Journal of Pharmaceutical and Biological Sciences 2024;12(1):8–18

Content available at: https://www.ipinnovative.com/open-access-journals

Journal of Pharmaceutical and Biological Sciences

Journal homepage: https://www.jpbs.in/

Review Article

Biomagnification of mercury in aquatic ecosystem and effect on human being

Shweta Gupta[1], **Upasana Yadav**[1]*

[1] *Amity University Lucknow Campus, Lucknow, Uttar Pradesh, India*

ARTICLE INFO

Article history:
Received 03-07-2024
Accepted 11-07-2024
Available online 08-08-2024

Keywords:
Mercury (Hg)
US Environmental Protection Agency (USEPA)
Gaseous oxidized mercury (GOM)

ABSTRACT

The problem of mercury biomagnification poses a significant risk that needs to be addressed immediately. This paper summarizes, in brief, the mercury biomagnification process, its effects on water ecosystems, and potential health hazards associated with the consumption of mercury-contaminated fish. Methylmercury, the more toxic form, is slowly becoming more widespread as it moves up the aquaculture food chain and reaches greater concentrations in larger predator species posing significant risks to aquatic life as well as humans and other animals. We are looking at the mechanisms and variables that affect bioavailability, including fish populations and bird species, as well as effects on aquatic biodiversity. In addition, we assess possible health risks to human beings, particularly for children and women of childbearing age. In conclusion, the techniques to reduce mercury biomagnification in light of international initiatives such as the Minamata Convention on climate change are explored in order to solve this problematic environmental problem. Thorough knowledge of mercury biomagnification is a necessity, which underlines the need for consistent management of marine ecosystems in order to perform efficient conservation efforts and lay down necessary health regulations in order to avoid profound health implications for human beings.

1. Introduction

Mercury (Hg) is a naturally occurring trace metal found everywhere in the environment. Revelation to tall points of mercury canister outcome in serious harm to the fundamental anxious classification, leading to symptoms like tremors, speech difficulties, kidney issues, breathing problems, dizziness, vision problems, delusions, and smooth expiry.[1] Additionally, confident research has shown that children might experience developmental delays due to mercury exposure, and there can be negative effects on cardiovascular health and the immune system.[2] More recently, mercury's potential as an immunotoxin has been explored, especially in vulnerable mouse models, revealing its capacity to cause immune system impairment.[3]

Human activities such as the use of fuels and artisanal gold mining subsidize the issue of elevated mercury absorptions in the atmosphere, affecting the air, soil, and water.[4] Moreover, the toxic and carcinogenic nature of mercury has both indirect and direct implications for human health and aquatic life. Similarly added heavyweight metallic element, hg cannot be naturally broken down within ecosystems. Therefore, addressing the problem requires methods that either remove or control its presence. Consequently, organizations like The maximum granted mercury concentrations in drinking water were determined by the World Health Organization or WHO, and the US Environmental Protection Agency (USEPA), set at 0.002 mg/L and 0.001 mg/L, separately.[5,6]

Hg is commonly created within biological developments, usually by way of sulfide ore known as vermilion (HgS). It is also a suggestion component in other naturally

---

* *Corresponding author*.
E-mail address: profupasana@gmail.com (U. Yadav).

https://doi.org/10.18231/j.jpbs.2024.003

occurring deposits like coal.[7] Mercury possesses distinctive attributes, including its remarkably in height gas heaviness. Different from most weighty metallic elements, the hg container transforms into vapor on lower fevers, releasing the situation into the surrounding air. In the atmosphere, mercury manifests in three primary forms: gaseous elemental mercury (GEM), gaseous oxidized mercury (GOM), and particulate-bound mercury (PBM). GEM prevails, accounting for 95–99% of the total atmospheric mercury.[8,9] Mercury exists in multiple forms: inorganic variants, encompassing metallic mercury, mercury vapor (Hg0), as well as mercurous (Hg2++) or mercuric (Hg++) salts; and organic forms, which involve compounds where mercury is chemically bonded to structures containing carbon atoms, like methyl, ethyl, phenyl, or similar groups.

The organic form of mercury that has been methylated, referred to as methylmercury or MeHg, is recognized as one of the most harmful pollutants.[10] This is primarily because it has a strong affinity for proteins, leading to its retention within tissues. As a result, there is a process of biomagnification that occurs throughout the whole nutrition chain, after plankton to the highest pillagers. The accumulation of mercury in fish is particularly significant, especially in areas where fish is the primary food source for the local population and the primary source of fibrin.[11] Once inanimate hg mixtures stay released into aquatic or loam and are subjected to microbial actions, they get converted into methylmercury over time. This conversion process results in a decrease in the quantities of these inorganic mercury compounds. It can also lead to issues like undesirable taste, color, or odor in water.[12]

The significance of phytoplankton in biogeochemical cycles and climate regulation cannot be overstated. Amplifying human-driven impacts on ecosystems have caused the Earth's temperature to surge by about 0.6 ○C over the last century, an unparalleled increase when contrasted with the past millennium.[13,14] Prolonged shifts in climate and extensive climatic fluctuations can also impact environmental developments that reshape planktonic algae. Alterations in the current erection of aquatic columns might incline the balance towards smaller algal cells and species adept at adjusting to buoyancy changes and higher temperatures.[15] This transition to smaller phytoplankton could potentially lead to reduced biomass production.

