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Mercury pollution and its impact on aquatic organisms

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Abstract

Mercury is a heavy metal that is extremely toxic. There are three types of it: inorganic, organic, and elemental. Mercury in all its forms has been shown to have harmful effects on living things. It can multiply its concentration from lower to higher trophic levels and accumulate in the body's various tissues. Aquatic organisms bodies have been exposed to mercury mostly through various human activities. The largest source of mercury pollution in the air is thermal power plants that mostly use coal as fuel. It is carried to a body of water after being deposited on the ground surface from the air. The way it enters the food chain is through aquatic plants and animals. Mercury accumulations in the kidney, liver, gills, or gonadal tissues of species that are readily exposed and ingested in aquatic organisms environments. There are possible effects of mercury exposure at both acute and long-term levels. The length of time, the mode of exposure, and the dosage all affect how harmful a substance is. The current study provides information about the harmful effects of mercury in aquatic organisms environments. Even though significant mitigation measures and recommendations were implemented, this assessment provides a comprehensive account of mercury sources and emissions, as well as their destiny and movement across the various environmental compartments. Because of the existing mercury emissions and stability, eating fish still poses a major risk. Aquatic life may be toxically affected by mercury pollution in freshwater environments. Through the food chain, mercury buildup in aquatic organisms can also endanger human health. Aquatic creatures include macroinvertebrates and fish. which people ingest and put their health at serious risk. The effect of mercury on hydrocarbons and how it enters the food chain to reach humans has been identified.

Keywords: Environment; Mercury; Contaminated; Organisms; Pollution

1. Introduction

An unwanted consequence of contemporary civilization's rising need for natural resources is environmental damage on a global scale. But ever since human communities first emerged there have been areas of environmental contamination, but not to the extent that we observe now. Almost every environment on the planet is contaminated to some extent. Contaminants like lead and mercury, which are dispersed globally in the atmosphere, are present in even the most isolated places, like the Antarctic, in amounts higher than those predicted for the area. Therefore, environmental organizations increasingly focus on determining the extent of pollution rather than whether an environment is contaminated (1) Generally speaking, there are two major categories of contaminants that harm ecosystems the most. The first includes the compounds found in the wastewater generated by major cities, particularly those connected to the inappropriate disposal of solid waste (trash) and the poor or non existent sanitary wastewater treatment The areas most severely impacted by the pollutants produced by these sources are aquatic ones, including rivers, estuaries, and coastal zones. This team comprises nutrient overload, especially of nitrogen and phosphorus, which leads to the growth of algae and plankton in natural waters, and organic matter, which increases the biochemical demand on oxygen in aquatic habitats Ecosystemic eutrophication, which is the outcome of this kind of environmental pollution, is typified by the rapid growth of simple photosynthetic organisms like bacteria and algae and the removal of species that are more

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vulnerable to altered environmental conditions, hence intensifying the elevated oxygen demand in metabolic processes.When these pollution processes persist, ecosystems become anoxic or suboxic, meaning that there is not enough oxygen present to sustain the entire growth of aquatic organisms. This kind of pollution is mainly found in poor and populated countries, and its source is closely related to substandard living circumstances. among the populace, with inadequate sewage treatment and basic sanitation(2).

