphragm-cell and membrane-cell chlor-alkali plants are more efficient than mercury-cell plants.

* The overall chemical for the electrolysis of brine is 2NaCl + 2H2O → Cl2 + 2NaOH + H2.

In addition, the caustic soda and possibly the chlorine compounds produced by mercury-cell chlor-alkali plants are typically contaminated with mercury. Caustic soda is used in the production of food products such as corn syrup, and mercury has been found in both corn syrup on the market and also in food products that contain corn syrup. Under an agreement with the U.S. government, the U.S. chlorine industry in the United Sates voluntarily agreed to limit the amount of mercury in the caustic soda it sells to 1 percent or less.[256]

UNEP's "Global Atmospheric Mercury Assessment" estimates global mercury emissions from chlor-alkali plants to be 60 metric tons. "The Technical Background Report to Global Atmospheric Mercury Assessment" from UNEP, however, estimates that mercury-cell chlor-alkali plants consumed 492 metric tons of mercury in 2005. This reported total was distributed as follows:

Region	Mercury Consumption in Metric Tons
European Union	175
CIS and Other European Countries	105
North America	60
Middle Eastern Countries	53
South Asia	36
South America	30
Others listed	33
Total	492

In the case of chlor-alkali plants, the annual mercury consumption is simply the amount of mercury that the plant loses over the course of the year. Plants lose much of this mercury directly to the air because the process generates heat and because regular maintenance practices include the opening and closing of cell containments. Some of this mercury is released into bodies of water or contaminates the land surrounding the plant. Other mercury lost through the process goes to landfills or to other disposal facilities. Some ends up in the products that are produced or becomes bound to metallic materials in the plant. Additionally, because elemental mercury is volatile, much of the plant's mercury that ends up in water, in contaminated soils, in landfills, and other disposal facilities subsequently volatilizes and enters the air.

Historically, the chlor-alkali industry has done a very bad job of accounting for and reporting on its annual mercury releases into the environment. Both the industry and its regulators have acknowledged that until recently, they had very little information on the quantities and pathways of mercury losses from mercury-cell chlor-alkali plants.[257] In recent years, however, some governments have exerted regulatory pressures on the chlor-alkali industry to begin phasing out mercury-cell plants and, in the interim, to do a better job of preventing environmental releases of mercury and also to more accurately account for the releases that do occur. Operators in some countries now report annually on their mercury consumption.

According to a 2004 trade industry report, U.S. chlor-alkali plant operators calculated the amount of mercury consumed at a plant in a year in the following way. The plant operator performed plant mercury inventories on January 1 and December 31. Each inventory was an accounting of the amount of mercury present in the plant's chlor-alkali cells plus the amount of mercury present in the plant's warehouses on the date the inventory was taken. The operator also did an accounting of the amount of mercury that the plant had purchased during the year. Mercury consumption for the year was calculated by adding the amount of mercury in the inventory at the start of the year plus the amount purchased during the year and then subtracting the amount in the inventory at the end of the year (consumption equals inventory on January 1 plus purchases during the year minus inventory on December 31).[258]

In later reports, the U.S. industry trade association indicated that operators revised how they calculate mercury consumption to take into account mercury that the operator has sent off-site for recovery and for subsequent reuse. These reports introduce a new category, Mercury Transferred Out, which is defined as the amount of mercury that the operator has sent off-site for recovery and that has not been returned during the same calendar year. Starting in 2004, when calculating annual mercury consumption, operators subtracted the amount of Mercury Transferred Out from the amount of mercury purchased during the year.[259] In summary, according to the U.S. industry trade association, operators now calculate annual mercury consumption as follows:

Annual Mercury Consumption equals

- the amount of mercury in inventory on January 1 plus
- the amount of mercury purchased during the year minus

- the amount of mercury shipped off-site for recovery and not returned by the end of the year minus
- the amount of mercury in inventory on December 31[260]

In addition to calculating annual mercury consumption, the U.S. industry trade association's annual reports allocate the consumed mercury into three categories:

1. Mercury released into the environment and reported to the EPA as part of the U.S. Toxics Release Inventory (TRI)*

2. Mercury that leaves the plant in products (that is, in alkali and chlorine the plant sells)

3. The balance, which the reports call Unaccounted For Mercury[262]

As recently as its annual report for 2003, the U.S. chlor-alkali industry was able to account for only a small fraction of the mercury it consumed in the year. Of the 38 short tons (34.5 metric tons) of mercury that the industry trade association reported was consumed by U.S. chlor-alkali plants in 2003, operators could account for the fate of only 8 short tons (7.25 metric tons). A full 30 short tons (27.2 metric tons) were classified as Unaccounted For Mercury. That is, U.S. chlor-alkali operators could account for the fate of only 21 percent of the mercury they consumed in 2003; the remaining 79 percent was mercury losses that the operators could not account for.[263]

Since 2003, reported U.S. chlor-alkali industry annual mercury consumption has substantially declined as has the amount of mercury losses it cannot account for. This suggests that technically capable operators can respond to regulatory pressures and reduce both the annual mercury consumption of their plants and also improve their ability to account for and report on mercury losses.[264]

* The Toxics Release Inventory is a publicly available online database established by the U.S. EPA. Many industrial facilities in the U.S. are required to report to the EPA their releases of toxic chemicals to various environmental media, their off-site transfers of toxic wastes, and other waste-management activities. The EPA compiles the responses and makes them available to the public online.

Mercury-Contaminated Soils from Chlor-Alkali Plants

Researchers tested mercury-contaminated samples of soil taken from mercury-cell chlor-alkali plants in Europe. One sample was of soil that had originally been excavated from under a plant's cell house and then stored outside for approximately three years. This sample was found to be contaminated with mercury at the concentration of 569 ppm (mg/kg). Another sample was taken of the upper soil layer in the vicinity of a mercury-cell chlor-alkali plant and was found to be contaminated with mercury at the concentration of 295 ppm (mg/kg).[265]

The authors of the study noted that elemental mercury has an extremely high affinity for organic matter and binds tightly to organic soils. They noted further, however, that mercury bound to organic soils can, nonetheless, still be emitted from the soil into the atmosphere, especially during periods of high temperature.

There are indications that the number of operating chlor-alkali plants in the world has continued to decline since 2005, but it has been difficult to find a listing of all mercury-cell chlor-alkali plants still in operation. An April 2010 European industry association statement indicates that 39 mercury-cell chlor-alkali plants remain in operation in fourteen European countries.[266] A 2009 fact sheet from a leading North American chlor-alkali operator states that approximately 13 percent of chlor-alkali products in North America come from mercury-cell plants.[267] A report by the World Chlorine Council (WCC) to UNEP indicates that in 2007, a total of 70 mercury-cell chlor-alkali plants were operating in the following countries: the United States, Canada, Europe, Russia, India, Brazil, Argentina, and Uruguay.[268] It is likely that a number of other mercury-cell plants are still operating in countries not covered by this WCC report including plants possibly in some Middle Eastern countries, in some CIS countries other than Russia, and in some Asian countries other than India.

A global mercury-control treaty could establish a time schedule for the phase-out of all mercury-cell chlor-alkali plants, require that mercury recovered from those plants be kept off the market and put into long-term storage, and establish rigorous cleanup requirements for the site of former mercury-cell plants.

8.3 Mercury Catalysts Used for Chemical Production

Mercury-containing catalysts have been used for many years in industrial chemical production. These catalysts remain in large-scale commercial use in the manufacture of vinyl chloride monomer (C_2H_3Cl), and this use appears to be growing. On the other hand, it appears that most other industrial uses of mercury-containing catalysts are declining or have been phased out.

As indicated above, the tragedy of Minamata disease was caused by a chemical plant that used mercury sulfate as a catalyst in the production of the chemical acetaldehyde. It appears that mercury catalysts are no longer being used in the industrial production of acetaldehyde.

Historically, organic mercury compounds were considered to be the catalysts of choice in the manufacture of polyurethane plastics and coatings in many applications. When mercury-containing catalysts are used for this purpose, mercury residues remain in the polyurethane. Between the 1960s and 1980s, many schools in the United States installed polyurethane flooring in their gymnasiums that typically contained between 0.1 percent and 0.2 percent mercury. One manufacturer alone claimed to have installed more than 25 million pounds (11.3 million kg) of this flooring material. The surface of this flooring slowly releases elemental mercury vapor, particularly from damaged areas. Officials have measured airborne concentrations of mercury in some school gymnasiums. One school district reported mercury vapor in the range of 0.79 micrograms to 1.6 micrograms of mercury per cubic meter of air in the breathing zone. Another school reported 0.042 micrograms to 0.050 micrograms of mercury per cubic meter of air. The variation in measurements may be attributed to the size of the floor, relative damage to the flooring material, ventilation in the gymnasium, and the kind of environmental sampling equipment that was used.[269]

Recently, alternative mercury-free catalysts for polyurethane production based on titanium, bismuth, and other materials appear to have largely replaced mercury catalysts for this use.[270] However, the extent to which mercury catalysts may still be in use for polyurethane manufacture in some countries or regions is not generally known.

Some other chemicals have also historically been manufactured using mercury catalysts such as vinyl acetate and 1-amino anthrachion.[271] It is possible that these and most other uses of mercury catalysts may have been globally discontinued, but this still needs to be verified.

Mercury catalysts, however, remain in large-scale commercial use in the manufacture of vinyl chloride monomer (VCM), and this use appears to still be growing. VCM, whose chemical formula is C_2H_3Cl, is the main feedstock in the manufacture of polyvinyl chloride plastic (PVC), also known as vinyl. VCM is produced using acetylene (C_2H_2) as a raw material. The acetylene is combined with hydrogen chloride (HCl) and flows through a mercuric chloride catalyst to produce the VCM. VCM manufacture from acetylene and a mercuric chloride catalyst was in use in the United States as recently as 2000. [272]

The production of VCM in most countries does not use any mercury catalysts but instead uses a different manufacturing process. In most countries, acetylene is not used as the hydrocarbon feedstock in VCM production, but rather, ethylene is used. An important difference between these two feedstocks is that ethylene is produced from petroleum or natural gas while acetylene is produced from coal.

Until recently, the use of ethylene as the feedstock was considered to be the state-of-the-art process for VCM manufacture. However, as the prices of petroleum and natural gas have increased relative to the price of coal, the acetylene process has become more attractive. This is especially the case in countries such as China that must import petroleum but which have large coal reserves that are mined with low-cost labor. Another factor that has discouraged building new plants using ethylene as a feedstock is the wide fluctuations in the price of petroleum. Enterprises building PVC plants in northwest China near coal mines feel confident they can count on a steady supply of cheap coal at stable prices.[273] These considerations have not only led to the rapid growth of VCM plants using mercury catalysts in China, but they could also apply elsewhere and encourage the further expansion of this industry in other countries and regions.

Based on information provided to the NGO, Natural Resources Defense Council (NRDC), by the Chemical Registration Center (CRC) of China's State Environmental Protection Administration, total PVC production in

China was 1.9693 million metric tons in 2002 and rose to 3.0958 million metric tons in 2004, with 62 PVC manufacturing facilities known to be using mercury catalysts.[274] Information was not available on the further expansion of this industry after 2006, but given the rapid rate of its growth between 2002 and 2004, it is likely that growth has continued.