Zooplankton play a vital role in connecting different levels of the food chain in ecosystems. They do this by serving as consumers of primary producers and serving as a preferred food source for numerous economically valuable fish species. Mercury (Hg) toxicity can have harmful effects on zooplankton, as it can on various aquatic organisms. Mercury exposure can impair the reproductive capabilities of zooplankton. It may result in reduced reproductive rates, fewer offspring, or even reproductive failure, Mercury toxicity in zooplankton can disrupt the flow of energy and nutrients through the aquatic food web. As zooplankton are a crucial link between primary producers and higher trophic levels, their contamination with mercury can have far-reaching ecological consequences.

Methylmercury (MeHg) is prevalent in both marine and freshwater fish, originating from either natural environmental processes or human activities that involve the circulation of mercury.[16] Microbial actions facilitate the conversion of inanimate hg hooked on the extremely poisonous MeHg procedure through a methylation process.[17] Subsequently, MeHg becomes integrated into the aquatic food chain, contributing to the overall buildup of MeHg levels in aquatic organisms.[18] Fish, in particular, serves as a prime example of how mercury accumulates through the food chain.[19] According to research by Soares et al.[20], as much as 98% of MeHg tends to accumulate in fish. This makes MeHg in fish a primary source of mercury pollution with potential implications for human health due to the biomethylation of discharged mercury compounds.[21]

Prolonged consumption of fish and other marine organisms contaminated with methylmercury poses a significant health risk, particularly during developmental stages, which can lead to neurological changes.[22–24] Additionally, mercury exposure has been scientifically linked to increased susceptibility to cardiac sicknesses than incidents. Trendy instances of plain revelation, there is a potential for adverse effects on the reproductive and immune systems, as well as a heightened risk of premature mortality.[25,26]

The goal of this review is to offer a succinct overview of recent findings concerning the different forms of mercury (Hg) and their interactions with phytoplankton, zooplankton, fish, and human beings in their natural habitat.

2. Source of Mercury to the Environment

2.1. *Natural source of mercury*

Mercury is also found in the earth's crust, mainly as a mineral cinnabar. The metal is released due to volcanic activity, rock weathering, and the weather of rocks. In addition, deposited oxidized mercury can be reduced by photochemical or biological processes and is released back into the atmosphere. The redeployment of mercury from soil, plant, and marine surface is considered to be important when compared with primary sources; so secondary sources are also influencing the amount of mercury in the atmosphere. But also by reactivating to a considerable extent. Mercury was probably more or less uniformly distributed in the atmosphere, as well as in terrestrial and aquatic compartments before (major) anthropogenic emissions began since the cycle was active in the pre-industrial environment.[27–29]

2.2. Anthropogenic source of mercury

Anthropogenic sources of mercury (Hg) refer to human activities that release mercury into the environment. These activities are a major contributor to the global mercury cycle and can have significant environmental and health impacts. "The main cause of hg corruption in the environment remains attributed to human doings, with significant contributions coming from artisanal small-scale gold mining, industrial facilities, coal combustion, waste incineration, mining operations, and their associated processing activities. These anthropogenic actions have led to an approximately 4.5-fold increase in atmospheric mercury levels compared to natural concentrations, as reported by various studies[30–34] Coal combustion and thermal conversion account for a total of 24% of anthropogenic mercury emissions, according to some sources[35] Evidence also suggests that mercury used for the mining of precious metals increased inputs into the atmosphere, in turn increasing the input to the ocean, prior to the onset of a highly industrialized era before the 20th century's conclusion.[13] It is estimated that between 6,000 and 9,000 tons of mercury are released into the atmosphere each year, mostly as elemental Hg0 and occasionally as divalent HgII.[36] Recent studies show that natural processes account for about 800 tons of atmospheric Hg, of which varieties active roughly 18% of the total pool of atmospheric mercury.[37] The section below summaries, briefly, the main anthropogenic mercury sources taken into account in this work. More detailed information, particularly on the principal byproducts of man-made activities, is available in the global mercury assessment.[38]

2.3. Main anthropogenic by-product and source of mercury

The most important sources of primary anthropogenic mercury are those from which mercury productions are mainly accidental; by-product; excluding mercury mining, mercury emissions result from mercury in the form of mercury; attachment; in used fuel or raw materials. the head; by-product; releases originate from coal or oil burning industries, production of iron and steel, production of non-ferrous metals and production of cement. Stationary combustion of coal and to a lesser extent other fossil fuels related to energy or heat production at large power stations, small industrial or residential heating units, smaller-scale home heating systems also as well and various industrial processes constitute the largest single source category for anthropogenic mercury emissions into air. Despite the fact that coal doesn't contain a lot of mercury, The large volume of coal that is burnt and the fact that emissions mainly flow to the atmosphere are primary anthropogenic causes for an increase in unintended mercury emissions into the environment.

