International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133, Print ISSN: 2664-7125
Received: 01-03-2024, Accepted: 15-03-2024, Published: 30-03-2024
Volume 6, Issue 1, 2024, Page No. 45-49

Mercury pollution: A looming global threat to human and environmental health

Koushik Ghosh*
Research Scholar, Department of Soil Science and Agricultural Chemistry, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India

Abstract
In present times, mercury pollution remains a critical environmental concern, posing substantial risks to both ecosystems and human health on a global scale. This article explores the sources, pathways, and consequences of mercury contamination, highlighting its persistent and accumulative characteristics in aquatic and terrestrial environments. Natural sources like volcanic eruption, geothermal activities as well as human activities such as mining, industrial processes, and the burning of coal are primary sources of mercury emissions into the atmosphere, where it eventually settles into water bodies and soil. Once absorbed by organisms, mercury bioaccumulates up the food chain, potentially causing neurological and developmental harm to both humans and wildlife. Addressing this issue effectively demands international collaboration, rigorous regulatory measures, and innovative technologies aimed at reducing emissions and mitigating the severe impacts of mercury pollution on our planet's vulnerable ecosystems and populations.

Keywords: Bioaccumulation, environment, human health and mercury

Introduction

Mercury, symbolized as Hg, derived from the Greek word *hydrargyrum* meaning liquid silver, is a natural element known for its unique properties. It is a silvery-white metal that remains liquid at standard temperature and pressure. It is present in the environment in various forms, including elemental mercury (Hg^0), inorganic like Mercurous (Hg^+) and Mercuric (Hg^{++}) salts, as well as organic compounds such as methyl-, ethyl-, and phenyl-mercury. Each form varies in toxicity and behaviour in the environment, influencing its ability to accumulate and pose risks to living organisms (Verma *et al.*, 2018) [13]. However, organic forms of mercury (mainly methyl mercury) are especially concerning due to their high bioaccumulation potential, presenting greater toxicity compared to inorganic species. mercury is one of the most toxic elements known to pose significant threats to wildlife, particularly through its ability to accumulate and magnify to hazardous levels within aquatic food chains (Munthe *et al.*, 2007) [9]. Mercury, an element neither created nor destroyed by humans, is mainly released into the environment by naturals process like volcanic eruptions and naturally occurs in the earth's crust, primarily as mercury salts like mercury sulphide (HgS) and other mercury-containing minerals include corderoite ($Hg_3S_2Cl_2$) and livingstonite ($HgSb_4S_8$), both of which are rare on Earth. Mercury is found in uncontaminated soils at around 100 parts per billion (ppb) on average, while in naturally contaminated areas (near Hg-bearing deposits), its level can be as high as 3500 ppb. Since the industrial revolution, human activities such as intensified mining operations, extensive burning of fossil fuels, and widespread use of raw materials containing mercury have significantly contributed to environmental mercury contamination. The World Health Organization (WHO) has set a maximum allowable level of 1 microgram per liter (1 µg/L) for mercury in drinking water (Azimi & Moghaddam, 2013) [3]. The U.S. Environmental Protection Agency (EPA) classifies mercury as a highly hazardous element because it remains in the environment for long periods and builds up in living organisms. This accumulation leads to increased toxicity over time, posing severe risks to both ecological systems and human health (Saturday, 2018) [11].

Definition and Sources of Mercury Pollution

Mercury pollution refers to the contamination of the environment by mercury, a highly toxic element released from natural sources like volcanic eruptions and human activities such as industrial processes, mining, and fossil fuel combustion, resulting in significant ecological and health hazards on global scale due to its persistent and bio accumulative nature.

Mercury pollution sources can be classified into two main categories: natural and anthropogenic, are briefly described below.

1. Natural Sources

Natural sources of mercury emissions to the atmosphere arise solely from natural processes without human influence. These include geothermal activities, volcanic eruptions, natural volatilization from ocean surfaces, and weathering of mercury-containing minerals etc. The contribution of natural sources of mercury pollution are depicted in fig. 1.