The catalysts used in the plants are in the form of activated carbon that has been impregnated with mercuric chloride. When the catalysts are installed, they are between 8 percent and 12 percent mercuric chloride. Over time, however, the catalyst is depleted and the amount of mercuric chloride in the catalyst decreases. When the amount drops to about 5 percent, the catalyst is replaced. The fate of the mercury that is lost from the catalyst is not well understood.[275]

According to CRC estimates, the amount of mercury present in catalysts that were used and subsequently replaced in 2004 was 610 metric tons. These spent catalysts were sent to recyclers, who processed them and were able to recover approximately 290 tons of elemental mercury.[276] This suggests that in 2004, the manufacture of VCM in China resulted in as much as 320 metric tons of mercury losses to the environment.*

The international community currently has no data on the mercury emissions from VCM plants that use mercury catalysts or from the recycling facilities that process their spent catalysts. Because the experts who prepared the report had no emissions data to work with, UNEP's "Global Atmospheric Mercury Assessment" treats VCM plants as if they release zero mercury emissions into the atmosphere. This means that that the UNEP estimate of 1,930 metric tons of total global anthropogenic mercury emissions per year from all sources does not count any emissions associated with VCM manufacturing as part of the total.

Because VCM production in China using mercury catalysts appears to be expanding, it is likely that unreported mercury losses from VCM manufacture will grow with time. In addition, if the VCM manufacturers that use mercury catalysts are able to achieve significant savings in their feedstock

* The UNEP "Technical Background Report to the Global Atmospheric Mercury Assessment" estimates 2005 global mercury consumption from VCM manufacturing to be 770 metric tons, a figure we cited earlier. This estimate may take into account growth in the industry from 2004. It also likely does not subtract the amount of mercury recovered by recyclers from the amount of mercury originally present in the used catalysts.

costs compared with VCM manufacturers who do not use mercury catalysts, this might over time create market pressures on manufacturers in other countries to convert from PVC manufacturing using petroleum and natural gas as feedstocks to the possibly less costly acetylene/mercuric chloride manufacturing process.

A global mercury-control treaty will need to directly address the use of mercury catalysts in chemicals manufacture. For processes other than VCM manufacture, it may not be difficult for governments to agree to immediately ban them (or to quickly phase them out if some of these processes are still being used in some countries). Doing this can shut the door on the possible future resurgence of these processes.

Agreements on treaty measures to control the use of mercury catalysts in VCM production, however, will likely be more difficult to reach. As an immediate step, the convention should require better monitoring and international reporting on the use of mercury catalysts and on the fate of mercury losses associated with VCM manufacture. Ideally, the goal should be to establish a phase out schedule for this and all other uses of mercury-catalysts in industrial chemistry, but this will likely require a longer-term effort. As interim steps, some have suggested promoting research into alternative, mercury-free catalysts that can be used with acetylene feedstocks. Others have suggested research into developing technologies to produce ethylene from coal which would allow using cheaper coal to manufacture VCM by processes that do not require mercury catalysts. Both these suggestions, though, are problematic for two reasons. As the world grapples with controlling climate change, it is not a good idea to promote new coal technologies that are major greenhouse-gas emitters. Also, even though the manufacture of VCM using ethylene as a feedstock avoids mercury releases, it is still an extremely dirty process that creates and releases other serious environmental pollutants such as dioxins.

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9. Unintentional Mercury Sources

Unintentional sources of mercury include burning, cleaning and refining fossil fuels, mining and refining metal ores, and the use of mercury-containing materials in high-temperature processes such as cement production. According to UNEP's estimates, air emissions from these unintentional sources contribute more than 65 percent to total atmospheric global mercury emissions from all anthropogenic sources.

9.1 Coal-Fired Power Plants

According to UNEP's 2008 "Global Atmospheric Mercury Assessment" report, the largest source of global anthropogenic mercury emissions is burning fossil fuels, especially coal. The assessment estimates that electric power plants generate 25 percent of all global anthropogenic mercury emissions and that industrial and residential heating generates an additional 20 percent.[278] Mercury is present in coal in what is considered to be trace amounts, generally ranging from 0.01 mg to 1.5 mg of mercury per kilogram of coal (ppm).[279] However, the quantities of coal burned each year for electric power and for heating are so enormous that, according to UNEP estimates, in 2005, coal combustion from these sources released 878 metric tons of mercury emissions into the atmosphere.[280]

Coal Combustion and Greenhouse Gas Emissions

Coal combustion also accounts for approximately 20 percent of all global greenhouse gas emissions.[281] Proposed measures to reduce coal combustion are currently being debated in the context of global intergovernmental negotiations to adopt a new climate-change treaty that will replace the Kyoto Protocol. In climate-change negotiations so far, the governments of several large countries have indicated an unwillingness to agree to binding measures that will significantly restrict their coal combustion. Some of them have cited an urgent need to greatly expand national electricity generation as an important part of their national economic-development strategies.

It is highly unlikely that certain influential governments who continue to oppose binding restrictions on coal combustion in the context of climate-change negotiations will agree to similar binding restrictions on coal combustion during mercury-treaty negotiations. It would therefore be unrealistic to view mercury-treaty negotiations as an alternative venue in which to secure agreement from reluctant governments to restrict greenhouse gas emissions from coal-fired power plants before these same governments are also ready to revise their negotiating posture in climate-change negotiations.

Nonetheless, mercury-treaty negotiations create a second venue for high-profile international discussions about the harmful impacts of coal combustion, and they open up additional opportunities for promoting energy efficiency and conservation together with the expansion of renewable energy sources.

To calculate the true costs of using coal-combustion technologies, one must incorporate into the cost equation its harms to the global environment and to human health. These include the mercury-related harms to human health and the environment addressed in this booklet. They also include harms associated with sulfur dioxide, nitrogen oxide, and numerous other toxic and hazardous pollutants released from coal plants. Finally, calculations of the true costs of using coal-combustion technologies must, of course, take into account costs associated with greenhouse gas emissions and climate change.

Efforts to phase out coal-combustion technologies will succeed when global mechanisms are in place to ensure that these and all the other external costs associated with coal combustion are internalized into the price of coal-derived energy. When this happens, it will become clear that energy-efficiency interventions and alternative-energy sources are actually less costly than coal technologies. Alternatives will then be able to quickly outcompete and replace coal.

Although mercury-treaty negotiations are not likely to become an alternate venue for negotiating climate change prevention measures, the mercury-treaty-negotiating process can be very useful in advancing public understanding and governmental recognition of the health and environmental costs associated with coal combustion. The mercury negotiations also have the potential of establishing binding measures that mandate governments—at least under some conditions and on some schedule—to require that new or existing power plants in their counties meet certain minimum-efficiency and/or pollution-control standards. Higher pollution-control standards will generally increase costs. Furthermore, the treaty may include provisions that promote or require the use of cost-effective, available, alternative technologies that eliminate or minimize mercury emissions if such technologies can satisfy national or local energy needs. Finally, a mercury treaty will likely establish mechanisms for providing financial and technical assistance that support the implementation of its measures, and these might complement financial and technical assistance provided under an international climate-change regime.

As a first approximation, the amount of mercury emissions released from a coal-fired power plant is related to the amount of coal it burns to generate a unit of electricity. Other things being equal, a more efficient power plant uses less coal to produce a kilowatt hour of electricity and thereby emits less mercury per unit of electricity than does a less efficient plant.

Increases in the efficiency of coal-fired power plants can be accomplished by measures such as improving or replacing burners, optimizing combustion, improving the efficiency of the boiler and heat transfer devices, improving plant operation and maintenance, and other measures. There have been claims that in some cases, these approaches can more than double power plant efficiency. A combination of economic factors and pollution-control regulations can also result in decisions to shutter old, inefficient power plants and industrial boilers and replace them with more efficient ones or with alternative energy sources.

Air pollution control devices (APCDs) that clean the flue gases of power plants can capture mercury and reduce emissions. The most common of these capture fly ash, the fine particles that rise with the flue gases. Some also capture acid gasses. APCDs include electrostatic precipitators, fabric filters, and flue gas desulfurization systems. Strategies for controlling mercury pollution should therefore include the use of new APCDs: Power plants should retrofit existing flue gas cleaning equipment to improve mercury capture and use additional flue gas cleaning devices. They should also employ techniques that can increase the mercury-capture efficiency of their existing APCDs.

The efficiency of mercury capture by APCDs is influenced by several factors. At the high temperatures of the combustion zones of coal-fired power plants, most of the mercury in the coal is released into the exhaust gas in the form of gaseous elemental mercury. This gaseous elemental mercury is not water soluble, and APCDs cannot easily capture it. Some of the elemental mercury, however, is oxidized by chemical reactions with other substances present in the flue gas. The oxidized mercury (often in the form of mercury chloride) is water soluble, and flue gas desulfurization systems can capture it. Oxidized mercury also has a tendency to associate with the particles in the flue gas and form particulate-bound mercury. Fabric filters and electrostatic precipitators can capture much of this particulate-bound mercury.[282,283]

Depending on the relative proportions of elemental mercury, oxidized mercury, and particle-bound mercury in the flue gases—and depending on the effectiveness of the APCDs in use—the removal efficiency of mercury from flue gas reportedly ranges between 24 percent and 70 percent.[284]

The proportion of the elemental mercury in the flue gas that is converted into oxidized mercury and into particle-bound mercury depends on many factors, including the flue gas composition and the amount and the properties of the fly ash that is present. These factors, in turn, are dependent on the type and properties of the coal, the combustion conditions, and the design of the boiler and heat-extraction equipment. When coal has relatively high chlorine content, more of the elemental mercury in the flue gas tends to be oxidized; when coal has relatively low chlorine content, less of the elemental mercury tends to be oxidized. Thus, measures that increase the amount of chlorine present in the process can, under some conditions, increase the mercury-removal efficiency of APCDs.*

Additionally, unburned carbon in fly ash tends to absorb the mercury in the flue gas and create particle-bound mercury, much of which can be captured by APCDs. Some, therefore, support interventions that increase the amount of unburned carbon present in the fly ash with the intent of thereby increasing the mercury-removal efficiency of APCDs.[286] Such interventions, however, have the potential to reduce efficiency and increase risks from pollution caused by products of incomplete combustion. Finally, when coal-fired plants use selective catalytic reduction (SCR) to control releases of nitrogen oxide, this process also can convert elemental mercury to oxidized mercury and enhance mercury removal by APCDs.[287]

Several techniques that maximize the conversion of gaseous elemental mercury in the flue gas into oxidized mercury and/or particle-bound mercury have been recommended to optimize the capture of mercury using existing combustion and flue gas cleaning equipment. These techniques include the following:

- Adding reagents to coal or to the high-temperature combustion gases to promote the oxidation of elemental mercury
- Modifying the combustion process to increase the amount or the reactivity of unburned carbon in fly ash to increase the adsorption of mercury and/or to promote the oxidation of elemental mercury

* Unfortunately, increased chlorine content in the flue gas can have the negative consequence of increasing the unintentional formation and environmental release of dioxins, furans, and other persistent organic pollutants (POPs), which are also serious global pollutants. The Stockholm Convention on Persistent Organic Pollutants seeks to minimize and, where feasible, eliminate the formation and release of these POPs.

- Blending coal to change the composition of the flue gas and the properties of fly ash to increase the formation of oxidized and/or particulate-bound mercury
- Combining the above steps[288]

Mercury in Wastes Recovered from Pollution-Control Devices

When power plants use APCDs to remove mercury from flue gases, there are concerns about the long-term fate of this mercury. Some of these wastes go to landfills or dumps where they have the potential to give off mercury air emissions or to leach mercury into surrounding soils and water systems. Some plants process wastes from control devices on-site, which can result in local environmental pollution and discharges of mercury into waterways. Much of these wastes, however, are recycled for use in the manufacture of construction materials and other uses.