As a result of fuel burning, mercury is present in ores as impurities, and through accelerating the exposure of rock to natural weathering processes, mining and industrial processing of ores, in particular, in primary production of iron and steel and non-ferrous metal production (particularly copper, lead, and zinc smelting), release mercury. Gold production also uses mercury, since it is contained in ores and is used in some industrial processes for the extraction of gold from lode deposits, in addition to mining, which is a relatively small source of mercury. For the purpose of obtaining gold, mercury is deliberately employed by smaller-scale and artisanal gold mining operations.

Mercury is released mostly as a result of the combustion of fuels (primarily coal but also a variety of wastes) to heat cement kilns, which is the third greatest source of mercury "by-production" discharges. Fly ash that contains mercury may occasionally be added to cement after the manufacturing process.

2.4. Artisanal gold mining

The biggest source of mercury consumption worldwide is still artisanal and small-scale gold mining (ASGM). According to reports, it keeps rising along with the trend in the price of gold and is the main environmental emission from global mercury use. It is intricately tied to problems with poverty and the health of people.

The UNIDO/UNDP/GEF Global Mercury Project[39] estimates that at least 100 million people, mostly in Africa, Asia, and South America, depend directly or indirectly on ASGM for their livelihood in over 55 countries. Approximately 500 to 800 tonnes of gold are produced annually by ASGM, which accounts for 20 to 30 percent of global gold production.

2.5. Chlor-alkali production

The third largest global usage of mercury is the chlor-alkali sector. Many plant operators have switched over to the more energy-efficient and mercury-free remembering technique, while others either have intentions to do so or have not yet made any such announcements. Governments have frequently partnered with business leaders and/or offered financial incentives to hasten the phase-out of mercury technology.

2.6. Battery

Although mercury use in batteries remains important, as more and more countries establish policies to address the issue of diffuse mercury release from batteries, usage is decreasing. Although the consumption of mercury in Chinese batteries is widely reported to have increased during 2000 and has been found to be above average throughout this period, a large majority of China's manufacturers are still switching towards designs with lower mercury content. Observance of world legal trends and client needs in different parts of the world,[40] Despite this, the consumption of mercury continues to be significant because batteries are still being manufactured in China and other countries with massive quantities that exceed tens of billions.

3. Impact of Climate Change on Mercury Toxicity

Weighty metallic elements remain the prime reason for Pollution of the environment, then Hg remains Single of the biggest threats to human health worldwide, it is a common contaminant.[41] The trophic transmission and of Hg in the aquatic food chain is one of the main problems with Hg contamination.[42] Methylmercury (MeHg), in particular, is a strong neurotoxin that is susceptible to biological magnification and biotic extension in sea aquatic nutrition nets, which remain the primary mechanisms through which MeHg associates or arrives people.[43]

Mercury is of a different nature from the majority of pollutants in the environment. Mercury may change form through oxidation, dilution, and methylation; processes that are repeated in the environment as described in the preview section. Once the mercury has been removed, it's returned in a fairly large volume to the atmosphere. This mercury cycle, as presented by Gonzalez[44] is shown in Fig. 1. Recent research has indicated that mercury's ecological fate will affect climate change over time and into the future.[44–47] Climate change typically affects several physical factors such as those related to long-range transport from wind direction, precipitation rates, ocean currents, melting of polar ice caps and mountain glaciers, higher frequency of extreme events, and biotic transport. In addition, increased mercury emissions into the Arctic could have serious health consequences for humans.

A study has been presented that shows the effects of mercury emissions in the Arctic region. For a variety of reasons, the Arctic region has an important habitat for Hg cycle and pollution monitoring. Four hypothetical situations have been examined by the authors. A scenario that takes into account all Hg emissions resulted in a 12% increase in atmospheric deposition and 9% of the oceanic deposition between 2015 and 2050.[45]

Mercury is a pollutant that is present across the world, but not everywhere has a problem with it. Mercury is often only a concern when the natural generation rate of methylmercury from inorganic mercury is larger than the opposite reaction, with the exception of very contaminated situations. Methylmercury is a single kind of mercury that significantly builds up in fisheries. Certain kinds of wetlands, diluted low-pH lakes in the Northeast and Northcentral United States, portions of the Florida Everglades, recently flooded reservoirs, and coastal wetlands, particularly those along the Gulf of Mexico, Atlantic Ocean, and San Francisco Bay, are environments that are known to favor the production of methylmercury.

