MERCURY CHALLENGES IN A CHANGING WORLD

The UNEP Global Legally Binding Treaty on Mercury (Minamata Convention) was signed by 140 countries in January 2013 and ratified in 2017. So, with such a high level of internationally agreed action, it might seem logical to assume that the environmental and health effects of mercury pollution will rapidly diminish. Unfortunately, this has not yet been the case, and mercury remains both an imminent and persistent threat.

Background

Mercury was designated a chemical of global concern by the United Nations Environment Programme (UNEP) in 2006. This was because of its long-range transport capability in the atmosphere, its persistence in the environment, its toxicity, its ability to bio-accumulate in ecosystems and its significant negative effects on human health.

Mercury emissions from a variety of sources can enter the food chain and represent a threat to human health. High levels of mercury in a human diet can lead to long-term and sometimes permanent neurological changes. The dangers are especially significant in young children who may develop neurological disorders. Mercury exposure can also lead to developmental problems in the brain, which can affect physical functions such as motor skills. In adults, mercury poisoning may result in circulatory failure, and permanent brain and kidney damage.

Some types of bacteria and fungi can change mercury into its most toxic form, methyl mercury, which accumulates to some degree in fish, but accumulates in predatory fish such as shark, swordfish, and certain species of tuna where the mercury concentrates as it passes up through the food chain. Seafood is the main source of protein for about one billion people worldwide, so dietary consumption of fish, shellfish, and marine mammals that are contaminated with methyl mercury is an important source of exposure. Rice grown in sites heavily contaminated with mercury may also be a source of mercury exposure for some communities.

Mercury Sources

Anthropogenic emissions account for around 30% of mercury emitted annually to the atmosphere, the remainder coming from environmental processes (60%) that result in re-emission of mercury previously deposited to soils and water (much of which is itself derived from earlier anthropogenic emissions and releases), and natural sources (~10%). Mercury comes from a range of natural sources such as volcanoes, soils, undersea vents, mercury-rich geological zones and forest fires, as well as from fresh water lakes, rivers and oceans. However, human activity has increased the amount of mercury in the environment in several ways, including through a variety of combustion and industrial processes such as coal-fired power generation, metal mining and smelting, and waste incineration.

The AMAP/UN Environment, Technical Background Report for the Global Mercury Assessment 2018 shows that mercury emissions patterns in 2015 were very similar to those in 2010. The majority of the 2015 emissions occurred in Asia (49%) followed by South America (18%) and sub-Saharan Africa (16%). In the latter two regions, emissions associated with artisanal and small-scale gold mining (ASGM) accounted for ~70–85% of the emissions.

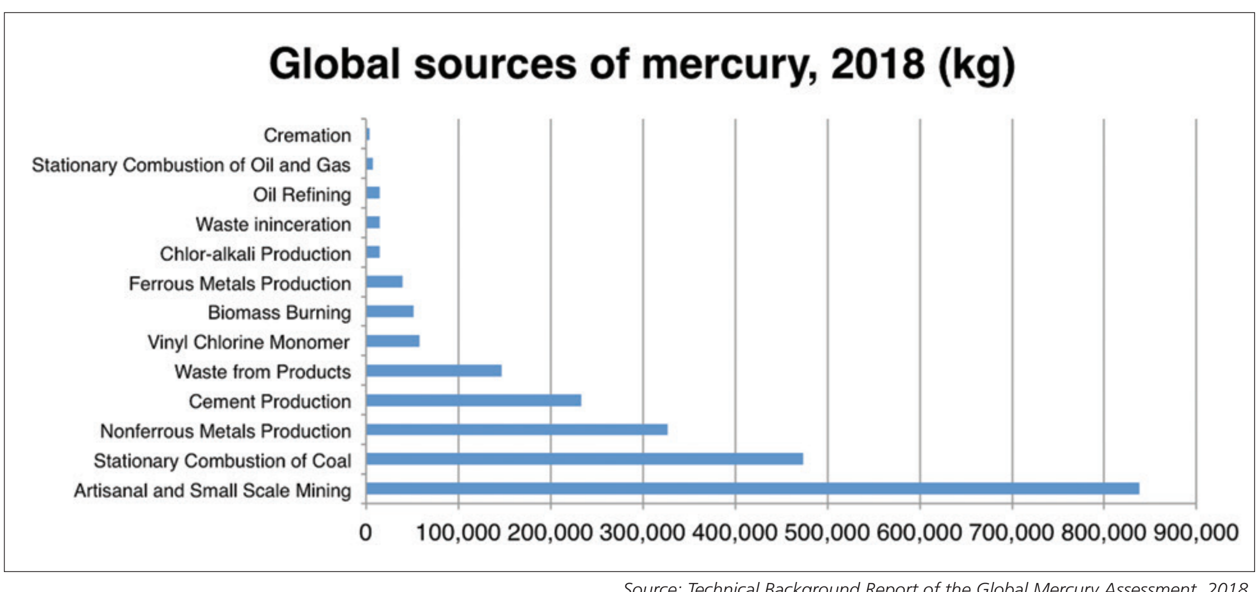
Worryingly, the global mercury emissions to air from anthropogenic sources in 2015 were estimated to be around 17% higher than the inventory for 2010. High apparent increases in emissions from ASGM (almost 160t) are most likely to be associated primarily with improvements in the information upon which these estimates are based. Since most ASGM activities are illegal and unregistered, no reliable data are available. The second major contributor to the increase is industrial sectors (142t) where increased economic activity in certain regions is reflected in activity data for production and use of raw materials.