According to an industry trade association and lobby group, the American Coal Ash Association, the sale and use of coal-combustion products is a multi-billion dollar industry. The association defines coal-combustion products as including power plant by-products such as fly ash, bottom ash, boiler slag, and various other residues from flue gas emission-control and desulfurization devices.[289]

Wastes from flue gas desulfurization systems (FGDs) can be recovered and used to produce synthetic gypsum. In the United States, for example, 75 percent of this waste is recovered and used. Most goes into making synthetic gypsum wallboard, a building material widely used in the inside of homes.[290] An average of about 8 tons of gypsum is present in the wallboards of a new U.S. home. As recently as 2001, 15 percent of the total gypsum supply in the U.S. came from coal wastes. By 2009, the use of gypsum derived from coal wastes more than tripled and now accounts for more than half the gypsum used in the U.S.[291]

Because FGDs operate at relatively low temperatures, studies have found that during their use, some volatile trace elements condense from the vapor phase and are removed from the flue gas. It has been suggested that FGDs may remove some gaseous elemental mercury from flue gas in this way.[292] This suggests, however, that elemental mercury may be present in the wastes from FGDs and has the potential for revolatilization and release.

There is not much data on mercury releases from waste-derived synthetic gypsum, but the available data is troubling. Tests were done at a wallboard-manufacturing plant that uses wastes recovered from power plant FGDs. Researchers measured the mercury content of the incoming synthetic gypsum and the mercury content of the outgoing gypsum and calculated the mercury that is lost during the manufacturing process. A series of five tests were done on wallboard products that used synthetic gypsum derived from different power plants and from different configurations of pollution-control devices. In the first test, the reported total mercury that was lost between the incoming gypsum and the final product was 5 percent. In the second test, the reported total loss was 8 percent. In the third test, the reported total loss was 46 percent. The total losses in the fourth test were not reported but appear to have been small. And in the fifth test, the total reported loss was 51 percent.[293]

These test results suggest that there may be significant releases of mercury into the environment and the workplace during the manufacture of wallboard from waste-derived synthetic gypsum. There may also be mercury releases from synthetic gypsum before the material even reaches the wallboard plant. The growing use of waste-derived synthetic gypsum may negate the effectiveness of FGDs in removing mercury from flue gas because much of the mercury originally removed by FGDs may be subsequently reemitted into the environment before or during the manufacture of the wallboard.

The above-described tests and the report on them were done for the U.S. EPA by scientists at a leading company that manufactures wallboard with synthetic gypsum. The report indicated that the mercury content of the outgoing wallboard in the tests ranged from a high of 0.95 ppm to a low of 0.02 ppm.[294] Little independent data, however, appears to be available on the mercury content of wallboard made from synthetic gypsum. One study by the U.S. EPA did report that the mercury content of two tested samples of wallboard manufactured in the U.S. were 2.08 ppm and 0.0668 ppm. The same study found that the mercury content of two tested samples of wallboard manufactured in China were 0.562 ppm and 0.19 ppm.[295] Much more independent data is needed on the mercury content of waste-derived synthetic gypsum wallboards.

There appear to be no available studies on the mercury exposure of workers who install these wallboards. One published study by industry scientists and consultants, however, purports to show that mercury in the indoor air of rooms with wallboards made from synthetic gypsum is not a cause for concern. It is not clear from the study, however, how its methodology and results can be used to justify this conclusion. The report on the study does provide some interesting data. It measured mercury fluxes in small chambers containing samples of natural gypsum wallboard and chambers containing samples of synthetic gypsum wallboard. It found fluxes of 0.92 ± 0.11 nanograms per square meter (ng/m^2) per day for natural gypsum wallboard and found fluxes of 5.9 ± 2.4 ng/m^2 per day for synthetic gypsum wallboard.[296] That is, the measured mercury fluxes associated with the synthetic gypsum wallboard were six times higher than those associated with the natural gypsum wallboard. This suggests a possible cause for concern. Independent research on mercury releases from synthetic gypsum would be most useful.

Fly ash that has been captured in the fabric filters and electrostatic precipitators of coal-fired power plants is also put to use. According to an industry trade association, 70 million tons of fly ash are produced in the United States each year. Nearly 45 percent of this fly ash is subsequently recycled for some use, and the power plant operators are doing what they can to increase this percentage. Much of the fly ash is mixed in various portions with cement to make concrete. Industry sources claim that the mercury is tightly bound to the fly ash and very little mercury is released from the finished concrete or during concrete mixing and drying. There does not, however, appear to be sufficient independent data available to support this claim. Nor does there appear to be any data available that estimates total global mercury emissions associated with the manufacture and use of building materials derived from fly ash. Furthermore, as plant operators around the world introduce technological innovations to increase the mercury-capture efficiencies of their air pollution control devices, the total mercury content of fly ash and other APCD residues will grow. Work is needed to track the ultimate environmental fate of mercury contained in fly ash and in other residues captured by APCDs.

Power plants send some of the fly ash captured in electrostatic precipitators and fabric filters to cement kilns, where the fly ask is mixed with other raw materials and the mixture is then heated to as high as 1450°C. At these high temperatures, virtually all of the mercury in the fly ash—mercury that had originally been removed from power plant flue gas by electrostatic precipitators and fabric filters—is vaporized and again released, this time into cement kiln flue gas.[297]

Power plant operators seek uses for their coal-combustion products in order to reduce their waste disposal costs. As the world moves toward stricter regulatory controls on mercury emissions from coal-fired power plants, global supplies of mercury-rich fly ash and other APCD residues will grow rapidly as will incentives to expand existing markets for APCD residues and to find new ones.

The practice of reusing APCD residues, however, appears to remobilize much of the mercury that APCDs at coal power plants had previously captured. A global mercury treaty should give careful consideration to the prevention of practices that result in mercury reemissions that contribute to global atmospheric mercury or that pollute the indoor air of homes and workplaces.

Local and Global Aspects of Mercury Pollution

Mercury emissions from coal-fired power plants often attract more public and political attention and study than do most other mercury pollution sources. One reason is that the air emissions from poorly controlled coal-fired power plants include not only gaseous elemental mercury emissions but also large quantities of particle-bound mercury and oxidized mercury (such as mercury chloride and mercury oxide). Though most of the gaseous elemental mercury emissions remain in the atmosphere for a long period of time, the particle-bound mercury and the oxidized mercury tend to have much shorter residency in the atmosphere and tend to fall to earth downwind of these power plants. For example, research in the U.S. state of Ohio found that more than 70 percent of the mercury associated with precipitation (wet deposition) came from local coal-fired power plants.[298] Because much of a power plant's particle-bound mercury and oxidized mercury emissions falls to earth relatively near the plant, this tends to increase the amount of methylmercury in lakes and rivers downwind of power plants and in the fish caught in them. When regulators and the public become aware of this connection between poorly controlled coal-fired power plants and heightened levels of methylmercury contamination in fish from downwind lakes and rivers, public and political pressure for monitoring and better controlling power plant emissions often intensifies.

On the other hand, any anthropogenic mercury source that releases mainly gaseous elemental mercury emissions will tend to have a much smaller localized environmental impact. Gaseous elemental mercury emissions tend to remain in the atmosphere for six months to two years and tend to be spread by winds all across the earth. This mercury eventually also falls to earth, but with little, if any, obvious connection between the pollution source and the water body where the polluted fish are found. As a result, there is often less public and political understanding of the relationship between sources of gaseous elemental mercury emissions and their eventual environmental impact. For those human activities that mainly release mercury into the atmosphere in the form of gaseous elemental mercury, the impact tends to be globally diffuse rather than local or regional. Therefore, a global approach is needed to fully understand the impact of such emissions, and only a global approach can effectively protect human health and the environment from them.

Another strategy that coal power plants can use to reduce mercury emissions is coal cleaning and other forms of coal preprocessing. Plants widely use coal cleaning on bituminous coal to remove mining residues and to reduce ash and sulfur. Current common bituminous coal-cleaning practices are estimated to reduce mercury emissions from power plants by approximately 37 percent.[299] More advanced coal-cleaning and coal-treatment processes that can achieve higher mercury-removal efficiencies have also been discussed and promoted. One example that has been cited is K-fuel technology. This is a proprietary technology that uses heat and pressure to physically and chemically transform low-rank fuels into low-moisture, high-BTU solid fuels. The process removes ash and mercury from the coal and thus has the potential to produce fuels with low mercury content and with increased heating value.[300]

In most cases, decisions by power plant or boiler operators to use cleaned or treated coal are driven by economic considerations such as the need to increase the fuel efficiency of available coal or the need to meet pollution-control standards without large new investments in plant efficiency or APCDs. Expert opinion, however, appears to be divided on the extent to which advanced coal-cleaning and coal-treatment processes are economically competitive with other potential mercury-control technologies.[301] A global mercury treaty, however, might influence such economic calculations: It might encourage additional research and development in this area, and it may even create incentives for operators to both improve their plant efficiencies and APCDs and to also use coal that has been subjected to advanced cleaning or treatment processes.

To review, many different techniques can be used to reduce mercury emissions from coal-fired power plants and industrial boilers. These include the following:

- Measures to increase power plant and boiler efficiency
- Installing and/or upgrading air pollution control devices
- Using various techniques to more completely convert gaseous elemental mercury in flue gases into oxidized mercury and/or particle-bound mercury
- Cleaning, blending, or otherwise preprocessing coal
- Substitution, that is, deciding to replace coal-fired power plants with alternative energy sources that generate less mercury pollution or that generate no mercury pollution

A mercury-control treaty can promote research into improving the efficiency and reducing the price of mercury-reduction techniques and technologies such as those listed above. Additionally, it can promote research on approaches that can expand the available choices. In the end, however, which of these techniques, if any, that an operator decides to employ in order to reduce mercury pollution will depend on many factors. One important factor will be the characteristics and prices of locally available coal supplies, because the performance of different mercury-control techniques may vary depending on the characteristics of the coal being burned. Other important factors include the local cost and availability of technologies and techniques to enhance facility efficiency or to effectively remove mercury from flue gasses; the cost of appropriately managing any resultant wastes, especially mercury waste releases or transfers; and the availability of the local know-how necessary to make good technology selections and to then effectively deploy them.

In most cases, however, even if effective mercury-control techniques and technologies are available, power plant operators will not invest in them in the absence of a regulatory driver, an economic driver, or both. This is because power plant operators have a strong incentive to generate electricity at the lowest possible cost. On the other hand, a global treaty with legally binding measures can minimize the economic advantage that the biggest polluters now get and can help level the playing field for everyone.

However, operators will spend their own money to reduce mercury emissions if driven to do so by government policy and government regulations, especially if they understand that not complying will cost them even more than their compliance costs. Additionally, even in the absence of a specific binding requirement, operators will agree to employ effective mercury-reduction techniques if they are given appropriate incentives. Such incentives can include financial or technical assistance. Or they can include enhanced access to technologies and techniques that improve plant-operating efficiencies and thereby reduce the cost of producing a unit of energy output. The challenge to governments involved in negotiating the new global mercury-control treaty will be to reach agreements on a package of measures that includes both well-designed and enforceable, legally binding regulations and also sufficient financial and technical incentives that, when put together, will be able to drive significant global reductions in power plant mercury pollution.

The negotiated package will need to reconcile the competing goals of positively contributing to reductions in global mercury emissions while, at the same time, maintaining or even enhancing national economic development and poverty-reduction objectives. Achieving this will take hard work and creative efforts by negotiators who recognize both the serious harms to human health and the environment caused by mercury pollution but also the urgent need of many developing countries to enhance their access to reliable electricity by expanding national energy-generation capacity.

In order to reach meaningful agreements on controlling mercury releases from coal-fired power plants, it may be necessary to phase in binding and enforceable control measures over a period of time. The measures might be formulated in terms that are similar to the provisions on best available techniques (BAT) contained in the Stockholm Convention on Persistent Organic Pollutants. These measures could, under agreed-upon conditions, require governments that are party to the treaty to mandate and/or promote the use of BAT at coal-fired power plants in their countries. Additionally, treaty BAT measures could be strictly linked to the treaty provisions that address giving technical and financial assistance to developing countries and countries with economies in transition in order to ensure that parties can implement the treaty's provisions without undermining their national economic development and poverty-reduction objectives.