One of the most hazardous heavy metals, mercury (Hg) is found in the environment as a lethal contaminant. Mercury is the third most hazardous material for the environment, behind lead and arsenic, according to the US This heavy metal is transported and redistributed to the air soil and aquatic ecosystem by both natural and man-made activities, according to the Environmental Protection Agency (EPA) and the Agency for Toxic Substance and Disease Registry (ATSDR)(3).Numerous toxicants have been introduced into the aquatic ecology. The survival of aquatic species is seriously threatened by anthropogenic activities such as mining, the widespread use of synthetic pesticides, fertilizers, fungicides, and insecticides, and industrial effluents. Reducing the use of fertilizers and pesticides in the surrounding areas, which is seriously endangering the local bird species, can help Sultanpur National Park maintain the purity of its water. Mercury is a special kind of heavy metal that can be found in nature in three different forms: inorganic, organic, and elemental. There are three distinct hazardous potentials for each of these three types of mercury. There are three different oxidation states of mercury: metallic mercury (Hg°), mercury salt (Hg^{+}), and mercury salt (Hg^{++}). Metallic mercury is a dense, silvery white, and lustrous metal that forms an organo-metallic complex when it covalently links with a carbon atom. Among the organic compounds of mercury, methyl mercury is thought to be the most prevalent and hazardous type. A small number of Anaerobic microbes present in aquatic bodies' sediment such as , Ponds and lakes wetlands, and oceans transform methyl mercury from inorganic mercury (4). Additionally, the industrialized waste that enters The body of water is transformed into Mercury methylation , which pollutes The watery environment. Methyl mercury is readily absorbed by lower trophic level species and then added to the food chain. Iron reducers, methanogens, and anaerobic sulphate-reducing bacteria are examples of microorganisms that methylate inorganic. After entering the food chain, it begins to exhibit a propensity for bioaccumulation and penetrates aquatic organisms' bodies, particularly fish. There are numerous additional sources of organic mercury, including emissions from fossil fuels, battery factories, medical waste incineration, dental amalgam, teething powder, and germicidal soap , certain devices, such as a sphygmomanometer, barometer, and thermometer (5). Since a few microliters of dimethylmercury can be fatal splashed on hands or gloves, it is regarded as the most poisonous organic form of mercury. Additionally, it can cause neurological abnormalities, blindness, mental retardation, altered muscular tone, and hearing loss (6). Although its excretion rate is sufficiently sluggish, mercury has a propensity to accumulate in tissue (7). Another hazardous inorganic form of mercury is mercuric chloride ($HgCl_2$). It is naturally corrosive. When taken orally, the digestive tract disintegrates, causing symptoms such as nausea, vomiting, and diarrhea. Additionally, mercury intoxication was found to cause changes in the central nervous system and behavioral patterns (8). Numerous factors, including an individual's age or other characteristics related to their size or weight, may potentially have a direct or indirect impact on the bioaccumulation of mercury in fish (9). A study by(10) indicated that the concentration of mercury within Ganga River ecology in Varanasi was distributed as follows: water < sediments < fish < benthic macro-invertebrates. According to (11) the order of mercury bond formation was Fish < sediments < water < big watery invertebrates that are becoming more. By infecting fish or water-based species via their overall body surface, gills, or digestive system, mercury compounds reduce cellular adaptive immunity, cause histopathological abnormalities, and change how Lipids, fats, and glucose are metabolized (12)Researchers have also looked into how Heavy metals like mercury affect Health and bioaccumulation of fish(13). In addition to affecting fish populations, these accumulated heavy metals in aquatic environments also affect other trophic levels further up the food chain or web. Human health is negatively impacted by the Trophic transfer of these elements from water to land transitioning ecosystems, which raises the likelihood of illnesses like cancer and nervous disorders (14). This review's major goal is to draw attention to the harmful effects of mercury toxicity, which is steadily rising due mostly to human activity despite numerous conventions aimed at reducing it. These heavy metal accumulations in aquatic ecosystems affect fish populations, but they also have an impact on other trophic levels farther up the food chain or web. The trophic transmission of these components from aquatic to terrestrial ecosystems has a detrimental effect on human health, increasing the risk of neurological illnesses and cancer (15). The main objective of this appraisal is to of this review is to highlight the detrimental consequences of mercury poisoning, which is steadily rising mostly as a result of human activity in spite of multiple conventions designed to lower it.