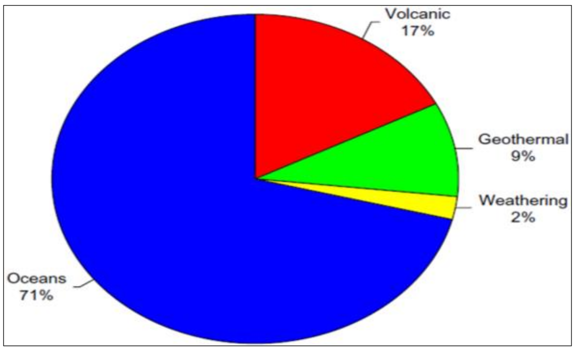

Fig 1. Relative contributions of estimated mercury emissions to the atmosphere from natural sources (*Source:* Varekamp and Buseck, 1986) [12]

2. Anthropogenic Sources (Human Activities)

Anthropogenic sources of mercury emissions to the atmosphere originate from human activities such as small-scale gold mining, dental amalgams in cremation, consumer product waste disposal, coal combustion, chlor-alkali industry, mining, and smelting operations, and refining of oil and natural gas etc. The contribution of anthropogenic sources of mercury pollution are presented in fig. 2.

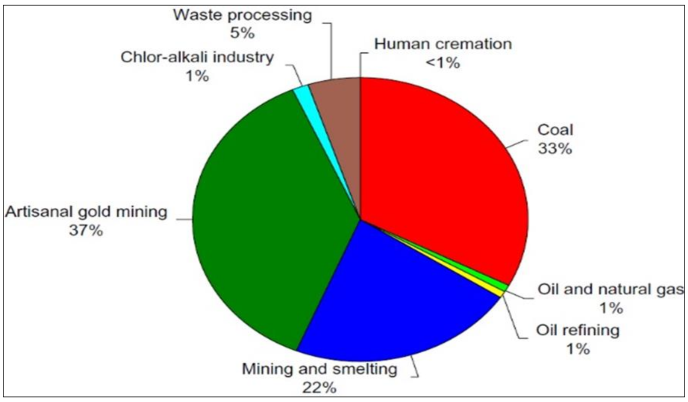

Fig 2: Relative contributions of estimated mercury emissions to the atmosphere from anthropogenic sources (*Source:* Varekamp and Buseck, 1986) [12].

Mercury Cycle

The mercury cycle refers to the natural processes and human activities that involve the movement of mercury through various environmental compartments, such as air, water, soil, and living organisms. It begins with natural sources like volcanic eruptions and weathering of rocks, releasing mercury into the atmosphere. From there, mercury settles onto land or water bodies through precipitation or air deposition. In aquatic environments, mercury can be converted by bacteria into methylmercury, a highly toxic form that bioaccumulates in aquatic food chains. This methylmercury then bioaccumulates and biomagnifies as it moves up the food chain, potentially reaching harmful levels in fish and other wildlife. Human activities such as mining, industrial processes, and burning fossil fuels also release mercury into the environment, contributing to the global mercury cycle and increasing environmental and health risks. The mercury cycle is depicted in figure 3.

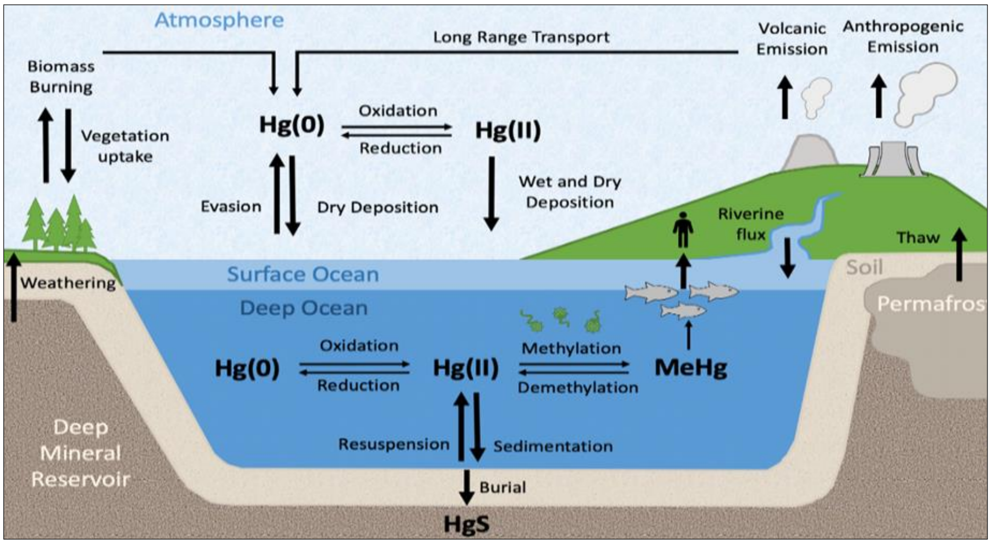

Fig 3: Mercury Cycle in the Environment

Toxicological Impact of Mercury on Human and Environmental Health

1. Effect of Mercury Exposure on Human Health

Mercury is extensively utilized in healthcare settings, found in items such as thermometers, sphygmomanometers, medical batteries, fluorescent lamps, and electrical switches, as well as in preservatives, fixatives, and reagents commonly employed in hospital laboratories. The ensuing sections explore the ramifications of mercury exposure in detail.