As with the Stockholm Convention, a fully-elaborated BAT definition and guidelines need not be written into the treaty text itself. Rather, the treaty could define BAT in conceptual terms and instruct its Conference of Parties (COP) to establish a BAT Experts Group to prepare draft BAT guidelines for adoption by the COP and to also periodically review and update the guidelines. These evolving BAT guidelines might include revisions and updates that address the schedules and conditions under which treaty BAT provisions become legally binding.

On a parallel track, the COP could also undertake periodic reviews of the practical availability of technical and financial assistance that support the implementation of the BAT guidelines. The outcomes of such reviews might be closely linked to decisions on the schedules and conditions under which the BAT provisions become legally binding. Such a two-track approach might contribute to agreements on a treaty that can impose meaningful controls on coal-fired power plants without undermining national economic development and poverty-reduction objectives.

As in the Stockholm Convention, BAT guidelines might additionally include provisions that encourage operators wishing to build a new power plant or to substantially modify an existing one to give consideration to alternative-energy technologies that release less or no mercury into the environment. If such provisions are written into the guidelines, then technical or financial support that might become available to assist in the implementation of mercury treaty BAT provisions could be used to instead deploy alternative-energy technologies.

9.2 Other Fossil Fuel Combustion

Commonly reported estimates of mercury emissions from fossil fuel combustion sources other than coal-fired power plants appear to be less complete and less accurate than are estimates of emissions from coal-fired power plants. Many governments in Western Europe, North America, and elsewhere have required extensive monitoring of the stack-gas emissions of coal-fired power plants in their countries, and this monitoring has often included measurements of mercury emissions. As a result, much data has been collected on mercury emissions from coal-fired power plants in many countries. This data has made possible the development of emissions factors that have been used to roughly estimate power plant mercury emissions even in countries where power plant stack-gas monitoring has been less common. On the other hand, estimated mercury emissions from fossil fuel combustion sources other than coal-fired power plants appear to be based on less data and less-extensive study.

Residential Heating

Mercury emissions from coal combustion for residential and commercial heating, cooking, and other similar sources have been estimated to be approximately 20 percent of total global anthropogenic mercury emissions.[302] The use of coal for residential heating also releases greenhouse gasses into the environment. It additionally releases other noxious pollutants that contribute to serious local air pollution and associated respiratory and other diseases. Therefore, measures to promote and enable the replacement of coal-burning furnaces and stoves with less-polluting residential-heating alternatives will not only reduce total global mercury pollution but can also help reduce global greenhouse gas emissions as well as harmful local air pollution.

Petroleum Products

Refining and burning petroleum and its products also contributes to global mercury pollution. According to an industry technology provider, mercury is a common component of petroleum, and the processing of petroleum is often accompanied by generation of waste streams that contain some mercury. Mercury-removal systems are common in the industry, and the main incentive for their use is to protect the plant's equipment and catalysts. Plants without mercury-removal systems generate mercury-contaminated sludge, sediments, and other waste streams. In some locations where the mercury concentration in process feeds is high, treatment systems for properly managing mercury wastes may not be readily available or affordable.[303]

The UNEP "Technical Background Report" states that there is very limited data on the concentrations of mercury present in crude oils and indicates that there are reports in the literature of mercury concentrations in crude oil as high as 30 ppm. It concludes, however, that the best data suggests that concentrations of mercury in crude oil tend to be in the range of 0.01 ppm and 0.5 ppm. (By comparison, the "Technical Background Report" indicates that the concentrations of mercury in coal tends to be in the range of 0.01 ppm and 1.5 ppm.) The "Technical Background Report" suggests that mercury emissions associated with the combustion of petroleum products tend to be between one and two orders of magnitude lower than mercury emissions from coal combustion, but this conclusion is admittedly based on limited data. More work is needed to develop better estimates of mercury atmospheric emissions and other releases from plants that process petroleum and its products, and work also is needed to estimate mercury emissions from facilities and vehicles that burn petroleum products.

Petroleum Products from Shale and Oil Sands

Producing petroleum products from shale is expensive at current oil prices and at present only a few deposits of oil shale are being used to produce petroleum products. Oil production from shale currently takes place in Brazil, China, Estonia, Germany and Israel.[304] No data appears to be available on mercury releases from the production of oil from shale. Nonetheless, processing shale to produce oil can be a source of mercury releases to the environment. Large reserves of oil shale exist and as oil prices rise, these reserves may increasingly become utilized for oil production.

A 1983 study of Green River Formation shale suggests that producing oil from shale can release large quantities of mercury to the environment.[305] The study estimates that between 8 and 16 kilograms of shale must be processed to produce each liter of product oil. Trace quantities of mercury are present in the shale in concentrations that are typical for sedimentary materials. During processing, the shale is heated to 500°C and there is a potential for the mobilization of almost all its mercury content due to the volatility of mercury and its compounds. The study estimates that a facility that processes sufficient Green River Formation shale to produce 8 million liters of oil per day would generate approximately 8 kilograms of mercury air emissions per day. This suggests that a global mercury control treaty should include provisions to control mercury emissions from shale oil production in anticipation of a possible future date when greater quantities of shale oil are processed.

The production of petroleum products from oil sands (also called tar sands) can be another source of mercury pollution. Little data is available on mercury releases from this source, but a recent study has found evidence that the Canadian oil sands industry has released significant quantities of mercury to the Athabasca River and its watershed.[306] More and better data should be made available on mercury releases from both the oils sands industry and the shale oil industry.

Natural Gas

There is also little information available on mercury releases associated with the combustion of natural gas. As indicated in an earlier section of this booklet, mercury is routinely removed from natural gas that is liquefied because even in quite low concentrations, mercury can corrode the downstream equipment used during the process. However, outside of the European Union, little data is available on the environmental fate of this removed mercury.

Also, some countries and regions have such high concentrations of mercury in their natural gas that operators must remove mercury from the gas before distributing it. This is reportedly the case in some countries bordering the North Sea and in Algeria and Croatia. Based on data provided in UNEP's "Summary of Supply, Trade and Demand Information on Mercury" report, it appears that natural gas with similarly high levels of mercury may be found in some South American, Far Eastern, and Middle Eastern countries and in South Africa, Sumatra, and possibly other countries as well. Presumably, if mercury is not removed from such gas, and if the gas is distributed and used, this will result in significant mercury emissions. As with oil products, there is clearly a need for more data and more work in this area by UNEP and others.

9.3 Cement Production

According to UNEP's "Global Atmospheric Mercury Assessment," cement kilns annually release an estimated 189 metric tons of mercury into the atmosphere. This is approximately 10 percent of UNEP's estimated total of global anthropogenic mercury emissions to the atmosphere.

Much of the mercury released from cement kilns occurs naturally in the raw materials used to manufacture cement. These include sources of calcium, the element of highest concentration in cement. Raw materials from which calcium is derived include limestone, chalk, sea shells, and other naturally occurring forms of calcium carbonate. Another raw material source category is ores and minerals that contain elements such as silicon, aluminum, or iron. These include sand, shale, clay, and iron ore.[307] These raw materials can all contain some quantity of naturally occurring mercury. They are ground and mixed together before going into the kiln.

Many cement kiln operators additionally mix into these naturally occurring raw materials quantities of the fly ash from power plant air pollution devices. As noted above, this fly ash contains mercury that was previously captured by fabric filters or electrostatic precipitators at the coal-fired power plants where the fly ash originated. In 2005, 39 cement plant operators in the United States reportedly mixed a total of 2.7 million metric tons of fly ash into the raw materials going into their cement kilns.[308]

In addition to the raw materials, cement kilns also use large quantities of fuels to heat the raw materials to a high temperature. Fuels used in cement kilns include coal, petroleum coke, heavy fuel oil, natural gas, landfill off-gas, and oil refinery flare gas. In addition to these primary fuels, combustible waste materials are also often fed to kilns, including used tires and hazardous wastes.[309] These fuels can also contain significant quantities of mercury. Landfill off-gas may be especially problematic because it may contain mercury that had originally entered the landfill through end-of-life mercury-containing products. More information is needed on the mercury content of all the fuels used at cement kilns because all are likely to be significant sources of mercury.

The mixed raw materials, often including fly ash, are fed into the kiln and heated to temperatures as high as 1,450°C. At these temperatures, the elements in the raw materials melt and react with one another to produce silicates and other compounds. The material produced in the kiln is called clinker, and it contains two-thirds or more calcium silicates by weight. The clinker is then ground into a find powder, which is the main constituent of cement.[310]

At the high temperatures reached in the cement kiln, the mercury that is present in the raw materials, the fuel, and the fly ash vaporizes. Air pollution control devices may capture some in the cement kiln stack, but much of this mercury is released into the atmosphere.

A List of Cement Kiln Pollutants

Cement kilns release not only mercury and its compounds into the atmosphere but also many other pollutants. The main pollutant released from cement kilns is the greenhouse gas carbon dioxide, which is produced by both fuel combustion and reactions taking place in the raw materials.

Other cement kiln emissions include the following:

- Lead and its compounds
- Chromium and its compounds
- Manganese and its compounds
- Zinc and its compounds
- Nickel and its compounds
- Benzene, ethylbenzene, toluene, xylene, ethylene glycol, and methyl isobutyl ketone
- Polycyclic aromatic hydrocarbons
- Dioxins, furans, and PCBs
- Tetrachloroethylene and dichloromethane
- Particulate-matter emissions
- Nitrogen oxides
- Sulfur dioxide and sulfuric acid
- Carbon monoxide
- Organically bound carbon
- Gaseous inorganic chlorine compounds such as hydrogen chloride
- Gaseous inorganic fluorine compounds[311,312]

In August 2010, the U.S. EPA finalized new regulations that will control mercury emissions from all U.S. cement kilns. According to agency claims, when these new rules are fully implemented in 2013, mercury emissions from U.S. cement kilns will be reduced by 7.5 metric tons (16,600 pounds). This would be a reduction of 92 percent from present levels.[313]

The regulation establishes mercury emission limit values for cement kilns. Under normal operating conditions, new cement kilns will be limited to 21 pounds (9.5 kg) of mercury emission per million metric tons clinker produced. Existing mills will be limited to 55 pounds (25 kg) of mercury emissions per million metric tons of clinker produced. Operators will be required to continuously monitor their mercury emissions to ensure they comply with the emission limit values. The new rules will relax existing U.S. restrictions on the use of fly ash as a feedstock in cement kilns but only after the rules on mercury emission limit values are being enforced (and presumably met). Besides controlling mercury emissions, the new rules will also control cement kiln emissions of total hydrocarbons, particulate matter, acid gases, sulfur dioxide (SO2), and nitrogen oxides (NOx).[314] Continuous monitoring of mercury emissions from cement kilns is also a legally binding requirement in at least two other countries: Germany and Austria.[315]

The U.S. EPA estimates that compliance with its new cement kiln rules will cost the industry between USD $926 million and $950 annually starting in 2013, when the rules take effect. The EPA additionally estimates that the rules will yield health and environmental benefits valued at between USD $6.7 billion and $18 billion annually.[316]

Based on the U.S. EPA's new cement kiln rules, three observations can be made:

1. Substantially reducing mercury emissions from cement kilns is technically feasible.

2. There are significant costs associated with reducing mercury emissions from cement kilns.

3. The health and environmental benefits achieved by substantially reducing mercury emissions from cement kilns have a value that can be between seven and 20 times greater than the costs of reducing the emissions.