Data for mercury from the oil and gas sector is somewhat contentious because it is likely that the figures shown above do not include the mercury that is produced and collected by processes involving raw materials. This mercury is not emitted to the environment, (which is probably why it is not included) but it is collected and stored or recycled, so some believe that it should be included in the global mercury inventory.

Progress Since the 2013 Minamata Convention

According to the UNEP's Global Mercury Assessment 2018, progress on global mercury reduction has been limited, and given the levels of 'legacy' mercury, combined with the threat of re-mobilisation by climate change, significant challenges remain in initiatives to reduce mercury exposure. The UNEP report included a number of Key Findings, namely:

1. A new global inventory of mercury emissions to air from anthropogenic sources in 2015 quantifies global emissions from 17 key sectors at about 2,220 tonnes.
2. Estimated global anthropogenic emissions of mercury to the atmosphere for 2015 are approximately 20% higher than



Source: Technical Background Report of the Global Mercury Assessment, 2018.

they were in updated estimates for 2010. Continuing action to reduce emissions has resulted in modest decreases in emissions in North America and the European Union. Increased economic activity, notably in Asia, and the use and disposal of mercury-added products appears to have more than offset any efforts to reduce mercury emissions.

3. Emissions patterns in 2015 are very similar to those in 2010. The majority of the 2015 emissions occur in Asia (49%; primarily East and South-east Asia) followed by South America (18%) and Sub-Saharan Africa (16%). Emissions associated with ASGM account for almost 38% of the global total and are the major contributor to the emissions from South America and Sub-Saharan Africa. In other regions, emissions associated with energy production and industrial emissions predominate.
4. Stationary combustion of fossil fuels and biomass is responsible for about 24% of the estimated global emissions, primarily from coal burning (21%). The main industrial sectors remain non-ferrous metal production (15% of the global inventory), cement production (11%) and ferrous metal production (2%). Emissions from waste that includes mercury added products comprise about 7% of the 2015 global inventory.
5. Human activities have increased total atmospheric mercury concentrations by about 450% above natural levels. This increase includes the effects of mercury emitted from human sources in the past which is still circulating in the biosphere, known as legacy mercury. Historical emissions up to the end of the 19th century, mainly from gold, silver, and mercury (cinnabar) mining and refining in the Americas, contributed more to the present-day anthropogenic mercury in soils and the oceans than all of 20th century industrial sources combined. The presence of legacy mercury and the potential for climate change to influence its re-mobilisation complicates our ability to assess potential future changes.
6. Artisanal and small-scale gold mining introduced about 1,220 tonnes of mercury into the terrestrial and freshwater environments in 2015, but this amount cannot be reliably separated between discharges to soils and releases to water. Global releases of anthropogenic mercury from other sources to aquatic environments totaled about 580 tons in 2015. The major contributors are waste treatment (43%), ore mining and processing (40%), and energy (17%).
7. Natural production of methylmercury in the oceans and in some lakes is no longer limited by the input of inorganic mercury. Other factors such as climate change, biogeochemistry, and changes in soil processes are playing increasingly important roles in the mercury cycle, affecting the distribution and chemical interactions of mercury in the environment.
8. Reductions in mercury emissions and resulting declines in atmospheric concentrations may take time to show up as reductions of mercury concentrations in biota. For some time to come, methylmercury will continue to be produced from the legacy mercury already present in soils, sediments, and aquatic systems.
9. Mercury loads in some aquatic food webs are at levels of concern for ecological and human health. Anthropogenic mercury emissions and releases, current and legacy, are the major contributors to increased mercury levels and exposure.
10. All people are exposed to some amount of mercury. For many communities worldwide, dietary consumption of fish, shellfish, marine mammals, and other foods is arguably the most important source of methylmercury exposure.