2. Mercury Impacts on fish Environment

Even at sub lethal concentrations, mercury is exceedingly toxic to fish and changes the physiology, biochemistry, and structure of the nervous system. It accumulates in fish neural tissues because it can cross the blood-brain barrier. Mercury modifies the physical properties and structural integrity of cell membranes by rearranging purines, pyrimidines, and nucleic acids. The kidney tubule of Clarias exhibits evidence of damage and necrosis due to prolonged exposure to mercury (16). Zebra fish exposed to inorganic mercury showed oxidative stress in the gonads and hepatological abnormalities. Furthermore, exposure to mercury changed sex hormones via interfering involves the Hypothalamic-Pituitary-Gonadal (HPG) axis's gene transcription. The male reproductive system of the tropical fish Gymnotous carapo showed hypersensitivity to mercury poisoning. Mercuric chloride induced proliferation of interstitial tissues, clogged blood vessels, disordered seminiferous tubules, and reduced the number of germ cells and sperm. Researchers have conducted A comparative analysis of (17) as well as biochemical (18) analysis of two distinct species of freshwater air-breathing fish Clarias in the control group. These ranges of references can be utilized as delicate indicators toward monitor subsequent alterations in the pathophysiology of fish brought on by a number of variables otherwise stressors like xenobiotics. Additionally, it will assist in monitoring fish health and the level of pollution in aquatic environments. Researchers looked at how the haematological and mercury metabolism of grass carp were impacted by mercury in water at different temperatures. The consequences of exposure to mercury, water temperature, and duration going on hemoglobin attention, hemocrit value, pyruvate kinase, malate, and hexokinase were shown to be strongly correlated (19). Since mercury has a high affinity for proteins, fish muscle contains almost 90% of all mercury (20). Muscle has also been found to have high levels of mercury (21). According to Evans et al. (1993), the liver also aids in the detoxification, storage, and transport of mercury. According to(22), fish are the most reliable markers of physiological changes and aquatic ecosystem health. Since fish seem to be the main mercury's source in humans, Using them as a bio-indicator could determine the possible effects of mercury on human health (23). Because they cannot avoid the harmful effects of aquatic contaminants, fish are particularly vulnerable to heavy metal contamination (24). Any anomalies Histopathology in hepatic tissue affects liver function and cause fish death because the liver is an essential metabolic center. Any tissue in the liver injury eventually results in a number of physiological issues, includes fish death (25). In one study, Clarias batrachus was subjected toward varying concentrations of mercury, and TEM was used to evaluate the treated liver tissues. Consequently, bile, hemorrhagic clots, and eosinophilic inclusions clogged the main veins of the hepatic tissues. Additionally, it displayed biliary atresia symptoms. Hepatic cellular necrosis, nodular regeneration, and disrupted hepatic cytoarchitecture are additional indicators of portal cirrhosis (26). According to(27), the kidneys help the body maintain its electrolyte and water balance. Its main function is the expulsion of nitrogenous waste. Despite being the primary site where metallic compounds build up over time due to prolonged exposure, it is regarded as a crucial organ for detoxifying and eliminating metallic pollutants (29). In her thesis, (5)discussed the effects of acute and chronic mercury toxicity on the Clarias batrachus renal tissues (Linn.). Under TEM, the effects of mercury were seen as collecting tubules in renal tissue degradation. Podocytes, glomerular capillaries, and constricted endothelial cells also showed some signs of degeneration. The cuboidal epithelial cell structure and the cell-to-cell line in the collecting tubules were no longer present. Acute tubular necrosis was also demonstrated by The shrinking of the tubular in almost every renal tubule , mostly in DCT and PCT.. The DCT lumen becomes obstructed by hemorrhagic clots. There was substantial lymphocyte infiltration in the intertubular gap, and the basal lamina showed discontinuity. Numerous autophagic organelles, autophagic apoptotic organelles, fibrous clots, fusiform vesicles, inflammatory cells, and pus were found in the lumen of collecting tubules (8). Because blood parameter analysis provides precise With direct knowledge of any inadequacies, long-term stress, and metabolic abnormalities, it is considered a good tool for assessing fish health. Reactive oxygen species (ROS) are produced when metal ions are present in excess, causing fish to react to oxidative stress (3). Mercury, cadmium, arsenic, lead, and nickel are examples of redox-inactive metals that degrade proteins by binding to their sulfhydryl groups (-SH) (19). Increased ROS production in fish causes lipid and protein oxidation, DNA damage, and modifications to the cellular redox state (15). Fish are employed globally as bioindicators of metals in the environment by analyzing the formation of oxidative stress; however, further research is required to determine the precise the types of biomarkers and how they function (7). There have been reports of high levels of sewage contamination in the Ganga, and the Gangetic dolphin, India's national aquatic animal, believes that heavy metals pose a threat (13). From Hathidah (Patna), A pipeline carries Ganga water to Rajgir. where it serves as the town water supply for Rajgir and Gaya. The absence of mercury toxicity in the water must be guaranteed (8). Mercury poses a threat to even wetlands with high biodiversity and significant environmental significance. Significant pollution from chemical fertilizers and pesticides poses a mercuric hazard to living things. The first wetland in Bihar, India, to be designated by Ramsar is Kabartal Wetland. The ancient Burhi Gandak river created Asia's largest freshwater oxbow lake (9). This marsh attracts a large number of Siberian migratory birds (11)

A teratogenic neurotoxin that can build up in food webs is mercury. The most frequent way that humans are exposed to mercury is through eating fish that contain mercury. Ataxia, tremor, dysdiadochokinesia, and other movement abnormalities are typically brought on by chronic mercury toxicity (21). In addition to skin issues including dermatitis and ulcers/wounds, Gastrointestinal symptoms such as stomatitis, hypersalivation, colitis, chewing difficulty, gingivitis, black lines on the gums (lead line), and loose teeth can all be signs of mercury toxicity (7). The Minamata sickness, which struck Japan in the 1960s, was the most common instance of mercury intoxication. Residents of this city had severe neuropathy as a result of eating seafood contaminated with mercury (24).