4. Transformation of Mercury in the Aquatic Environment

A variety of chemical and biological reactions are involved in the complex process of mercury transformation in the aquatic environment. Different forms of mercury exist, and their transformation can have substantial effects on the environment and people's health. Over the past century, anthropogenic emissions have increased the amount of mercury in the atmosphere by at least a factor of three.[13] There are naturally occurring hgs in dissimilar crystals, which are comparatively constant and do not pose important hazards. It creates problems since these elements are used in different human activities. During the mining of these reserves, a significant volume of Hg is released into the environment.[48,49] Recent research suggests that the fiery of relic oils, production of nonferrous metals, iron and steel making, waste incineration, cement manufacture, or some other industrial processes are also anthropogenic sources of mercury emission.[50]

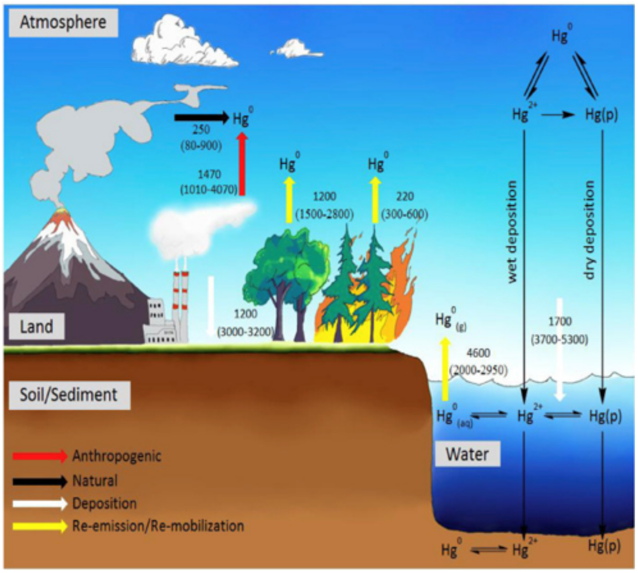

Figure 1: Mercury cycle in the environment (Hg amounts in Mg/y). Adopted from Gonzalez-Raymat et al. (2017), reprinted with permission

announcements of phreatic water from fumaroles, benthic sediments, river and estuary flow, and straight atmosphere deposition are the principal Hg sources that flow into ocean surface regions.[13] Replicas and dimensions indicate that straight atmospheric testimony into surface waters is the core foundation of Hg deposits in oceans, with universal contributions ranging from 2800 near 5800 t over the past decade.[13] Due to manufacturing releases that pollute waterways with the variability of contaminants, fluvial Hg is a significant cause of Hg for the aquatic environment.[51] Additionally, when particles in suspension come into contact with Hg gasses in the troposphere, they may form bonds with them and stick to them, leading to their deposition into seabed sediments.[52] As a result, Hg concentrations there are now five times as many greenhouse gases in the troposphere and two times as many in the oceans as they would have been otherwise, compared to what would have been the case if it had not been for these effects.[49]

By converting an inorganic divalent mercury HgII into MeHg when there are low oxygen concentrations in the environment, methylated microbes produce a main character trendy the environmental production of MeHg[53] (see Figure 2) CH3Hg microorganisms, which intermediate the change of inorganic bivalent mercury (HgII) into MeHg under O2 -deficient circumstances, are primarily responsible for the formation of MeHg in the environment.[53] Some sulfate-dropping microorganisms, iron-reducing bacteria, methanogens, and fermenters are examples of such mediators.[53–58] However, given that some education has shown that The oxygenated sea exterior waters should not be disregarded because 20–40% of the MeHg measured below the exterior diverse layer is shaped from the surface and then enters deeper marine liquids.[53] Most of this methylation occurs in the periphyton, water columns, and sediments.[59] Sulfate-reducing bacteria thrive in the oxygen-poor seafloor sediments (also referred to as "dead zones") that are abundant in dissolved sulfates.[55] Global warming and anthropogenic eutrophication of numerous water bodies are speeding up the formation of these dead zones.[53,55] A number of other environmental factors, including temperature, pH, and media composition, also affect the divalent Hg methylation process, as below describe.

The bioconcentrations in the base organisms of the chain, such as microalgae, are one of the most imperative environmental effects on the assignment of MeHg from the marine environment to the nutrition cable.[48,60] The handover of MeHg from a liquid medium to phytoplankton is a crucial step for subsequent bioaccumulation in higher organisms, which will largely determine the bioconcentration in them.