1.1. Neurological Effect: All forms of mercury pose significant risks to the Central nervous system (CNS). Methylmercury and metallic mercury vapours particularly hazardous due to their ability to penetrate the brain more readily than other forms. This increased access to the brain enhances their potential for causing harm. In adult, exposure to methylmercury results in neurological symptoms such as coordination difficulties (ataxia), widespread weakness (neurasthenia), sensory deficits impacting hearing and vision, tremors, and ultimately, loss of consciousness leading to fatality (Saturday, 2018) [11].

1.2. Reproductive Effect: Mercury exposure can disrupt the hypothalamus-pituitary-adrenal and gonadal axis, altering reproductive hormones like FSH, LH, estrogen, progesterone. Studies in Hong Kong indicate that higher mercury levels are linked to infertility in both genders, with males experiencing impaired spermatogenesis and lower sperm counts, while females may suffer from ovarian dysfunction and menstrual irregularities (Davis *et al.*, 2001) [4].

1.3. Nephrotoxic Effect: Chronic exposure to mercury compounds, such as methylmercury or inorganic mercury affect the kidneys, leading to renal toxicity. It has been associated with various forms of kidney injury, including nephrotic syndrome, tubular dysfunction, segmental glomerulosclerosis, nephrotic-range proteinuria, glomerular diseases (Miller *et al.,* 2013) [8].

1.4. Digestive System Effect: Mercury is absorbed through the epithelial cells of the gastrointestinal tract when it is ingested, can disrupt digestive processes by inhibiting the production of trypsin and pepsin, as well as impairing the function of enzymes like xanthine oxidase and dipeptidyl peptidase IV, lead to gastrointestinal symptoms such as abdominal pain, indigestion, inflammatory bowel disease, ulcers, and diarrhea.

1.5. Respiratory System Effect: Excessive inhalation of elemental mercury vapor can lead to lung inflammation (chemical pneumonitis), breathing difficulties (dyspnea), chest pain, and a persistent, dry cough, posing significant respiratory health risks.

2. Effect of Mercury Exposure on Environmental Health

Mercury exposure poses significant risks to environmental health due to its persistence, bioaccumulation, and toxicity. Here are key points on the effects of mercury exposure on environmental health:

2.1. Air Pollution: Mercury is emitted into the atmosphere during industrial processes like coal combustion and waste incineration. Once airborne, mercury can travel long distances before depositing onto land or water surfaces. In its gaseous form, mercury can be carried by rainfall into ecosystems, contributing to the contamination of soils and water bodies.

2.2. Water Pollution: Mercury contaminates water sources through direct discharge from industrial processes, mining activities, and improper disposal of mercury-containing products. In aquatic environments, mercury undergoes a transformation into methyl mercury, a highly toxic form that bioaccumulates and biomagnifies in the food chain. Methyl mercury accumulates in the tissues of fish and other aquatic organisms, posing risks to aquatic life and to humans who consume contaminated fish.

2.3. Soil Contamination: Mercury released into the environment accumulates in soils, particularly near industrial sites or areas with improper disposal practices. Soil contamination can disrupt plant growth and microbial activity, thereby impacting ecosystems. Humans can also be affected through the consumption of crops grown in mercury-contaminated soils, potentially leading to health issues.

2.4. Wildlife Impact: Mercury exposure harms wildlife, particularly in aquatic ecosystems where methyl mercury bioaccumulates in fish and other aquatic organisms. This accumulation can lead to reduced reproductive success, impaired growth and development, and population declines in sensitive species.

Acute Mercury Contamination and Minamata disease

The most infamous instance of acute mercury contamination occurred in the fishing villages around Minamata Bay, Japan, due to Chisso Corporation's discharge of wastewater containing inorganic mercury and methylmercury, by-products of their acetaldehyde production process (Figure 4). This led to bioaccumulation of methylmercury in local fish and shellfish, and consequently in the people consuming them, resulting in Minamata disease. The disease, characterized by numbness, loss of sensation in extremities, coordination issues, and sensory impairments, was first diagnosed in 1956. By 1959, methylmercury in contaminated seafood was identified as the cause. Marine products from the bay had high mercury levels (5.61 to 35.7 ppm), and affected individuals showed mercury concentrations up to 705 ppm in their hair. Out of 2252 officially recognized patients over 36 years, 1043 have died (Harada, 1995) [6].