3. Effect of mercury on benthic organisms

Mercury is a naturally occurring element that humans have discharged into the environment from geologically stable forms. actions. In addition to having the ability to directly harm lower trophic levels, such as benthic invertebrates, mercury biomagnifies via the food web Comparing the chemical concentrations in sediment to sediment is frequently the first step in screening for hazards that chemicals in sediment pose to benthic invertebrates. quality values (SQVs), sometimes referred to as benchmarks or guidelines for sediment quality.

SQVs are frequently created using paired chemical concentrations in sediment, usually with an upper bound statistic thought to be connected to a negative effect and a lower bound statistic thought to be connected to the absence of an effect (i.e., no effect). provide a new analysis of the mercury SQVs created to describe the dangers of mercury to benthic invertebrates (12). For contrast, information pertinent to comprehending the causal links between sediment toxicity and mercury concentrations was also examined.

Because of atmospheric deposition, terrestrial runoff, and local contamination sources, freshwater sediments are a crucial reservoir where mercury builds up (1–3).

Because methylation is preferred in anaerobic environments, sediments can be significant sites for it. circumstances caused by microorganisms that reduce iron or sulphate at the water-sediment contact (4,5). The most hazardous mercury molecule is methylmercury (MeHg), which has neurotoxic effects and is readily released by sediments. It also bioaccumulates in food webs (2,6,7). Additionally, there is a risk of secondary poisoning for top predators due to MeHg's great biomagnification potential, which increases both as concentration and as a percentage to total mercury (THg) with rising trophic level (8–10). Site-specific physical and chemical parameters, including pH, redox conditions, ligand presence, temperature, etc., have a significant impact on mercury transfer from abiotic compartments (water, sediment) to biota and are crucial for Hg bioavailability (5,11,12). In

These characteristics may exhibit significant fluctuations in riverine environments, making the study of mercury cycling potentially difficult. The issue of mercury pollution in freshwater habitats is quite serious. More than 45,000 water bodies in Europe do not meet the Water Framework Directive's "good chemical status" requirements due to mercury contents that are higher than the Environmental Quality Standard (EQS) for water or, more often, the EQS for biota (which is typically calculated from fish tissues) (13–15). Furthermore, elevated MeHg levels restrict fish eating in over 35% of US freshwaters, even in the absence of direct sources of mercury (2).

Because of their near closeness to sediments, benthic invertebrates are directly vulnerable to sediment contamination. These species play a crucial role in moving mercury from abiotic to trophic levels. In the aquatic environment, they provide food for numerous fish species, and adult insects are also consumed by birds, bats, and other terrestrial creatures (16). There are, however, few research on the bioaccumulation of mercury in freshwater invertebrates (e.g., (10,11). Relevant MeHg concentrations in aquatic invertebrates, which typically range between 10% and 90% of THg, can be used to identify considerable transfer to predators [10,20]. As a result, they are crucial. sensors for exposure to mercury in a variety of higher organisms. The absorption pathways and mechanisms underlying mercury bioaccumulation in invertebrates are poorly understood (21, 22). Nonetheless, it is generally acknowledged that for the majority of animals, food is the primary route of mercury exposure (2,12). Watery Since insects fall into every consumer category, including herbivorous and predatory ones, distinct Functional Feeding Groups (FFGs) may exhibit varying mercury contents, and biomagnification within invertebrate populations may also transpire [10,18]. Furthermore, the bioaccumulation potential of mercury may be influenced by additional factors, such as certain physiological systems (23). For instance, even though both mayflies are filter feeders, Cid et al. (16) discovered that the mayfly Ephoron virgo had two times greater mercury contents at the same location than the caddisfly Hydropsyche exocellata. Additionally,The same authors emphasized that aquatic insects' mercury contents vary according to their size and stage of life. Notably, some studies found comparable levels of mercury in freshwater insect larvae and adults, demonstrating the contaminant's effective movement to terrestrial habitats and higher trophic levels (26).