4.1. Bioaccumulation of mercury in the aquatic food chain

When mercury gets into the waterway stream, it is transformed by microbes into carbon-based substances such as CH3Hg and C2H6Hg. These are some of the most hazardous organic forms All sorts of organisms eat mercury with bioavailable properties, thus this is the case. Transferred via all the food chain's links.[52]

Human exposure to MeHg is primarily caused by eating marine organisms.[11] In comparison to the concentrations of MeHg in seawater, the Bioaccumulation, of MeHg in planktonic algae. and zooplankton can be as tall as 105 and 106 periods, respectively.[11] Later, the proteins of phytoplankton cells bind the intracellular MeHg, which is then bioaccumulated in marine food nets. Thus, algae play a significant part in the uptake and conversion of Hg classes in marine environments as a major point of entry for Hg into aquatic food webs.[61]

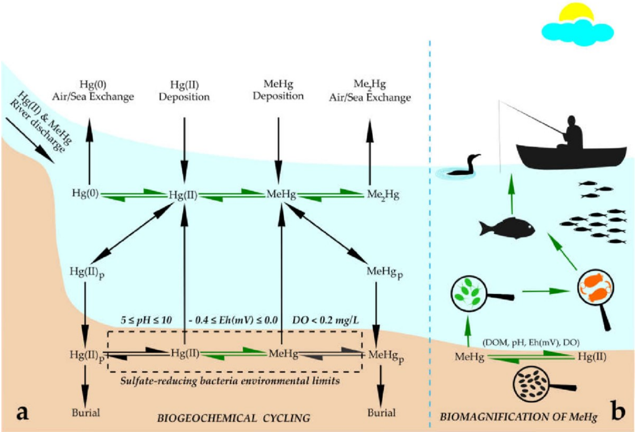

Figure 2: Diagram image of **(a)** rudimentary procedures in the biological generate chemical pedaling of Mercury in sea zones. Contractions: mercury (0), rudimentary mercury; Hg(II), bivalent mercury; MeHg, methylmercury; Me2Hg, dimethylmercury; MeHgP, methylmercury convinced to particulate matter carbon-based material; Hg(II)P, bivalent hg certain to particulate matter carbon-based material. Lime missiles specify geographically interceded; ecological environments for sulfate-reducing microorganisms, wherever Hg methylation occurs, are: 5 ≤ pH ≤ 10; −0.4 ≤ Eh(mV) ≤ 0.0; DO < 0.2 mg/L. **(b)** Biomagnification of MeHg through the marine nutrition trap: MeHg arrives the nutrition network at the actual lowest via bacterial methylation activity, then it is partially taken up by microalgae; from that point on, it biomagnifies through rotifers that scrape on microalgae, and additional via slighter fish that target on rotifers, then marauder fish that target on smaller fish, and lastly transmissions to marine natures and people that eat polluted fish. Contractions: Hg(II), divalent mercury; MeHg, methylmercury; DOM, dissolved organic matter; Eh(mV), redox potential; DO, liquified oxygen. Modified since.[62–65]

4.2. Mercury exposure's effects on phytoplankton

As the base of the food chain in aquatic environments, plankton is a group of autotrophic and heterotrophic drifting organisms. Bacterioplankton, phytoplankton, and zooplankton all belong to this group. The concentrations of nutrients, the physical and chemical characteristics of the water, and the abundance of other plankton all affect the abundance and distribution of plankton. Their abundance changes with the seasons, vertically, and horizontally.

Half of the world's CO2 is sequestered by photosynthetic marine microorganisms (phytoplankton), which also produce half of the world's oxygen, or 1% of all plant biomass.[66] Consequently, in order to control the biogeochemical cycles of the planet, especially carbon cycles and global ecosystems and climate change, they play an essential role. Future CO2 capture systems based on microalgae could be made possible by the high ability of phytoplankton to fix CO2, by way of they require considerably fewer planetary and capitals while also fixative CO2 with productivity that is between 10 and 50 times higher than that of other photosynthetic creatures.[67,68] Therefore, they have a central role to play in the management of biogeochemical cycles on Earth, including carbon cycles and global ecosystems as well as climate change. A high ability of phytoplankton to process CO2 could make it possible to develop future microalgae systems that would capture CO2 at a level that is 10 or 50 times more efficient than the efficiency of existing photosynthesis species, as they have very little space and resources while requiring much lesser energy;[69] Eukaryotic algae and cyanobacteria, which are hydrophytic plants, and photosynthetic microbes found in the highest sheet of normal waters, are included in phytoplankton.[70] Microalgae affect the arrangement and efficiency of groups of all advanced animals through the production of photosynthetic biomass.[70] Microalgae benefit from their surroundings, including of metallic elements, to perform photosynthesis.[70] Due to the fact that metallic elements accrued by planktonic algae will eventually be transported near additional bacteriological groups and grazers, this has an important effect on the biogeochemical cycling of these fundamentals.[71] Multiple pollutants that are present in aquatic ecosystems can have an impact on microalgae.[72] Due to their severe metabolic toxicity to organisms, heavy metals are significant environmental pollutants.[73] Mercury and other heavy metals may build up in primary producers like microalgae and then move to higher trophic levels.[74]