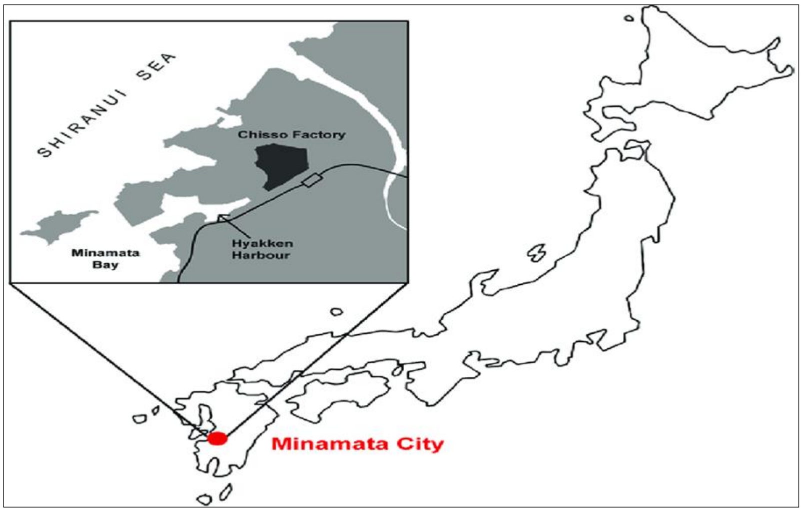

Fig 4: Map displaying the geographical position of Minamata city, Japan (*Source:* Esteban, 2016) [5]

Effective Treatment for Mercury Poisoning

Like other heavy metals, mercury resists degradation within ecosystems, necessitating treatment strategies focused on removal or installation methods. Removal techniques such as adsorption, oxidation, and reduction aim to separate or convert toxic mercury species into less harmful forms. Meanwhile, installation techniques like stabilization and containment prevent mercury transfer through chemical immobilization or physical isolation, respectively (He *et al.*, 2015) [7]. Various methods are employed for mercury removal and mitigation across different environmental contexts. Catalyst oxidation is widely utilized in gas phase mercury removal, proving cost-effective for removing Hg^0 from flue gas. Novel oxidation techniques, including advanced free radical oxidation, are also explored, albeit with limited efficiency for Hg^0 removal. Meanwhile, functional covalent thioether of triazine nanoparticles exhibit remarkable adsorption capacities for both Hg^{2+} and Hg^0 from water, highlighting their potential in water treatment. Reduction of Hg^{2+} to Hg^0, crucial for mitigating methyl mercury formation, is effectively achieved using zerovalent iron or Fe (II) in wetland sediments (Amirbahman *et al*, 2013) [2]. Adsorption methods employing high-surface-area adsorbents and chelation mechanisms are pivotal for removing Hg (II) from aqueous solutions. Additionally, stabilization approaches, such as chemical fixation using sulfur-containing reagents like elemental sulfur and pyrite, immobilize mercury effectively in contaminated sites, minimizing environmental exposure (Piao and Bishop, 2006) [10]. Processes engaged in addressing mercury contamination is depicted in figure 5.

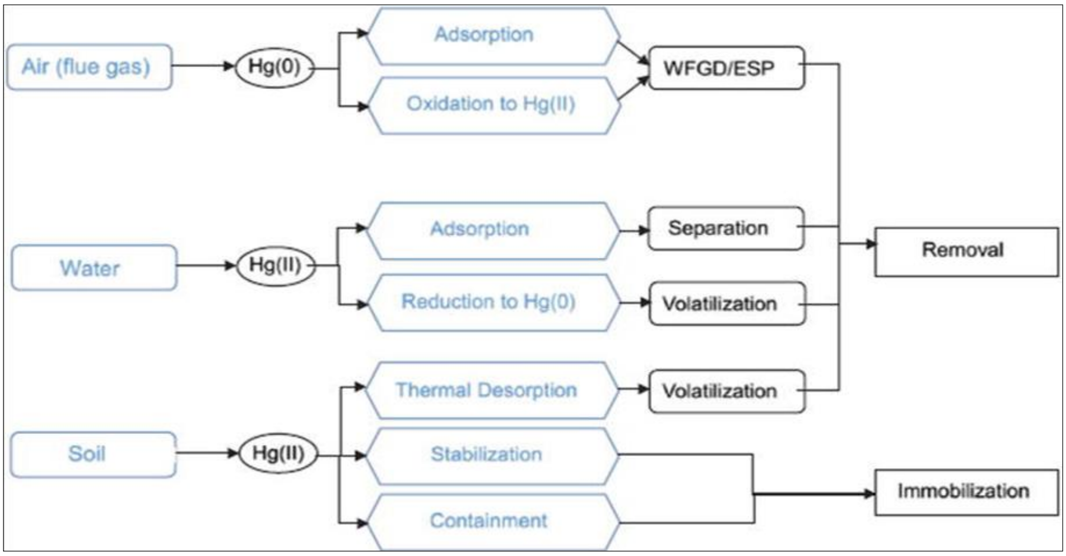

Fig 5: Mechanisms involved in mercury pollution treatment. Acronyms: WFGD, wet flue gas desulfurization; ESP, electrostatic precipitation (*Source:* Al-Zahra Gabar Gassim, 2023) [1]

