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Mercury in the environment

Info sheet

Mercury is a chemical element naturally occurring in the environment. Mercury compounds are very toxic to living organisms including humans, with particular concern for unborn children and infants. In the environment, mercury occurs in several forms. It is most harmful as methylmercury, a product of microbial activity. Methylmercury accumulates in food webs with the highest concentrations found in fish, through whose consumption most people are exposed. In Switzerland, the use, release and marketing of products containing mercury is strictly regulated by two ordinances [1, 2]. In the EU, mercury and its compounds are on the priority substance list of the Water Framework Directive and thus need to be monitored and reduced. At the international level, Switzerland has ratified the Minamata Convention [3], which aims to reduce emissions and anthropogenic releases of mercury and mercury compounds to protect human health and the environment. The Minamata Convention on Mercury entered into force on 16 August 2017, and the first Conference of the Parties was held in Geneva in September 2017 [4].

Use and emissions

Mercury has been used as a pesticide, a disinfectant, in measuring instruments (e.g. thermometers), in batteries, in dental fillings as well as in various industrial processes. It is still extensively used in several countries mainly for artisanal and small-scale gold mining (ASGM). The worldwide anthropogenic emissions of mercury to the atmosphere are estimated at 1670 t/year and mainly stem from the combustion of fossil fuels, mostly coal, for electricity and to a lesser extent from metal extraction and industrial operations such as cement production. The natural emissions are in the range of 500-900 t/year [5]. These emissions come from terrestrial geological activity (volcanoes) as well as from the evaporation of zones that are naturally enriched in mercury.

According to data from FOEN, 660 kg of mercury per year are released into the air in Switzerland and 70 kg into the water ([6], data for 2015). In Switzerland, the major contributors of emissions to the atmosphere are the combustion of fossil fuels and waste incineration (44%), industrial combustion mainly from the cement industry (27%) and industrial processes (12%). In surface waters, 15% of total mercury are estimated to come from point sources such as communal WWTPs and industry and 85% from diffuse sources such as atmospheric deposition and soil erosion. The mercury release to the environment in Switzerland decreased sharply (approx. 85%) between 1985 and 2003 but since then has remained at a constant level [7].

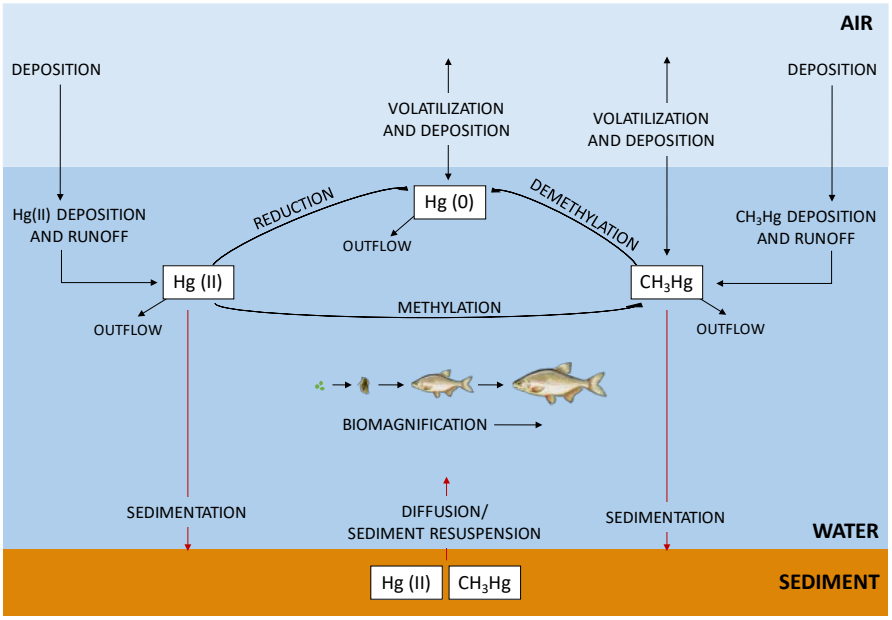

Fig. 1: Mercury cycling pathways in the aquatic environment. Adapted from: Mercury pollution: Integration and Synthesis. Lewis Publishers, CRC Press

Mercury in the environment

Mercury naturally occurs in magmatic rocks as well as in crude oil, coal and shale. There are more than a dozen mercury-containing minerals but only a few occur abundantly in nature. The most important one is cinnabar, or mercury sulfide, which contains 86% of mercury by weight.