4. Impact Murcry on equatic plant

Research has indicated that mercury can hinder cell division and lower the photosynthetic rate of algae (5). Additionally, it has been noted that goldfish are toxically affected by water bodies containing 0.003 g/L of mercury [6]. Furthermore, because of the

As poisons in food chains become more prevalent, mercury is building up in animal internal organs at an exponential rate (7) When this bioaccumulated mercury enters the human body, it can lead to chromosome breaks as well as illnesses of the brain, heart, kidneys, and lungs (8,9). Ion exchange, precipitation, and reverse osmosis are examples of conventional techniques for cleaning up heavy metal contamination in water, but they are not economical and may have negative effects on aquatic ecosystems (10). Thankfully, the science of phytoremediation, which focuses As a workable substitute for traditional techniques, the capacity of plant roots, stems, and leaves to absorb and accumulate heavy metal components has been well studied (11). It has been determined that several floating, submerged, and emergent plants have the ability to accumulate heavy metals (12–15). These aquatic plants exhibit resistance to elevated heavy metal concentrations because they typically absorb heavy metals by chelation and compartmentalization [16]. In particular, by binding to heavy metals and lowering free heavy metal ions in plant cells, glutathione and chelating peptides produced from it are crucial for plant-assisted detoxification (17). The remediating effect of aquatic plants on heavy metal pollution has been the subject of numerous studies by researchers; some review articles have also qualitatively characterized the process by which these plants absorb heavy metals (10–16). But methodical and There are currently no statistical techniques available for a thorough assessment of aquatic plants' ability to absorb mercury. Additionally, even when the influencing conditions are the same, aquatic plants' capacity to absorb certain heavy metals from contaminated water vary (18). As a result, a thorough and quantitative analysis of the Hg absorption and transport capabilities of several aquatic plant species exposed to varying Hg concentrations and environmental conditions is required. Point estimation, bias-corrected 95% CI, other central trends, and accuracy are all included in the quantitative statistical analysis technique known as meta-analysis (19). It can be applied to compare and summarize research findings on a certain research topic and also provide a synopsis of the area's general guidelines [19,20]. The study of ecological issues has increasingly turned to meta-analytical approaches [20]. (1) The ability of various plants to absorb mercury, (2) the absorption of mercury ions in plant roots and their movement throughout the plants, and (3) the impact of various influencing factors on the heavy metal were all quantitatively examined using meta-analysis The plants' ability to absorb(21)

5. Discussion

The increase in aquatic bodies' mercury concentrations in recent years has put many aquatic species in serious danger of going extinct. Furthermore, mercury poses a serious risk to human health because It is a heavy metal that can enter the liver through the food chain and loves to build up in the fatty areas of fish tissues. The current study makes clear the persistently harmful effects of mercury exposure on aquatic life. The hematological, biochemical, histopathological, and stress tolerance profile of fish may be seriously threatened by mercury, which is lethal to aquatic organisms even at low concentrations, according to biochemical and haematological study. More research is needed to develop detoxifying methods and gain a deeper understanding of the molecular mechanisms behind the toxico-kinetics of mercury toxicity in fish. techniques that will improve the overall health of this significant commercial fish. WHO guidelines state that local, national, and worldwide initiatives are. need to reduce or completely eradicate mercury and its component emissions into the environment(12). It's important to note some of the steps taken to stop heavy metal poisoning, especially mercury. Along the Ganga, riverfront work has been completed in Patna, India, as part of the Namamai Ganga Mission. During the puja season, idols are submerged in A distinct idol immersion pool has been built at Barharwa Ghat. The river is shielded from pollution by pumping out this water (8). The species is threatened by migratory birds that consume seafood tainted with mercury (16). The disposal of industrial effluents into adjacent water bodies is addressed separately in contemporary industrial area planning. In Rajasthan's industrial areas, distinct ETPs are designed to handle all toxic wastes (18).

6. Conclusion

Long-term exposure to mercuric toxicity has a serious negative impact on health, and its effects on biological systems can affect the entire ecosystem. It is urgently necessary to reduce the use of fossil fuels and increase reliance on clean and green energy sources. In order for our kids to notice the kingfisher's fluttering feathers as it dives deep into the blue ocean, we should work to give them the best minds and eyes possible. Human health is more at risk when freshwater fish contaminated with mercury are consumed. In many nations, mercury contamination is a major worry. Research on this topic has been conducted frequently to monitor and warn consumers of high levels of this hazardous element. To comprehend the dynamics of mercury in the aquatic environment and, hence, in aquatic species, a number of biotic and abiotic elements are essential. These consist of water pH, organic matter content, oxygen, age, length, growth rate, and trophic level and, thus, feeding type.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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