Global Action to Reduce Mercury Emissions

According to the US EPA, power plants are currently the dominant emitters of mercury (50%) from human activities in the United States. Newer plants (and a significant number of older power plants) already control their emissions of mercury, heavy metals, and acid gases. However, approximately 40 percent of the current electricity generating units still do not have advanced pollution control equipment.

In 1990, three industry sectors made up approximately two-thirds of total U.S. mercury emissions: medical waste incinerators, municipal waste combustors, and power plants. The first two of these sectors have been subject to emissions standards for years and as a result have reduced their mercury emissions by more than 95 percent. In addition, mercury standards for industries such as cement production, steel manufacturing and many others have reduced mercury emissions from these sources. The USA has amongst the tightest emission standards in the world for mercury emissions from coal-fired power plants, requiring that at least 90% mercury capture be achieved on most units. Whilst some plants could achieve compliance through co-benefit control from existing pollution control systems, many have had to install mercury-specific technologies such as oxidant or sorbent addition.

In 2020, the US EPA published the first in a series of triennial reports on the supply, use, and trade of mercury in the United States, supported by Agency's mercury inventory reporting rule. Based on the information collected under the rule, the 2020 Mercury Inventory Report identifies any manufacturing processes or products that intentionally add mercury and recommends actions to achieve further reductions in mercury use. Some States prohibit the sale of products that contain mercury unless they have: a label indicating that the product contains mercury and information concerning proper disposal. Strict regulations have been created to control waste containing mercury.

The EU has banned almost all mercury-containing products and requires the use of best available techniques (BAT) to reduce emissions from all relevant industrial activities, especially coal combustion, waste incineration, cement production and the manufacture and smelting of metals. In the EU, Mercury emissions to air dropped by around 73% between 1990 and 2014, and to water by 71% between 2007 and 2014.

According to the BAT conclusions for large combustion plants adopted in July 2017 under the 2010/75/EU Industrial Emissions Directive all new installations have to reduce emissions of mercury to below 3 µg/Nm^3. Monitoring of mercury emissions to air must be carried out once every three months in plants with a thermal output under 300 MWth or continuously in plants with output higher than this. Monitoring of emissions to water should be undertaken at least monthly, and with the use of BAT should be an average of 0.2-3 µg/l daily.

A new BAT Reference Document (WI BREF) for Waste Incineration was published in December 2019. Compared with the existing standards, the new BAT conclusions deliver a reinforced level of protection, with particular emphasis on toxic and persistent organic pollutants such as mercury and polychlorinated dioxins and furans. This includes the continuous measurement of mercury and the long-term sampling of polychlorinated dioxins and furans. For plants incinerating wastes with a proven low and stable mercury content the continuous monitoring of emissions may be replaced by long-term sampling (no EN standard is available for long-term sampling of Hg) or periodic measurements with a minimum frequency of once every six months. In the latter case the relevant standard is EN 13211.

Chlor-alkali plants currently operating with mercury technology were mostly built before the 1970s, with around 100 in operation globally (UNEP, 2012). Mercury cells are being phased out, due to concerns about their environmental impact.

In cement manufacturing, mercury is present in natural and waste-derived raw materials as well as in conventional and waste-derived fuels. As such, mercury enters clinker production systems by all three principal feeding points - raw materials, the main burner and the secondary firing system. Almost all of the mercury and mercury compounds from the raw materials and fuels are volatilised in the clinkering process and exit the kiln system as a vapour. So the mercury that enters the kiln system will be emitted via the stack unless a mercury removal system is in place.