Mercury is present in the environment in **three general forms** that can be converted to another (Fig. 1): (1) as elemental mercury Hg(0), which is the only metal that is liquid at atmospheric temperature and pressure. In the air, mercury is mainly present as Hg(0) and can be transported over large distances. Mercury has limited solubility in water; in sediments, elemental mercury is typically a small fraction of total mercury and is not directly bioavailable to organisms. (2) as inorganic mercury (mostly Hg^{2+}). Hg^{2+} is highly reactive and easily forms complexes with chloride/organic ligands or adsorbs to particles. Hg^{2+} is the most abundant form of Hg in contaminated sediments. (3) as organic mercury, where mercury forms a bond with a carbon atom. Organic mercury compounds are easily taken up by organisms because they are liposoluble. They bioaccumulate and are known to biomagnify (i.e. increase in concentration with each level of a food chain). The most important organic mercury compound is methylmercury, which is formed by microbial activity in water ecosystems.

Mercury enters the aquatic environment primarily through atmospheric deposition, but also through runoff from mercury deposits in soil and rock. Mercury concentrations in the environment can vary considerably depending on the geological characteristics. The natural background concentrations in surface waters are generally lower than 0.1 µg/L mercury. Higher mercury concentrations can occur in underground waters, hot springs, vapours from fumaroles and steam. Mercury's high affinity for organic ligands on particles means that mercury tends to sorb to various materials. Particles in water and in sediments therefore contain higher mercury concentrations than the water itself [9]. Sediments downstream of mercury ore deposits and mercury-contaminated industrial discharges may contain mercury concentrations from a few hundred µg/kg to several hundred thousand µg/kg. In sediments, inorganic mercury is the most abundant form, although microbial activity methylates mercury to some extent. On average, soil contains about 100 µg/kg mercury. Concentrations of mercury in Switzerland range from 30 µg/kg to 290 µg/kg in agricultural, meadow and forest soil. In urban soil the levels are higher: 220 µg/kg of mercury were measured in Winterthur in 2008 and 390 µg/kg in Lugano [8].

Accumulation and toxicity in organisms

Like many environmental contaminants, mercury bioaccumulates, which means that it is taken up more rapidly by organisms than their bodies can eliminate it, thus the amount of mercury accumulates over time. Total mercury concentrations in aquatic invertebrates from the same environment can vary five- to ten-fold and bivalves are the most efficient invertebrates at accumulating mercury. The conversion of inorganic mercury to methylmercury by bacteria in marine and freshwater systems is important for two reasons: (1) methylmercury is much more toxic than inorganic mercury, and (2) organisms take much longer to eliminate methylmercury than mercury. The highest tissue concentrations of mercury are found in fish and predators at the top of the food web such as birds and mammals due to biomagnification. Fish tissue, for example, can contain up to six orders of magnitude higher concentrations of methylmercury than the surrounding water [10]. Fish and seafood are the major exposure route for mercury to humans. For humans, about half the body burden of mercury can be eliminated in 70 days if no mercury is ingested during that time [11]. However, if exposure and accumulation are continuous, toxic effects can occur.

Mercury is neurotoxic. According to the World Health Organisation it is one of the top ten chemicals of major public health concern. Mercury poisoning can result from exposure to water-soluble forms such as mercury chloride or methylmercury, by inhalation of mercury vapour or by ingesting any form of mercury. How someone's health is affected by exposure to mercury depends on a number of factors such as the form of mercury, the level and route of exposure (amount, duration, breathing, eating, skin contact), and the age and health of the person exposed (the fetus is the most vulnerable). Exposures to metallic mercury can occur when metallic mercury is spilled so that mercury is exposed to the air. The exposure with the highest concern is from the burn-off of Hg in ASGM.

The best-documented case of mercury poisoning happened in Minamata, Japan, between 1932 and 1968. There, a chemical factory discharged waste that contained high concentrations of methylmercury into the bay. Many people lived on the bay's fish and shellfish and for a long time no one realized that the fish were contaminated with mercury. At least 50 000 people were poisoned and more than 2000 cases of Minamata disease were diagnosed, with severe cases suffering brain damage, paralysis, incoherent speech and delirium [12].