There is strong evidence that exposure to IHg and MeHg causes general toxic effects in primary producers, such as oxidative stress, growth and photosynthesis reductions, and reduced photosynthesis.[70,72,75] By resulting in physiological and metabolic abnormalities, these detrimental effects in turn prevent their development and reproduction.[76] Fortunately, it has been determined that the typical levels of Hg found in water are much lower than those that have a significant impact on microalgae growth and photosynthesis.[77] Mercury stands out since extra heavyweight metallic element unpaid to its propensity to biomagnification throughout the entirety of aquatic food chains, though.[78] When combined with the oxidative stress brought on by exposure to mercury, which has a specific interaction with sulfhydryl groups in enzymes, mercury can exert toxicity at all trophic heights.[78] Hg whitethorn quandary to cytosolic ligands once inside algal cells and then be distributed throughout organelles. The basic idea behind Hg harmfulness is the blocking of enzyme purposeful collections by removing particles from these sites or altering their shape.[70]

By influencing the electron transportation shackle, altering the photosystem II, and eventually reducing the significant production of photorespiration, HgII has been shown to remain extremely contaminated to the photorespiration structure of microphytes.[72] Additionally, excessive reactive oxygen species (ROS) resulting from HgII exposure can harm protein sequence appearance and ultimately result in cellular harm.[72] Although IHg straight marks hemoglobin crust trustworthiness, some training has shown that MeHg indirectly affects membrane integrity while MeHg might non consume a substantial impact on the electron transportation cable at low concentrations.[75]

The bioavailability of metallic elements, which is influenced by metal speciation and abundance, drives the uptake of metallic elements by planktonic algae. prison cell through inactive (dispersal and adsorption) and energetic approval machinery (complexation of liquefied metallic element).[79] Phytoplankton remains one of the defense mechanisms that have been developed by both plants and animals to combat mercury exposure.[80] At least three intracellular or extracellular techniques are used by microalgae to reduce mercury toxicity, as well as increase antioxidant production.[81] The first tactic is metal exclusion, which involves decreasing the number of ligands on the metal-responsive compartment superficial to prevent excessive metallic growth.[61,71,82–94] Metal toxicity can be considerably decreased by immobilizing Hg on the cell surface. According to some sources, cellular debris fractions can store awake to 56% of the overall cellular hg that has been accumulated.[80] The second method involves reducing intracellular mercury to the less bioavailable form of dissolved gaseous Hg0[80,82]

As for the durable intracellular compulsory of Hg, the defecation of collected Hg appears to be a difficult decontamination machine.[41] Additionally, it appears that MeHg is a weak inducer of phytochelatins.

5. Mercury Exposure Effect on Zooplankton

Small animals known as zooplankton can be found in the water column of almost all bodies of water, including lakes, ponds, and oceans, though they are typically unable to survive in rivers and streams. They can include the larval stages of larger animals like mussels and fish and range in size from a few millimeters to a few microns (one micron is equal to 1/1000 of a millimeter

The MeHg that is present in phytoplankton is consumed by zooplankton, but it is removed from their cells more slowly than it is taken in. In contrast to phytoplankton, zooplankton has higher MeHg concentrations due to bioaccumulation. It's interesting to note that the range of zooplankton concentrations varies less than the range of phytoplankton concentrations. This is due to the connection between the availability of nutrients, the uptake of MeHg, and the overall mercury content of the phytoplankton. The conditions that result in the highest levels of MeHg in phytoplankton are also those in which there is a lack of food for their predators, which lowers consumption rates and consequently lower zooplankton MeHg intake. The conditions linked to low phytoplankton MeHg are also the conditions where zooplankton eat a lot. They consume a lot of MeHg because there is a lot of food available, but they are also growing more rapidly and effectively, which reduces their own MeHg concentration through growth. This results in concentrations of MeHg in zooplankton being 50,000-1,000,000 times higher than in the surrounding seawater. This large increase compared to the seawater, before even making it to fish, makes tiny mercury concentrations in the ocean lead to much larger mercury concentrations in marine food webs.

The cardiovascular and nervous systems are primarily affected by long-term exposure to mercury. For Hg intoxications, the kidney cortex and endocrine glands are most affected, and the kidney cortex and thyroids are most affected.[84] Accidental MeHg poisoning in humans has been documented in Iraq and Japan. In Japan, industrial MeHg emissions caused MeHg poisoning in Minamata and Niigata, leading to the first reports of Minamata disease (MD).[61]

Children are particularly at risk and may get sick from eating contaminated fish. Methylmercury may cause neurodevelopmental issues in the developing fetus if it bioaccumulates in fish and is consumed by pregnant women. The most hazardous exposure is transplacental because the fetal brain is extremely sensitive. Intellectual disability, seizures, loss of vision and hearing, delayed development, language problems, and memory loss are examples of neurological symptoms. Chronic mercury exposure has been linked to the development of the condition known as acrodynia (or "pink disease") in infants and young children. This condition is characterized by red, painful, and itchy extremities with localized swelling and sensitivity to light.[95,96]