A global mercury-control treaty can and should promote and require substantial reductions in mercury emissions from cement kilns, including requirements for the continuous monitoring of mercury emissions and the progressive phase-in of strict mercury emission limits. To be acceptable, however, such provisions may need to be closely linked to the availability of adequate technical and financial assistance to developing countries and countries with economies in transition.

9.4 Metals Mining and Refining

Mercury and mercury compounds are often present, sometimes in relatively high concentrations, in the ores from which metals are produced. According to UNEP's reported emission estimates, industrial gold production (not counting artisanal and small-scale gold mining) accounts for 5 percent to 6 percent of global mercury emissions from human activities, while mining and smelting metals other than gold account for approximately 10 percent of the total. According to the report, mercury is not intentionally used in mining or in producing metals other than gold, nor is the intentional use of mercury in industrial gold mining the norm. Therefore, intentional mercury use contributes only a small part to the mercury emissions from industrial mining and refining operations.[317] This suggests that approximately 15 percent of the total of all anthropogenic mercury emissions comes from unintentional mercury releases associated with industrial-scale metals mining and refining operations and facilities.

UNEP's "Global Atmospheric Mercury Assessment" report indicates that one of the mechanisms contributing to mercury releases from mining is the weathering of newly exposed mercury-containing rocks. The report suggests, however, that the main source of mercury emissions from industrial mining and refining is the processing of ores that have high mercury content, especially when these metal ores are processed using high-temperature smelting or thermal roasting. The report further suggests that air pollution control devices on smelters can prevent mercury emissions in the same ways that APCDs prevent emissions from coal-fired power plants.[318]

Silver, gold, copper, lead, zinc, and mercury all tend to occur in the same or similar geological formations and tend to be intermixed.[319] The amount of mercury in ore varies greatly. According to a U.S. EPA source, gold ores in the U.S. typically contain between 0.1 ppm and 1,000 ppm mercury, zinc ores typically contain between 0.1 ppm and 10 ppm mercury, and copper ores typically contain between 0.01 ppm and 1 ppm mercury.[320] A recent study estimated that primary zinc-production facilities in China released between 81 and 104 metric tons of mercury emissions into the atmosphere between 2002 and 2006.[321] Another recent study found that modern-scale production facilities equipped with pollution-control devices such as an acid plant and a mercury-reclaiming tower can significantly reduce mercury emissions from zinc smelters in China.[322]

Iron ore typically contains less mercury than most other metal ores. In the U.S. state of Minnesota, where iron ore is mined and processed, for example, tests of the mercury content of the ore have found concentrations as low as 0.001 ppm and as high as 0.9 ppm, although it appears most of the tested ores had mercury concentrations less than 0.32 ppm. Iron ore pellets are heated for processing to reduce the impurities in the ore before it is shipped to primary iron- and steel-making facilities. Minnesota iron ore produces an estimated 300 kg to 350 kg of mercury emission per year.[323]

The main source of mercury emissions in primary iron and steel production, however, is not the ore but metallurgical coke. The coke is made from coal, and iron producers use it to reduce the oxidized iron present in the ore in order to convert it into metallic iron. Most mercury emissions from primary iron and steel production appear to result from the mercury content of the coal and are released when the coke is produced or used. Secondary steel production, on the other hand, does not use iron ore or coke. Instead, it produces steel from steel scraps such as old automobiles and appliances. Nonetheless, there are considerable mercury emissions from secondary steel production that come mainly from mercury-containing switches or other electrical devices that are often present in the scrapped steel.

Metal Ore Mining Is a Huge Source of Mercury Pollution

The UNEP "Global Atmospheric Mercury Assessment" report suggests that most of the global mercury air emissions from metal mining and refining activities derive from smelters and other high-temperature ore refining processes and not from mining itself. It appears, however, that mercury air emissions and other mercury pollution that result directly from metal ore mining may have been underestimated.

This conclusion follows a review of 2008 data found in the U.S. Toxics Release Inventory (TRI),[324] which covers all reported U.S. releases and disposal of mercury and mercury compounds from 46 *metal ore mining* facilities and 143 smelters and other *primary metals refining* facilities.

The data on *metal ore mining* comes from all U.S. establishments that are primarily engaged in developing mine sites or mining metallic minerals as well as establishments primarily engaged in ore dressing and beneficiating (i.e., preparing) operations, which involve crushing, grinding, washing, drying, sintering, concentrating, calcining, and leaching the ore.

The data on *primary metals refining* comes from all U.S. establishments that smelt and/or refine ferrous and nonferrous metals from ore, pig iron, or scrap using electrometallurgical and other metallurgical process techniques.[325]

When we consider the reported air emissions of mercury and mercury compounds from the facilities in the two categories listed (including the total of both *point source air emissions* and *fugitive air emissions*), smelting and refining operations have slightly higher reported air emissions than do metal ore mining facilities. The reported 2008 mercury air emissions from U.S. metal smelting and refining operations is 3.86 metric tons (8,515 pounds); the reported 2008 mercury emissions from U.S. metal ore mining operations is 2.13 metric tons (4,701 pounds).

However, when we compare all the waste releases and waste transfers of mercury and mercury compounds from the facilities in the two categories listed above the picture changes. In 2008, the total of reported mercury releases and transfers from all U.S. metals smelters and refining facilities was 10.06 metric tons (22,174 pounds). The 2008 total of reported mercury releases and transfers from all U.S. metal ore mining facilities, on the other hand, was 2,486.24 metric tons (5,481,215 pounds). In other words, *the total of mercury releases and transfers from all U.S. metal ore mining operations was almost 250 times greater than the total of 2008 mercury wastes and transfers from all U.S. metal smelters and refining facilities*.

This is not to suggest that metals smelters and refiners are not a significant source of mercury pollution. It is only to suggest that metal ore mining is a large and often relatively ignored source of mercury releases to the environment.

Of the almost 2,500 metric tons of mercury and mercury compounds released into the environment in 2008 from U.S. mining operations, almost all of it stayed on-site and was released to land. None (0 pounds) was put into certified hazardous waste landfills, and approximately 10 percent was put into landfills that are not certified for hazardous waste. The majority, approximately 90 percent of the mercury and mercury compounds—a reported 2,205.22 metric tons (4,861,684 pounds)—was just dumped. (The technical description of this waste disposal category is "on-site land disposal other than landfills including activities such as placement in waste piles and spills or leaks.")[326]

When we consider that metal ore mining in the United States (where good data is easily available) makes up only a small fraction of total global metal ore mining and that in the United States alone, the amount of mercury and mercury compounds in wastes dumped at metal ore mining sites in one year (2008) was more than 2,200 metric tons, we see that the global total of mercury and mercury compounds contained in all dumped mining wastes at all past and present metal ore mining operations must be extremely large. These dumped wastes are continuously subject to weathering activities and other natural processes that certainly result in high but unrecorded air emissions, water discharges, and other mercury releases from mining waste dumps.

A global mercury-control treaty will need to address mercury atmospheric emissions and other environmental releases from both nonferrous and ferrous metals mining and refining operations.

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10. Mercury Wastes and Contaminated Sites

Whenever mercury or a mercury compound is intentionally used in a product or a process, mercury wastes are created. Burning fossil fuels, many mining activities, and high-temperature processing of mercury-containing ores and minerals also create mercury wastes. At many locations, mercury wastes are directly released into local soils, local water bodies, and ground water, which leads to mercury-contaminated sites.

10.1 Product Wastes

Much of the mercury content of mercury-containing products is released into the environment at the end of the products' useful life. When the product is incinerated, mercury is released into the incinerator's flue gas: Air pollution control devices capture some of the mercury, but the rest is released into the atmosphere. Mercury captured by APCDs is also sometimes subsequently rereleased into the environment.

When a mercury-containing product is sent to a waste dump or to an engineered landfill, much of its mercury content will escape into the broader environment. One important pathway by which mercury escapes is dump fires and landfill fires. However, even in the absence of fires, some of the mercury in dumps and landfills will volatilize and enter the atmosphere. Water-soluble mercury compounds in landfills can leach from the site and enter water systems. Both elemental mercury and mercury compounds can attach to soils and can migrate off the site due to flooding or other conditions.

A report titled "Mercury Rising: Reducing Global Emissions from Burning Mercury-Added Products," produced by the Mercury Policy Project for the Global Alliance for Incinerator Alternatives (GAIA) and other NGO networks, estimates that between 100 to 200 metric tons of mercury were released into the global environment in 2005 from a combination of medical-waste incineration, the incineration of mercury-added products, the incineration of municipal wastewater sludge (with a contribution from mercury-containing products), landfill fires, and the open burning of wastes that contain mercury-containing products.[327]

Mercury from mercury-containing products is also released from waste dumps and landfills even in the absence of fire. It is released from these products in transit on the way to the landfill, from the working face (active portion) of the landfill, during landfill waste-handling operations, and as a contaminant in the landfill gas. The landfill gas, which is mostly methane and carbon dioxide, is burned, harnessed as an energy source, or vented directly into the atmosphere.[328]

One study found mercury at greater than 10 times background levels in 20 of 200 dumpsters used in transporting waste to a landfill. The mercury levels reached approximately 500 nanograms (ng) per cubic meter in these dumpsters. Another study measured mercury concentrations upwind and downwind of the working face at several landfills and found downwind mercury concentrations significantly elevated over upwind concentrations—often 30 to 40 times higher. Some measurements reached 100 ng of mercury per cubic meter downwind. Researchers also measured the mercury content of landfill gas and found concentrations ranging from a few hundred to several thousand ng per cubic meter.[329]

A study at a landfill site in China measured total gaseous mercury (TGM) in landfill gas and also measured both monomethylmercury and dimethylmercury concentrations in the landfill gas. It found concentrations of TGM in the landfill gas of approximately 665 ng per cubic meter and found combined concentrations of monomethylmercury and dimethylmercury of about 11 ng per cubic meter. The report indicates further that mercury is released directly from landfill soils but no measurements were taken.[330] Another Chinese study found concentrations of TGM in landfill gas as high as 1,400 ng per cubic meter and calculated that the annual amount of mercury contained in the landfill gas escaping from the landfills being studied was as high as 3,300 g of mercury per year.[331] More work is certainly needed to measure mercury emissions and releases from both engineered landfills and also large waste dumps.

According to the UNEP report "Summary of Supply, Trade and Demand Information on Mercury" from 2005, the estimated amount of mercury used in products was as follows:[332]

2005 Mercury Demand for Use in Products (in metric tons)

Product	Low Estimate	High Estimate
Batteries	300	600
Dental Use	240	300
Measuring and Control Devices	150	350
Lighting	100	150
Electrical and Electronic Devices	150	350
Other	30	60
Total	970	1,810

Since 2005, mercury use in batteries has declined while mercury use in lighting has increased. Nonetheless, the amount of mercury added to new products each year likely remains above 1,000 metric tons per year.

Each mercury-containing product has a time-limited useful life after which it is either discarded as a waste or, alternatively, some or all if it is recovered for reuse or recycling. Unfortunately, often when electronics wastes are processed for recovery and recycling, mercury-containing devices are broken up and/or heated, which releases mercury fumes into the workplace and the atmosphere. It appears also that only a small fraction of the waste from end-of-life mercury-containing products is responsibly managed in ways that capture the mercury content of the product and prevent its subsequent environmental release.

The long-term solution to the problem of mercury wastes and mercury-contaminated sites is prevention, the phaseout or minimization of mercury-containing products and processes, and strict limits and controls on unintentional anthropogenic mercury sources. In the interim, mercury-containing discards need to be better managed. The enterprises that produce or sell mercury-containing products should be required by law to take them back at the end of their useful life and to ensure the discarded material is responsibly managed in ways that minimize mercury releases into the environment. In particular, measures should be put in place to ensure that mercury-containing end-of-life products are not incinerated or openly burned, are not sent to dumps or landfills likely to become subject to landfill fires, and are not sent off for electronics-waste reprocessing at locations that are not equipped to properly manage the mercury content of the waste.