Strategies Involved to Control Mercury Pollution

Controlling mercury pollution is crucial due to its harmful effects on human health and the environment. Here are five important points to consider for controlling mercury pollution

1. **Regulate Industrial Emissions:** Implement strict regulations and standards for industries that release mercury into the environment. This includes industries involved in mining, coal combustion, and waste incineration. Technologies such as scrubbers and filters can be employed to capture mercury emissions before they are released into the air or water.

2. **Promote Cleaner Technologies:** Encourage the adoption of cleaner production technologies that minimize mercury use or emissions. For example, promoting renewable energy sources like wind and solar power reduces the demand for mercury-containing products like coal.

3. **Reduce Mercury in Products:** Phase out or limit the use of mercury in products such as batteries, thermometers, fluorescent lamps, and dental amalgams. Encourage the development and use of safer alternatives that do not pose environmental or health risks.

4. **Monitor and Clean up Contaminated Sites:** Regularly monitor mercury levels in soil, water bodies, and sediments. Implement cleanup measures for contaminated sites, including proper disposal of mercury-containing waste and remediation techniques to reduce mercury concentrations in affected areas.

Conclusion

Mercury pollution poses severe environmental and health risks, impacting ecosystems and human well-being globally. Effective mitigation strategies are imperative, focusing on stringent regulations, advanced remediation technologies, and international cooperation. Sustainable practices and innovative approaches are crucial to mitigate mercury's pervasive effects, safeguarding both current and future generations from its detrimental impacts on biodiversity, food security, and public health.

References

1. Al Zahra Gabar, Gassim F. Mercury Pollution: Dangers and Treatment. IntechOpen, 2023. doi: 10.5772/intechopen.108390.
2. Amirbahman A, Kent DB, Curtis GP, Marvin Di, Pasquale MC. Kinetics of homogeneous and surface-catalyzed mercury (II) reduction by iron (II).

Environmental Science & Technology,2013:47(13):7204-7213.
3. Azimi S, Moghaddam MS. Effect of mercury pollution on the urban environment and human health. Environment Ecology Research,2013:1(1):12–20.
4. Davis BJ, Price HC, O'Connor RW, Fernando R, Rowland AS, Morgan DL. Mercury vapor and female reproductive toxicity. Toxicological Sciences,2001:59(2):291-296.
5. Esteban M, Akiyama T, Chen C, Ikeda I, Mino T. Sustainability Science: Field Methods and Exercises. Springer, Switzerland, 2016, 95-96.
6. Harada M. Minamata disease: Methylmercury poisoning in Japan caused by environmental pollution. Critical Reviews in Toxicology,1995:25(1):1-24.
7. He F, Gao J, Pierce E, Strong PJ, Wang H, Liang L. In situ remediation technologies for mercury-contaminated soil. Environmental Science and Pollution Research,2015:22(11):8124-8147.
8. Miller S, Pallan S, Gangji AS, Lukic D, Clase CM. Mercury- Associated Nephrotic syndrome: A case report and systematic review of the literature. American Journal of Kidney Diseases,2013:62(1):135-138.
9. Munthe J, Bodaly RA, Branfireun BA, Driscoll CT, Gilmour CC, Harris R, *et al*. Recovery of mercury-contaminated fisheries. Ambio- A Journal of the Human Environment,2007:36(1):33-44.
10. Piao H, Bishop PL. Stabilization of mercury-containing wastes using sulphide. Environmental Pollution,2006:139(3):498-506.
11. Saturday A. Mercury and its associated impacts on environment and human health: A Review. Journal of Environment and Health Science,2018:4(2):37-43.
12. Varekamp JC, Buseck PR. Global mercury flux from volcanic and geothermal sources. Applied Geochemistry,1986:1(1),65-73.
13. Verma RK, Sankhla MS, Kumar R. Mercury contamination in water & its impact on public health. International Journal of Forensic Science,2018:1(2):72-78.