In 2010, the cement industry was responsible for 9% of global mercury emissions. According to the BAT conclusions (2013/163/EU, adopted under Directive 2010/75/EU) for production of cement, lime and magnesium oxide, companies should select materials with a low content of mercury, and limit the content of relevant metals in materials, especially mercury. In the BREF guidance for cement kilns (CLM BREF), mercury has a BAT-associated emission level of 50 µg/ Nm^3 for the half-hour average. However, some countries, such as Germany for example, have adopted stricter emission limits.

Other regions are also introducing mercury emission limits for coal-fired plants, including India and Indonesia which have both introduced limits of 30 µg/m^3. Whilst these limits are an order of magnitude more lax than those in the EU and USA, they indicate a commitment to move into command and control of the issue in the near future. The Minamata Convention now has 123 ratified parties. This will inevitably lead to a spread of activities focussing on reducing emissions of mercury around the world.

Monitoring and Analytical Challenges

Commenting on the current mercury monitoring issues, Dr Warren Corns, a member of the mercury emissions working group, CEN/TC 264/WG 8, says: "As international regulations drive down the maximum allowable emission levels; methods, standards and technologies need to follow suit. But this can be challenging, given the technical limitations of some methods and because funding for the development of new standards is not always easily available."

Mercury continuous emission monitors (CEMs) provide continuous data which creates a better picture of emissions and helps to highlight the causes of spikes. For this reason, continuous monitoring is becoming an increasing regulatory requirement, such as in the WI BREF. However, CEMs represent a significant capital investment, particularly in comparison with the non-continuous sorbent trap method for example, so some authorities have been reluctant to impose this extra cost on industry.

The certification requirements for mercury CEMs are different in the USA and Europe. The European system is based on performance specifications, whereby instruments are assessed in the lab and in the field, and are adjusted to follow equivalent readings to EN 13211. However, in the USA, mercury CEMs have to follow the Performance Specification 12 document and either pass or fail in comparison with Method 101A, which is similar to EN 13211.

Dr Corns also highlights a further issue relating to the emissions of mercury in wastewater: "Some abatement methods for emissions to air result in wastewater with an elevated concentration of key pollutants, including mercury, so there is also a requirement for effluent monitoring in many countries, often at challenging parts-per-trillion levels."

Summary

International initiatives since the ratification of the Minamata Treaty have reduced the volume of products containing mercury, as well as emissions of mercury from key sources in the USA and Europe. However, increased economic activity, and the use and disposal of mercury-added products appear to have more than offset efforts to reduce mercury emissions. Mercury remains, therefore a chemical of global concern, and further international collaboration will therefore be necessary to agree targets, share knowledge and find the best ways to reduce the threat of this toxic element. Researchers, academics, policy makers, heath practitioners and other mercury stakeholders will gather in Cape Town for the International Conference on Mercury as a Global Pollutant (ICMGP) from 24th to 29th July 2022. This will present an ideal opportunity for the world's leading experts in all mercury-related subjects to come together; assess current progress and define future mercury strategy. For updates on the conference topics, speakers and the exhibition, visit www.ilmexhibitions.com/mercury2022 and sign up to the Mercury e-Newsletter.

Further reading:

- The 15th International Conference on Mercury as a Global Pollutant: www.ilmexhibitions.com/mercury2022
- Minamata Convention on Mercury: www.mercuryconvention.org/
- Global Mercury Assessment 2018: www.unenvironment.org/resources/publication/global-mercury-assessment-2018
- Mercury and Air Toxics Standards (MATS) in the USA: www.epa.gov/mats
- US EPA 2020 Mercury Inventory Report: www.epa.gov/mercury/2020-mercury-inventory-report
- EC webpage on Mercury: https://ec.europa.eu/environment/chemicals/mercury/index_en.htm
- EU BAT Conclusions for Large Combustion Plants: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1502972300769&uri=CELEX:32017D1442
- EU WI BREF: https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/best-available-techniques-bat-reference-document-waste-incineration-industrial-emissions
- CLM BREF Production of Cement, Lime and Magnesium Oxide: https://eippcb.jrc.ec.europa.eu/reference/production-cement-lime-and-magnesium-oxide

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