10.2 Mercury Process and By-Product Wastes

Information related to mercury-process and by-product wastes has already been presented earlier in this booklet in sections addressing mercury supply, small-scale gold mining, mercury-cell chlor-alkali plants, the use of mercury catalysts in producing vinyl chloride monomer, coal-fired power plants, cement production, industrial-scale metals mining and refining, and other sections.

Some industrial gold and zinc mining and refining operations recover commodity-grade elemental mercury from their by-product wastes. Commodity-grade elemental mercury is also sometimes recovered from chlor-alkali plant wastes, from spent catalysts used in VCM manufacture and, in some cases, even by small-scale gold miners and gold merchants. The recovered commodity-grade elemental mercury then is either reused in the process, reenters the market, or is removed from the market and placed into long-term storage facilities.

Most often, however, industrial and other processes that use mercury as well as those that unintentionally generate mercury wastes do not recover commodity-grade elemental mercury and generally do an inadequate job in preventing their mercury wastes from entering the environment.

10.3 Mercury in Soils and Water

Once mercury contamination is present in soils or in water, all available options for cleanup and remediation are very expensive and are also less than fully satisfactory. In some cases, methods used to clean up contaminated soils and water merely shift the mercury to another medium. For example, some technologies promote the volatilization of mercury from soil or water into the air. In 2007, the U.S. EPA released a report entitled "Treatment Technologies for Mercury in Soil, Waste, and Water" that describes some of the available options.[333]

The report uses the term soil to include soil (a mixture of sand, silt, clay, and organic matter), debris, sludge, sediments, and other solid-phase environmental media. It uses the term waste to include nonhazardous and hazardous solid waste generated by industry. It uses the term water to include groundwater, drinking water, nonhazardous and hazardous industrial wastewater, surface water, mine drainage, and leachate. The following is a summary of treatment technologies available in the U.S.:

Technologies for Soil and Waste Treatment

Technology	Description
Solidification/Stabilization	Physically binds or encloses contaminants within a stabilized mass and chemically reduces the hazard potential of a waste by converting the contaminants into less soluble, mobile, or toxic forms.
Soil Washing/ Acid Extraction	Uses the principle that some contaminants preferentially adsorb onto the fines fraction of soil. The soil is suspended in a wash solution and the fines are separated from the suspension, thereby reducing the contaminant concentrations in the remaining soil. Acid extraction uses an extracting chemical, such as hydrochloric acid or sulfuric acid.
Thermal Desorption/ Retorting	Application of heat and reduced pressure to volatilize mercury from the contaminated medium, followed by conversion of the mercury vapors into liquid elemental mercury by condensation. Off-gases may require further treatment through additional air pollution control devices such as carbon units.
Vitrification	High-temperature treatment that reduces the mobility of metals by incorporating them into a chemically durable, leach-resistant, vitreous mass. The process also may cause contaminants to volatilize, thereby reducing their concentration in the soil and waste.

The report indicates that the solidification/stabilization (S/S) process is the most frequently used technology in the U.S. to treat soil and waste contaminated with mercury. S/S is a commercially available technology that has been used to meet regulatory cleanup levels. The technologies listed in the report other than S/S technologies for treating mercury-contaminated soils and wastes are less frequently used than S/S technologies and are typically used only for specific applications or soil types.

The authors of the report provided no information on the long-term stability of mercury-containing soil and wastes treated using S/S, and they indicated that they did not have the data necessary to provide this information.

More information is certainly needed, not only on the stability of mercury wastes treated with S/S technologies but also, more generally, on the long-term fate of the mercury content of the residues associated with all mercury-waste-treatment technologies. Concerns remain about mercury off-gassing from these residues into the atmosphere over time. Concerns also remain about other pathways through which mercury is released from these residues into the environment.

Technologies for Water Treatment

Technology	Description
Precipitation/ Co-Precipitation	Uses chemical additives to (a) transform dissolved contaminants into an insoluble solid, or (b) form insoluble solids onto which dissolved contaminants are adsorbed. The insoluble solids are then removed from the liquid phase by clarification or filtration.
Adsorption	Concentrates solutes at the surface of a sorbent, thereby reducing their concentration in the bulk liquid phase. The adsorption media is usually packed into a column. Contaminants are adsorbed as contaminated water is passed through the column.
Membrane Filtration	Separates contaminants from water by passing the water through a semi-permeable barrier or membrane. The membrane allows some constituents to pass, while it blocks others.
Biological Treatment	Involves the use of microorganisms that act directly on contaminant species or create ambient conditions that cause the contaminant to leach from soil or precipitate/co-precipitate from water.

Of the water-treatment technologies described above, precipitation/co-precipitation is the most commonly used process in the U.S. to treat mercury-contaminated water. Often, changing properties of the water such as its acidity (pH) or changing the chemical properties of the mercury ($Hg^{2}+$ to Hg^{0}) allow for better removal rates. The effectiveness of this technology is less likely to be affected by characteristics of the media and contaminants compared with the other listed water-treatment technologies.

Adsorption tends to be used in cases when mercury is the only contaminant to be treated, for relatively smaller systems, and as a polishing technology for effluent from larger systems. Membrane filtration is less frequently used because it tends to produce a larger volume of residues than do other mercury-treatment technologies. Bioremediation appears to be limited to pilot-scale studies.

10.4 Long-Term Storage of Elemental Mercury

In the section of this booklet called Mercury Supply, it was noted that both the European Union and the United States have adopted laws or regulations that will ban exports of elemental mercury. In some circumstances, this will require long-term mercury management and storage; in others it will require mercury disposal that is safe for human health and the environment. E.U. regulations classify as waste all mercury recovered from mercury-cell chlor-alkali plants and also mercury recovered from nonferrous mining and smelting operations and the cleaning of natural gas. This means that commodity-grade elemental mercury that is derived from these sources in E.U. countries cannot be sold or used, but instead must be disposed of.

In the United States, the export ban will mean that all supplies of commodity-grade elemental mercury in excess of demand will need to go into storage. Ongoing sources of mercury supply in the United States include mercury that has been recovered from the conversion or closure of chlor-alkali plants, mercury recovered as a by-product from gold mining and certain nonferrous metals refining, mercury recovered from product-collection programs, and other recycled mercury.

According to a UNEP assessment report, in the Latin America and Caribbean Region, the increasing capture of by-product mercury from mining operations and the increasing use of alternatives to replace mercury will result in excess mercury in the region. Governments in the region recognize that this excess mercury must be managed properly and stored to prevent its reentry into the global market. These governments consider identifying environmentally sound storage solutions for mercury a priority.[334]

Although other regions, such as Asia, do not currently appear to have an excess of mercury supply over demand, it is anticipated that this will change after a new global mercury-control treaty is adopted and its provisions enter into force. It is therefore expected that all regions will need to have programs in place to remove excess mercury supply from the market in order to prevent cheap excess mercury from becoming available for inappropriate uses, especially by sectors where legal restrictions on mercury use may be difficult to enforce, such as small-scale gold mining.[335]

The preferred mercury-storage method in some countries, such as the United States, is above-ground monitored storage. For example, the U.S. military has a large stockpile where mercury is stored in 76-pound flasks. These flasks, in turn, are sealed in airtight 30-gallon drums. There are six flasks per drum and five drums per pallet. Inside the drums, the flasks are individually sealed in plastic bags, separated by dividers, and placed on an absorbent mat that doubles as cushioning material. The drums rest on catch trays on wooden pallets on sealed floors. The pallets are not stacked in order to facilitate inspection and air monitoring.[336] This is likely to be an adequate approach to prevent mercury from escaping the warehouse so long as there is adequate maintenance and monitoring; so long as the warehouse does not become subject to a natural disaster such as an earthquake, flooding, or cyclone force winds; and so long as the location where the warehouse is located does not become a war zone. Other mercury-storage options in use in the U.S. include storing it in metric ton flasks and in plastic bottles.

In the European Union, regulations call for permanent or temporary storage of elemental mercury in salt mines adapted for the disposal of metallic mercury or in deep underground, hard rock formations if it is determined that they provide a level of safety and confinement equivalent to that of salt mines. Regulations also permit temporary storage of mercury for more than one year in above-ground facilities dedicated to and equipped for the temporary storage of metallic mercury.[337]

For mercury storage in salt mines, the E.U. regulations state that the rock surrounding the waste should act as host rock in which waste is encapsulated. The storage site must be located between overlying and underlying impermeable rock strata to prevent groundwater from entering and liquids and gases from escaping. Shafts and boreholes must be sealed during operation, and they must be hermetically closed after operation. The disposal area must be sealed with a hydraulically impermeable dam when there is ongoing mineral extraction at the mine. The stability of the host rock must be assured during operation, and the integrity of the geological barrier must be assured over unlimited time.[338]

E.U. regulations also permit mercury storage in hard rock formations. These are defined as underground storage areas at several hundred meters depth made of hard rock, which includes various igneous rocks such as granite or gneiss and also sedimentary rocks such as limestone and sandstone. Temporary or permanent mercury storage is permitted in such facilities only if it is determined that the facility provides a level of safety and confinement equivalent to that of salt mines. Other conditions also apply. The disposal facility must be adapted for the disposal of metallic mercury. It must provide for protection against mercury releases into groundwater and must protect against mercury vapor emissions. The site must be impermeable to gasses and liquids. The construction must be passive with no need for maintenance. It should allow for recovery of waste and future corrective measures. It should be stable for an extended period of time, up to thousands of years. And the storage site must be located below the groundwater table so there can be no direct discharge of pollutants into the groundwater.[339]

Other countries and regions are considering what options they may have for long-term storage of elemental mercury.

According to a draft outline report prepared for UNEP and presented to an April 2010 regional meeting for countries of the Latin American and Caribbean region,[340] some of the requirements for an above-ground special engineered warehouse include the following:

- The location must not be susceptible to earthquake, hurricanes, and flooding.
- More than one area should be considered.
- Dry locations are preferred.
- The site should be distant from any water basin or populated area.
- Mercury containers should be protected against groundwater.
- Vapor emissions should be prevented through packaging, handling, internal transportation, and temperature control.
- The site should be protected from groundwater and surface-water contamination.
- The site should be near roads or transportation infrastructures.
- Programs should be in place to prevent risks and accidents.
- Storage should be reversible.
- Systems should be in place to monitor the air, the containment, workers' blood and urine, etc.
- There should be emission controls on the facility.
- The facility should have permanent mercury vapor monitoring with a sensitivity ensuring that the indicative limit value of 0.02 mg mercury/m^3 is not exceeded.
- The facility should have a program for spill prevention and control.
- Packing standards need to be established..
- Buildings should have mercury-resistant sealed floors, and they should slope towards a collection sump.

- Facilities should have adequate security measures.
- Mercury should not be stored with other wastes.
- There should be yearly maintenance checks and yearly calibration of monitoring systems.
- The facility should be subject to regular independent audits.

Experts from the E.U. additionally noted that with above-ground storage, mercury still remains in the biosphere. They noted also that the safety of this option depends on political stability and that above-ground storage may not be a permanent solution.

The draft report also discusses underground disposal. The main consideration in underground disposal is to isolate waste from the biosphere in geological formations where it is expected to remain stable over a very long time. This is best done deep underground. Mercury is placed into containers before being put into the mine. Its containment and isolation is achieved by the containers, by additional engineered barriers, and by the natural barrier provided by the host rock. The draft report indicates that the most common rock or soil types used for underground disposal include clay and salt as well as hard magmatic, metamorphic, or volcanic rocks such as granite, gneiss, basalt, or tuff. The depth depends on the type of formation used and the isolation capacity of the overlying formations.