5.1. *Toxicity of mercury on fishes*

Due to its high nutritional value, fish is one of the most significant foods in the human diet. They are a famous cause of PUFAs, particularly omega-3 and omega-6, which can fend off thrombosis and atherosclerosis. These fatty acids have protective effects against coronary heart disease, autoimmune diseases, and arrhythmias, and they also lower blood pressure and plasma triglyceride levels. Fish contains nearly altogether of the reserves that our figures essential and are present popular fish. Ferrum, Calcium oxide, Galzin and ZnCl2, phosphor, selenocysteine, fluorite, and iodise are the reserves found in fish. Due to their high bioavailability, these minerals can be ready to be taken up by the body.[85] Mercury contamination from long food chains that accumulate in the body is a major issue with marine food fish.[86] The mercury contamination present in the fish body in this instance will enter the bloodstream and build up in the peritoneal cavity.[87] By encouraging oxidative damage and altering organ damage that lowers fish health status, mercury contamination can have an impact on fish behavior.[88,89] The liver, kidney, muscle, gonad, and brain are the first fish tissues to show the effects of mercury contamination[88] When using the histopathology assessment, the liver is one of the organs that is given priority. This is because, once likened to additional tissues, the liver-colored consume has been found to accumulate the most mercury.[89] The effects of mercury exposure led to tissue damage.

Fish gill deficiency due to mercury contamination is possible; HgCl2, at concentrations of 0.01 and 0.02 mg/L, can reduce the ability of yellowfin seabreams to exchange gases. According to earlier research, the length of exposure to mercury, its concentration, the fish's size, and the lesions that resulted in the gills can all affect how severe the lesions are.[90] Water-exposed sensory cells, such as mechanoreceptors of the lateral-line system, cutaneous sensory cells, and/or taste receptor cells, can pass through fish skin and oral epidermis and enter the fish brain.[91] Through the blood barrier, both organic and inorganic mercury can harm the Central Nervous System (CNS) of the brain in teleost fish.[92]

According to other studies, following exposure to MeHg and Hg (II), approximately 46.9% to 59.5% of MeHg and 42.3% to 64.9% of Hg (II) were discovered accumulated in gill, with nearly 41.9% of Hg (II) being detected in the stomach[93] The amount of mercury present will, however, increase linearly over the course of the exposure, whereas it will steadily decrease in the gills. When exposed to dietary mercury, there is a slow exchange of MeHg between the blood and internal organs, with the liver and gills absorbing the most at 1.5 days.[94] The gill and intestine had the highest concentrations of inorganic mercury because they were the main organs through which mercury entered a fish's body before being transported by the bloodstream to other fish organs.[71]

6. Toxicity of Mercury on Human Beings

Chemical pollutants like mercury are a concern for human health everywhere. Mercury is one of the top 10 chemicals that the WHO reflects toward stand of community healthiness anxiety.[97] Global valuation schemes have shown that (1) mercury pollution sources are distributed globally, (2) mercury emission levels are rising over time, and (3) anthropogenic activities are largely to blame for these emissions.[98] Mercury levels in some marine nutrition products, customer and manufacturing crops, and work environments may reach levels deemed hazardous to human health.[78] According to human biomonitoring studies, the majority of people in the world are exposed to some level of mercury, and certain populations are particularly at risk (such as Original Peoples and artisanal before moderate golden sappers (ASGM)) because of nutritional or industrial issues.[99] Catastrophic events at Minamata Bay and other locations in the middle of the 20th century warned the world that mercury pollution is still a major concern today. Since then, significant epidemiological studies have been conducted in the Faroe Islands, Seychelles, New Zealand, the Amazon, and the Arctic, and they have shown that hg is an autism, learning disabilities, and intellectual disability concern with mounting evidence that it also has an impact happening the circulatory and protected schemes. There is a vast physique of information about the effects of hg on anthropological healthiness that has been compiled in fresh excellent analysis papers.[81,99–101]

Methylmercury, one of the mercury compounds, is primarily to blame for the neurological changes seen in both experimental animals and people. The toxic rise in reactive oxygen species (ROS) is thought to be a factor in the mechanisms. Although these mechanisms have not yet been fully understood, oxidative stress is linked to the etiology of neurodegenerative diseases like amyotrophic lateral sclerosis, Parkinson's disease, and Alzheimer's disease.[102,103] Additionally, research shows that exposure to mercury during fetal development can decrease neuronal density and cytoarchitecture in humans.[104,105]

For decades, the toxic effects of mercury were associated mainly with the central nervous system; however, inorganic mercury also produces profound cardiotoxicity.[106,107] The increased risk of hypertension, myocardial infarction, coronary dysfunction, and atherosclerosis has also been linked by other studies.[108–111] According to data presented by Yoshizawa et al.[112] exposure to mercury was linked to the development of atherosclerosis and a higher risk of cardiovascular disease.[113]