In Europe, the Water Framework Directive (WFD) sets an acute and chronic environmental quality standard for surface waters (MAC- and AA-EQS) of 0.07 and 0.05 µg/l, respectively. Countries may decide to develop environmental quality standards for biota that ensure at least the same level of protection. The WFD sets a level of mercury in fish of 20 µg/kg wet weight, intended to protect predators from secondary poisoning. The threshold for human consumption is 500-1000 µg/kg wet weight. Monitoring of mercury concentrations in fish across Europe between the years 2007 and 2013 showed concentrations between 15.9 and 251 µg/kg wet weight.

The Minamata Convention on Mercury

In 2003, the Governing Council of the United Nations Environment Programme (UNEP) decided that there was sufficient evidence of significant global adverse impacts from mercury and its compounds to warrant international action to reduce their risks to human health and the environment [3]. Due to the global transport of mercury in the environment, global actions are required, and governments were urged to

adopt goals for the reduction of mercury emissions and releases with the support from UNEP. In 2009, the Governing Council adopted the Minamata Convention on Mercury. Since then, 128 countries have become signatories and 86 parties of the Convention, which entered into force on August 16, 2017 [13].

The objective of the Convention is to protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds. It bans new mercury mines and sets phase-out dates for existing ones. The Convention contains measures to control the supply and trade of mercury, and the phase-out and phase-down of mercury use in certain processes as well as mercury in products such as lamps, batteries or measuring devices by 2020. Measures for the environmentally sound storage of mercury and mercury-containing wastes, as well as for contaminated sites are included. Parties have to implement control measures on emissions to air (e.g. from coal-fired power plants or waste incineration) and the informal ASGM sector is to be regulated. The use of dental amalgam should also be reduced. The Minamata Convention highlights the need for the representative monitoring of levels of mercury and mercury compounds in vulnerable populations and in environmental media such as fish, marine mammals, sea turtles and birds, as well as of the impacts of mercury and mercury compounds on human health and the environment.

What is Switzerland doing in the context of the Minamata Convention?

Switzerland ratified the Minamata Convention on 26 May 2016. Existing national legislation governing the protection of water bodies and the environment and the application of chemicals ensures that Switzerland complies with most of the convention's requirements. The Chemical Risk Reduction Ordinance (ORRChem) already restricted or banned the placing on the market and the use of products containing mercury or requiring mercury for its use. This includes thermometers and other measuring instruments, dental amalgams, plant protection products, biocide products, paints, varnishes, and the use of mercury and mercury compounds as well as mercury-containing preparations as auxiliary substances in chemical synthesis on an industrial scale [1]. With regard to water quality, the Waters Protection Ordinance (WPO) regulates mercury requirements and sets maximum mercury concentrations on discharges into waters and public sewers from certain industrial sectors such as the chemical industry, surface treatment and electroplating, and public utilities and waste disposal plants such as waste incineration plants and plants processing wastes containing mercury [2]. The WPO sets a numerical value of 0.03 µg/l Hg (total) and 0.01 µg/l Hg (dissolved) that should not be exceeded in surface waters to protect against harmful effects. The Contaminated Sites Ordinance (CSO), which is intended to ensure that polluted sites are remediated if they cause (or there is a real danger that they may cause) harmful effects or nuisances, addresses the registration, monitoring and remediation of contaminated sites. In order to achieve the convention's overall aim, additional measures have been in effect since 31 December 2017. Those include the ban on elemental mercury for chlorine-alkali electrolysis and elemental mercury, mercury compounds and preparations containing mercury as auxiliary materials for chemical syntheses on an industrial scale if, based on the current status of technology, an alternative without auxiliary materials containing mercury is available.

Screening of mercury in Swiss WWTP

According to the 2014 inventory, 34% of a total of 9 kg of mercury estimated as released into surface waters in Switzerland came from wastewater treatment plants (WWTPs), and 64% from industrial sources. WWTPs play an important role in reducing pollutant loads in surface waters but little is known about mercury occurrence and fate in WWTPs. To fill this knowledge gap, in 2017 FOEN launched a project together with Eawag and others to monitor mercury in sewage sludge collected from 25 Swiss WWTPs. The aim is to quantify wastewater-related mercury fluxes in Switzerland and, in combination with geographical information on the catchment areas, to identify source hotspots. In addition, the efficiency of mercury removal during the treatment process is calculated based on mass balances. Inorganic and organic mercury compounds and mercury complexes can enter WWTPs and can vary in their physical and chemical behaviour and toxicity. The mercury speciation will be determined to assess the mobility of mercury compounds in wastewater and to allow evaluating the risk for potential remobilisation during treatment. Contact: Michael Berg m.berg@eawag.ch..