The draft identifies some requirements (not all of which are mutually compatible) for underground waste storage in old mining sites:

- It should be an available, unused, excavated area of a mine that is remote from areas where active mining is taking place and that can be sealed off from active mining areas.
- The cavities will need to remain open so the mine operator cannot have a backfill obligation.
- The mined cavities must be stable and accessible even after a prolonged time.
- The mine must to be dry and free of water.
- The cavities in which the waste is to be stored must be sealed off from water-bearing layers.

- To improve safety and to simplify mercury handling, the mercury should be stabilized, that is, it should be chemically treated to transform elemental mercury into mercury sulphide.
- Mercury purity must be higher than 99.9 percent because impurities result in increased water solubility.
- There should be no oxidizing agents present in the vicinity of the mercury.
- Because mercury has high vapor pressure, the facility needs good handling and ventilation systems.
- The waste acceptance criteria will depend on the local legal framework.[341]

An Asian regional meeting also reviewed options for long-term mercury storage. A report prepared by several Asian institutions and organizations for the meeting considered three options: above-ground specially engineered warehouses, underground geological formations such as salt mines and special rock formations, and export to foreign facilities. The report's authors concluded that the most important requirements for long-term mercury management are dry atmospheric conditions; political, financial and economic stability; security; appropriate infrastructure; and environmental security.[342]

The authors recommend that the establishment of mercury storage facilities should go hand-in-hand with efforts to establish facilities to process mercury-rich wastes. They note that this will be costly and that special mechanisms will be needed to address both financial costs and legal aspects.

The authors of the Asian report suggest that countries that have deserts and a stable socio-political situation should give consideration to hosting an above-ground storage facility. They recommend, however, that countries in Asia should not pursue the use of underground geological formations for storing mercury because of its high costs and the lack of appropriate sites. The authors recommend that countries without deserts and those with potentially unstable conditions export mercury and mercury-rich wastes to countries where safe, long-term mercury storage facilities can be arranged.[343]

As negotiations to establish a global mercury treaty proceed, discussions on how to establish long-term storage facilities and/or permanent disposal facilities for excess mercury will continue with the understanding that after the new treaty and its provisions enter into force, there will be a growing need for such facilities in all regions.

Notes

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11. Toward a Global Treaty to Control Mercury

In February 2009, the UNEP Governing Council (GC) met in Nairobi, Kenya, with representatives from 150 governments in attendance and agreed to establish an intergovernmental committee to negotiate the terms of a global, legally binding treaty to control mercury. The GC agreed further that intergovernmental negotiations on the text of the treaty should begin in 2010, with the goal of completing the negotiations and adopting the treaty at a Diplomatic Conference to be held in 2013.[344]

Intergovernmental debate on the need for international action to control mercury pollution had already started much earlier. In 2000, this was discussed by the Second Ministerial Meeting of the Arctic Council held in Barrow, Alaska. The Arctic Council is an intergovernmental forum whose membership is the governments of the eight countries bordering the Arctic. At the Barrow meeting, government representatives agreed that the eight Arctic States will coordinate closely on environmental matters of importance to the Arctic. They noted that releases of mercury have harmful effects on human health and may damage ecosystems of environmental and economic importance, including in the Arctic. To address these concerns, the Arctic Council called on UNEP to initiate a global assessment of mercury that could form the basis for appropriate international action and indicated that the Arctic States would actively participate in the assessment.[345]

11.1 Global Mercury Assessment Report

In response to this request by the Arctic Council, UNEP prepared its "Global Mercury Assessment" report which was released in December 2002.[346] Among the report's key findings were the following:

- **Mercury is widely present in the environment.** Levels of mercury in the environment have increased considerably since the start of the industrial age, and mercury is now present in various environmental media and food (especially fish) all over the globe at levels that adversely affect humans and wildlife.

- **Mercury is persistent and cycles globally.** Mercury persists in the environment where it circulates between air, water, sediments, soil, and biota in various forms. Current emissions add to the global pool of mercury that is continuously mobilized, deposited on land and in water, and remobilized. In the environment, mercury can change into methylmercury, which has the capacity to collect in organisms (bioaccumulate) and to become concentrated as it moves up the food chain (biomagnify). Nearly all of the mercury in fish is methylmercury.
- **Mercury exposure has serious effects.** Mercury causes a variety of significant adverse impacts on human health and the environment throughout the world. Human exposure to mercury can result from the consumption of fish, occupational and household uses of mercury, dental amalgams, and mercury-containing vaccines. Some populations are especially susceptible to mercury exposure, most notably the fetus, newborns, and young children. Indigenous and other populations that consume high amounts of contaminated fish or marine mammals as well as workers exposed to mercury are at risk. In many parts of the world, fish are an important part of people's diets, providing nutrients often not available in alternative food sources. Mercury pollution poses a major threat to this food supply. Some ecosystems and wildlife populations are also vulnerable, including fish-eating birds and mammals, Arctic ecosystems, wetlands, tropical ecosystems, and soil microbial communities.
- **Interventions to control mercury pollution can be successful.** Mercury pollution can be addressed through a range of actions that target reductions in mercury use, release, and exposure at the national, regional, and global levels.
- **Global action is needed because local and regional actions, by themselves, are not sufficient.** Due to long-range transport, even nations with minimal mercury releases may be adversely affected. High mercury levels are observed in the Arctic, far from the sources of any significant releases. Fish in international waters often migrate to remote and diverse locations, and after commercial fish are harvested, they are commonly exported to countries far removed from their place of origin. This makes mercury pollution a truly global issue that affects fishing industries and fish consumers around the world.
- **Mercury may be an especially important problem in less-developed regions.** In response to the growing awareness of the harms caused by mercury, many industrialized countries have reduced their mercury use

significantly, and competitive alternatives have become commercially available for most uses. This has lowered mercury demand relative to supply, which has kept mercury prices low. In turn, this has encouraged ongoing or increasing use of mercury and outdated mercury technologies in less-developed regions. Not surprisingly, these countries are suffering from a disproportionate amount of some of the health and environmental risks associated with mercury.[347]

In its final chapter, UNEP's "Global Mercury Assessment" report reviews options for addressing the globally adverse impacts of mercury pollution. Among these, was launching negotiations for a legally binding mercury-control treaty.[348]

11.2 Decision to Negotiate a Mercury-Control Treaty

Between 2003 and 2009, issues relating to international action on mercury were debated at each of the biennial meetings of UNEP's Governing Council. Support for establishing a global mercury-control treaty grew and, in 2009, governments attending the UNEP GC adopted decision 25/5 in which they agreed to start negotiations on a global, legally binding mercury-control treaty.[349]

Decision 25/5 acknowledges that mercury is a chemical of global concern because of its long-range atmospheric transport, its persistence in the environment, its ability to bioaccumulate in ecosystems, and its significant negative effects on human health and the environment. In the decision, governments agreed that the treaty could include both binding and voluntary approaches as well as interim activities to reduce risks to human health and the environment. They also agreed that some treaty obligations will require capacity building and technical and financial assistance for developing countries and countries with economies in transition. The decision specified that the treaty should include provisions that do the following:

a) Identify the objectives of the treaty

b) Reduce the supply of mercury and enhance the capacity for the environmentally sound storage of mercury

c) Reduce the demand for mercury in products and processes

d) Reduce international trade in mercury

e) Reduce atmospheric emissions of mercury

f) Address mercury-containing waste and remediation of contaminated sites

g) Increase knowledge through awareness-raising and scientific information exchange

h) Specify arrangements for providing capacity-building and technical and financial assistance

i) Address compliance[350]

In decision 25/5, governments also agreed that participation in the intergovernmental negotiating committee should be open not only to governments and regional economic integration organizations but also to relevant intergovernmental and nongovernmental organizations consistent with United Nations rules.

Finally, in decision 25/5, governments agreed that international action on mercury should not wait until the completion of the treaty-negotiating process but should continue in the following areas:

a) Enhancing capacity for mercury storage

b) Reducing the supply of mercury from, for example, primary mercury mining

c) Conducting awareness-raising and pilot projects in key countries to reduce mercury use in artisanal and small-scale gold mining

d) Reducing mercury use in products and processes and raising awareness about mercury-free alternatives

e) Providing information on best available techniques and best environmental practices and on the conversion of mercury-based processes to non-mercury-based processes

f) Enhancing the development of national inventories of mercury

g) Raising public awareness and supporting risk communication

h) Providing information on the sound management of mercury

Notes

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12. Negotiating an Effective Global Mercury-Control Treaty

It should be possible to secure international agreement on a comprehensive, strong, and effective global mercury-control treaty in time to have final agreed-upon text by 2013 as called for in the UNEP Governing Council decision. For this to happen, however, NGOs and other organizations of civil society have a critically important role to play. There is a need for NGOs to help build mercury awareness in their home countries in support of a strong and effective global treaty. NGOs can also help positively influence government representatives who participate in the negotiating process.

As governments negotiate a global mercury-control treaty, it will be important for civil society organizations and others to keep in mind that the main beneficiaries of an effective global mercury treaty will be the billions of people in the world who eat fish and shellfish as essential components of their diets—especially inhabitants of developing countries and countries with economies in transition, inhabitants of small island states, and Indigenous Peoples. For many of these people, avoiding harmful mercury exposure by restricting consumption of fish to a few fish meals per week or month is not a viable option. In these populations, children are damaged by mercury exposure starting before birth, and they suffer lifelong neurological deficits that can degrade the quality of their lives. The people who depend on fish in their diet need concerted global efforts that will lead to significant reductions in their methylmercury consumption. Governments of Least Developed Countries, Small Island Developing States, and other governments representing large populations that depend on fish should be looked to as key potential allies in treaty negotiations. Their active support and engagement will be needed if a strong and effective global mercury-control treaty is to be achieved.

At the same time, it is also important to keep in mind that some of the largest sources of global mercury pollution will be difficult to control. Several countries have plans to greatly increase electrical power generation as an important component of their development strategies and poverty-reduction programs. Despite coal-fired power plants being the largest source of mercury pollution and greenhouse gas emissions, it nonetheless appears that plans already in place make it likely that, at least in the short term, many new coal-fired power plants will continue to be built in several countries. The number of artisanal and small-scale gold mines also appears to be growing, and measures to achieve significant mercury-release reductions from this sector will be difficult and costly to implement. This suggests that despite agreement by governments to negotiate a global mercury-control treaty, global atmospheric mercury pollution may nonetheless grow.

One can expect that several governments will strongly resist proposals for treaty measures that can achieve real and substantial global reductions in mercury emissions from coal-fired power plants and some other unintentional sources. One can also expect a number of governments to strongly resist proposals for treaty measures that ensure sufficient financial and technical resources will be mobilized to enable developing countries and countries with economies in transition to effectively implement necessary mercury-control measures without undermining national poverty-reduction plans and goals. Nonetheless, the mercury treaty negotiations will not be considered a success if the treaty includes only voluntary agreements to control the largest mercury sources. To be seen as a success, it will need to include legally binding measures to control power plants and other major sources and also agreements to mobilize sufficient financial and technical resources to enable effective treaty implementation in the developing world. The treaty will also need to include measures that control mercury supply, demand, and trade; that phase out the production, sale, import, and export of mercury-containing products; and that address mercury wastes and contaminated sites.

Although it will be important not to compromise on the need for legally binding measures to control large global mercury sources such as power plants, small-scale gold mining, and others, there may be room to negotiate on schedules for phasing in legally binding measures and on linkages between developing-country obligations to implement binding measures and the availability of adequate technical and financial assistance. Additionally, though it is important that the treaty include provisions that mandate the use of best available techniques (BAT) for power plants and some other mercury-emission sources, it may not be necessary to have all the important details of the treaty's BAT provisions written into the treaty text. Instead, it may be sufficient to include general language on treaty BAT provisions and requirements in the treaty text along with a provision to establish an expert group that will develop detailed BAT guidelines and implementation schedules. The expert group would be established as a subsidiary body to the new treaty's Conference of the Parties (COP). Its membership composition would be agreed on by the COP, its work product would be in the form of recommendations to the COP, and its recommendations would only enter into force following approval by the COP.

Skillful negotiations and strong civil society support will be needed to secure a strong and comprehensive mercury-control treaty within the time frame allocated. But there are good reasons for optimism that this can be achieved.

13. IPEN Views on a Global Mercury Treaty

The International POPs Elimination Network, through its Heavy Metals Working Group, its Steering Committee, and its Global General Assembly, has adopted a policy paper, "IPEN Views on a Global Mercury Treaty," which defines its views.[351]

IPEN has agreed that to protect human health and ecosystems, the treaty should:

- Have, as its objective, to protect human health, wildlife and the environment from mercury by eliminating—where feasible—anthropogenic sources and releases of mercury
- Recognize particularly vulnerable populations such as children, women of child-bearing age, Indigenous Peoples, Arctic communities, island and coastal dwellers, fisherfolk, small-scale gold miners, the poor, workers, and others
- Have a broad scope and address the entire mercury life cycle
- Aim to control all anthropogenic mercury sources and all human activities that release significant quantities of mercury into the environment
- Establish an adequately funded and predictable financial mechanism with new and additional resources sufficient to enable developing countries and countries with economies in transition to fulfill their treaty obligations without compromising their poverty-reduction goals
- Use elimination-based control measures subject to possible limited, time-bound exemptions to phase out all products and processes that contain or use mercury and, in the interim, establish standards and controls for those products and processes that remain
- Reduce and minimize global commercial demand for mercury
- Reduce global mercury supply by banning primary mercury mining; mandating permanent, secure, monitored storage for existing mercury stockpiles and all mercury that is recovered from chlor-alkali plants; and restricting the trade of mercury generated from remaining sources

- Establish effective controls on international trade in mercury and mercury-containing products
- Mandate environmentally sound solutions for the management of wastes that contain mercury and mercury compounds, including measures to prevent mercury from entering municipal, medical, and industrial waste streams
- Address the remediation and reclamation of existing mercury-contaminated sites
- Expedite the phaseout of mercury use in the health care sector
- Promote alternatives to the use of mercury dental amalgams with the aim of eventually eliminating this practice
- Ban mercury-containing pesticides
- Establish best available techniques (BAT) for coal-fired power plants, cement kilns, and other combustion processes that release mercury into the environment with an agreed-upon schedule for its phased-in application and aim to phase out any of these sources when good alternatives are feasible, available, and affordable
- Promote the use of renewable, alternative energy sources as a substitute for coal-fired power plants that release mercury into the environment
- Institute effective measures to reduce and eliminate, where feasible, the use of mercury in gold mining
- Minimize the use of mercury in laboratories, schools, and other institutions; prohibit inappropriate uses; and incorporate information on mercury toxicity and proper techniques for handling mercury in school curricula
- Prohibit new uses of mercury
- Promote research and development on sustainable, nontoxic alternatives to products and processes that contain or use mercury, with special emphasis on addressing the needs of developing countries and countries with economies in transition
- Ensure that developing countries and countries with economies in transition do not become dumping grounds for mercury wastes and excess mercury supplies
- Establish mechanisms for capacity building and technology transfer
- Require each Party to establish and implement a National or Regional Treaty Implementation Plan; include in the plans inventories of mercury supplies, sources, wastes, and contaminated sites

- Ensure that civil society has an active role in the development and implementation of the treaty including the opportunity to participate in the development and implementation of National or Regional Implementation Plans
- Establish mechanisms to improve, provide, and exchange knowledge and information about
  - ✓ Mercury emissions, supply, and use
  - ✓ Human and environmental mercury exposure
  - ✓ Environmental monitoring data
  - ✓ Socio-economic impacts of mercury use, emissions, and controls
  - ✓ Alternatives for mercury in products, processes, and other sources
- Ensure that all scientific information about mercury is regularly updated and is made available and easily accessible to the public in a timely manner and in appropriate formats and languages
- Establish a reporting mechanism that requires Parties to periodically update their national mercury inventories and report on progress in implementing National or Regional Implementation Plans and treaty obligations
- Establish mechanisms for evaluating the effectiveness of the treaty including global monitoring of mercury in the environment and in humans
- Establish and maintain a global fish-monitoring network to assess progress in reducing the quantity of mercury circulating in the global environment and to gather the information necessary to enable government health agencies to carry out effective risk communication and outreach strategies to populations that consume fish
- Establish effective and enforceable treaty-compliance provisions

In addition to the above proposed treaty provisions, the IPEN network has additionally agreed on the following other considerations:

- The reduction and elimination of mercury sources should be rapid, orderly, and just. Provisions may be phased in over a period of time, but there should be no unnecessary delays. .
- Meaningful international action to reduce and eliminate mercury sources and supply should not be delayed until a global mercury treaty is adopted and

enters into force. Rather, adequately funded international mercury-control programs should be carried out starting immediately. There should also be resources for extensive environmental monitoring in all regions to establish a baseline and to expand the availability of regionally relevant information.

- Because mercury is a global problem that impacts all regions of the world, all countries have important roles to play in both the negotiation and the implementation of a global mercury treaty.
- The mercury treaty and its implementation should be complementary to other relevant international instruments including the Stockholm Convention on Persistent Organic Pollutants, the Basel Convention on Transboundary Movements of Hazardous Wastes, the Rotterdam Convention on Prior Informed Consent, the Strategic Approach to International Chemicals Management, and others. Appropriate synergies with these instruments should be developed.
- The mercury treaty should include provisions that will enable it to be expanded at a future date to also control other toxic metals such as lead and cadmium or other pollutants of similar global concern, without compromising the robustness of the mercury treaty.
- All countries should contribute to treaty implementation to the extent they are able.
- Developed countries should commit to providing sufficient new and additional financial resources and technological assistance to fully enable developing countries and countries with economies in transition to fulfill their treaty obligations. The treaty should include provisions for its Conference of the Parties to review whether funding levels are sufficient, whether recipients are using funds effectively, and whether actions taken result in full compliance with the provisions of the treaty.
- The treaty-negotiating process should be open and transparent. Provisions should be made to enable meaningful participation by relevant NGOs and other public interest stakeholders.
- Mercury-related phaseout transitions should proceed through a planned and orderly regime that is designed to keep economic and social costs to a minimum and to avoid disruptions and dislocations. In some cases, there may be need for transition assistance and/or other aid to specific groups of workers or communities who currently depend for their livelihood on activities that release mercury into the environment.

- Wherever possible, the responsibility for mercury-related phaseouts and cleanups should be consistent with the Polluter Pays Principle, in which costs are shared by responsible parties, with special attention to the private sector.
- Action on mercury should be consistent with the Precautionary Principle. It should rely on a weight-of-evidence approach, with special consideration given to the risks to fetuses, children, and other vulnerable populations.
- The treaty should incorporate other relevant Rio Principles including: Right to Development (3), Environmental Protection in the Development Process (4), Eradication of Poverty (5), Priority for the Least Developed (6), Capacity Building for Sustainable Development (9), Public Participation (10), Compensation for Victims of Pollution and other Environmental Damage (13), State Cooperation to Prevent Environmental Dumping (14), Internationalization of Environmental Costs (16), Women have a Vital Role (20), Indigenous Peoples have a Vital Role (22), and others.
- Monitoring and oversight of treaty implementation and financing should be conducted by independent bodies that are publicly accountable.
- Regionally specialized centers and a network of specialized facilities should be set up to provide assistance in the collection and management of mercury-containing wastes. There should be a ban on the disposal of these wastes in landfills and solid-waste dumps. A uniform system should be established for registering and reporting on their collection, transportation and processing.
- A clearinghouse mechanism for mercury should be established. It should provide direct access to relevant information about mercury including practical experiences, scientific and technical information, and other information that can help facilitate effective scientific, technical, and financial cooperation and capacity building. Civil society groups should be considered partners and an important source of information for the clearinghouse.
- The treaty should give special attention to the needs of small-scale artisanal gold miners. It should facilitate their access to effective and appropriate technologies that minimize or, where feasible, avoid the use of mercury. Where that proves to be impractical, the treaty should promote the establishment of programs to assist them in securing alternative livelihoods.

- The treaty should include provisions to enable and promote the effective participation of public-interest, health, and environmental stakeholders in treaty implementation.
- The treaty should provide for public information, awareness, and education, especially for women, children, workers, small-scale gold miners, the poor, marginal people, and the least educated. It should also provide this for Indigenous Peoples, Arctic communities, islanders, coastal people, fisherfolk, and others who rely on fish or other mercury-contaminated foods for their nutrition.
- New research should be supported, as needed, to expand knowledge about sources of mercury and about the transport mechanisms that carry mercury to remote locations. The public should receive timely access to relevant governmental and private-sector data on mercury hazards, mercury sources, and alternatives to mercury-containing products.
- New research should also be supported to develop effective, nontoxic, affordable alternatives to mercury-containing products, mercury-dependent industrial processes, and other activities that release mercury into the environment.
- A mechanism should be established to identify, manage, and remediate mercury-contaminated sites. This may include appropriate compensation for affected workers and communities.
- The treaty should call upon its Parties to give full consideration to the significant health and environmental impacts caused by the transformation of mercury in soils into methylmercury when dams are built and new areas are flooded.
- Sensitive testing technologies and methodologies should be made readily available for identifying mercury contamination of environmental media, food, and people.

Notes

351 See http://www.ipen.org/hgfree.

14. Conclusion

It has been known for decades that mercury pollution causes serious harm to human health and the environment. Until recently, governments have resisted many of the control measures needed to minimize mercury pollution. This hopefully is now changing.

Growing public concern and an expanded scientific understanding of the harms caused by local, national, and global mercury pollution has driven many governments to start taking meaningful action to control mercury atmospheric emissions and other mercury releases into the environment. The decision by governments to start negotiating a global mercury-control treaty makes it easier and very relevant for NGOs and others to initiate actions that address local, national, regional, and global mercury issues and concerns. This is true in countries where mercury issues are already well-established as part of the national environmental and political agenda, and it is increasingly true in countries and regions where concerns about mercury pollution are now just emerging.

This creates both an opportunity and an obligation for NGOs and other civil society organizations with missions relating to public health or environmental protection. It also creates opportunities and obligations for organizations that represent impacted constituencies such as people who eat fish as an important component of their diet, communities near mercury-polluting facilities, workers who are subject to mercury exposures, and many others. Taking action on mercury-related issues can be highly successful in this present political climate and can have a big impact. Finally, while the global mercury-control treaty is being negotiated, and later, while national governments consider its ratification and then its implementation, national public awareness about mercury pollution will greatly influence how they decide to act.

Because of the global nature of mercury pollution, a global movement of NGOs and other organization's of civil society working together for solutions is essential. The International POPs Elimination Network is committed to building and strengthening this movement.

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MERCURY-FREE: YOU, ME AND BABIES

www.ipen.org/hgfree

IPEN's Mercury-Free Campaign

is a response to growing knowledge about the alarming scale of human and environmental health harms caused by global mercury pollution. The campaign promotes initiatives by national and local NGOs and civil society organizations in all regions of the world to:

- Raise public awareness about the harms caused by mercury pollution and exposure
- Undertake targeted campaigns aimed at eliminating or better controlling sources of mercury pollution and exposure
- Promote mercury-free alternatives
- Build support among government officials, political leaders and opinion leaders for the adoption and enforcement of national mercury control laws and policies
- Build public and political support for the adoption and national ratification of a strong and comprehensive global mercury control treaty.

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