Hg contamination in the Grossgrundkanal

In 2010/2011 it was found that soils at several locations between Visp and Nidergesteln were polluted with mercury. A historical survey revealed that the chemical and pharmaceutical company Lonza had discharged 50-60 tons of mercury into the Grossgrundkanal between 1930 and the mid-1970s. The canal was periodically dredged for maintenance and the dredged sediments deposited on agricultural lands and gardens or used as filling material until the beginning of the 1990s, when the authorities intervened and the sediments began to be disposed of in discharges. So far, mercury has been found in communal discharges, canal sediments and soils in residential and agricultural lands. Several studies were done to elaborate measures for the environmentally sound management of mercury-contaminated sites. The remediation of soils started in 2017, initially tackling inhabited land followed by agricultural land and finally the canal. Contact: Yves Degoumois, yves.degoumois@admin.vs.ch

Literature

Useful summary

Tackling mercury pollution in the EU and worldwide http://ec.europa.eu/environment/integration/research/newsalert/pdf/tackling_mercury_pollution_EU_and_worldwide_IR15_en.pdf, EC, Science for Environment Policy, In-Depth Report 15, November 2017

Links

[1] Chemical Risk Reduction Ordinance
https://www.admin.ch/opc/en/classified-compilation/20021520/index.html

[2] Waters Protection Ordinance
https://www.admin.ch/opc/en/classified-compilation/19983281/index.html

[3] Minamata Convention on Mercury http://www.mercuryconvention.org

[4] https://www.bafu.admin.ch/bafu/en/home/topics/international-affairs/dossiers/fight-against-mercury.html

[5] See UNEP mercury assessment (http://wedocs.unep.org/handle/20.500.11822/7984); will be updated in 2018 (sse: http://wedocs.unep.org/handle/20.500.11822/21553 [tech background doc])

[6] Ritscher, A., von Arx, U., Bouchex-Bellomie, H., Buser, A. (2018) Verwendung, Entsorgung und Umwelteinträge von Quecksilber. Übersicht über die Situation in der Schweiz. Bundesamt für Umwelt, Bern. Umwelt-Zustand Nr. 1832. https://www.bafu.admin.ch/bafu/de/home/themen/chemikalien/publikationen-studien/publikationen/verwendung-entsorgung-umwelteintraege-quecksilber.html

[7] Federal Office for the Environment, Glossary of pollutants https://www.bafu.admin.ch/bafu/en/home/topics/chemicals/glossary-of-pollutants/mercury.html

[8] Reiser, R., Meuli, R. (2013) Quecksilber in Böden: Herleitung eines Prüfwertes gemäss VBBo für Nutzungen mit möglicher direkter Bodenaufnahme. Bericht im Auftrag des Bundesamtes für Umwelt (BAFU)

[9] The best estimate is that suspended matter may contain from five to 25 times as much mercury as the water around it in areas of industrial pollution. US Geological Survey (1970) Mercury in the Environment. Geological survey professional paper 713 (https://pubs.usgs.gov/pp/0713/report.pdf)

[10] Luoma, S., Rainbow, P. (2008) Metal contamination in aquatic environments: science and lateral management. Cambridge University Press , New York, U.S.A.

[11] Krabbenhoft, D.P., Rickert, D.A. (1995) Mercury contamination of aquatic ecosystems. US Geological Survey. Fact Sheet FS-216-95.

[12] Fact Sheet of the World Health Organisation http://www.who.int/mediacentre/factsheets/fs361/en/

[13] http://www.mercuryconvention.org/Countries/tabid/3428/language/en-US/Default.aspx, accessed on 1/19/2018.

[14] Ordinance on the Remediation of Polluted Sites (Contaminated Sites Ordinance, CSO) https://www.admin.ch/opc/en/classified-compilation/19983151/index.html

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