The risk of developmental issues caused by mercury is highest in children whose mothers ate a lot of contaminated fish while pregnant. According to the Centers for Disease Control and Prevention, about 6% of American women of childbearing age have blood mercury levels that are unsafe for a growing fetus. Mercury exposure during pregnancy, which can be brought on by a mother eating methylmercury-containing fish and shellfish, can harm a developing baby's brain and nervous system. Children's developing brains and nervous systems are extremely sensitive to mercury and may suffer permanent harm from it. Children may be exposed to methylmercury if they consume specific types of fish or if their mothers consumed fish tainted with mercury prior to giving birth.[114]

7. Conclusion

The environment and public health have been impacted by mercury contamination in water. Mercury is highly toxic to human health, posing a particular threat to the. Because mercury is a potent neurotoxin in fish, wildlife, and humans, it is one of the most dangerous contaminants in our country's waters. is a heavy metal that is very toxic. It comes in three different varieties: organic, inorganic, and elemental. It has been established that all forms of mercury have toxic effects on living things. It has the capacity to gather in the various bodily tissues, where it increases the concentration from lower to higher trophic levels. Mercury was primarily introduced to aquatic life through various human-made activities. The main cause of Hg pollution in the air is identified as thermal power plants, which use coal as their primary fuel. It is taken from the air, deposited on the ground, and then washed into a body of water. The process by which it enters the food chain is through aquatic plants and animals. In an aquatic ecosystem, organisms are easily exposed to and ingest mercury that accumulates in their gills, liver, and other organs. The public is becoming more and more aware of the harmful health effects of mercury pollution in the ocean since the Minamata incident in Japan. As a result, there has been a lot of interest in the health of people who eat fish that contain mercury (Hg). The toxicity of mercury to marine fish has, however, gotten much less attention. We sum up mercury buildup in marine fish and the toxicological effects of mercury exposure in this review. The findings demonstrated that mercury bioaccumulation in marine fish was highly variable and that the physiological and ecological traits of various fish species had an impact on mercury concentration. It's not only an environmental issue it's a human health issue also. MeHg toxicity is linked to neurological impairment in children and adults as well as damage to the nervous system in adults. Mercury that has been consumed may bioaccumulate, gradually increasing the burdens on the body. The systemic pathophysiology of specific organ systems linked to mercury poisoning is discussed in this review. The toxicological effects of mercury on cells, the heart, the blood, the lungs, the kidneys, the immune system, the nervous system, the endocrine system, the reproductive system, and the embryo are significant.

8. Source of Funding

None.

9. Conflict of Interest

None.

References

1. Bravo AG, Cosio C. Biotic formation of methylmercury: A bio-physico-chemical conundrum. *Limnol Oceanogr*. 2019;65(5):1010–27.

2. Karimi R, Fitzgerald TP, Fisher NS. A Quantitative Synthesis of Mercury in Commercial Seafood and Implications for Exposure in the United States. *Environ Health Perspect*. 2012;120(11):1512–9.
3. Monastero RN, Karimi R, Nyland JF, Harrington J, Levine K, Milkier JR, et al. Mercury exposure, serum antinuclear antibodies, and serum cytokine levels in the Long Island Study of Seafood Consumption: A cross-sectional study in. *Environ Res*. 2017;156:334–40.
4. Torres IV, Vanegas DC, Mclamore ES, Hurtado D. Mercury Pollution and Artisanal Gold Mining in Alto Cauca, Colombia: Woman's Perception of Health and Environmental Impacts. *J Environ Dev*. 2018;27(3):415–44.
5. Noyma NP, Magalhaes LD, Furtado LL, Mucci M, Oosterhout FV, Huszar VLM. Controlling Cyanobacterial Blooms through Effective Flocculation and Sedimentation with Combined Use of Flocculants and Phosphorus Adsorbing Natural Soil and Modified Clay. *Water Res*. 2016;97:26–38.
6. Awual MR. Novel Nanocomposite Materials for Efficient and Selective Mercury Ions Capturing from Wastewater. *Chem Eng J*. 2017;307(1):456–65.
7. Dabrowski JM, Ashton PJ, Murray K, Leaner JJ, Mason R. Anthropogenic Mercury Emissions in South Africa: Coal Combustion in Power Plants. *Atmos Environ*. 2008;42(27):6620–6.
8. Lyman SN, Gustin MS, Prestbo EM. A Passive Sampler for Ambient Gaseous Oxidized Mercury Concentrations. *Atmos Environ*. 2010;44(2):246–52.
9. Fang GC, Wu YS, Chang TH. Comparison of Atmospheric Mercury (Hg) among Korea. *J Hazard Mater*. 2000;162(2-3):607–15.
10. Seco J, Aparício S, Brierley AS, Bustamante P, Ceia FR, Coelho JP, et al. Mercury biomagnification in a Southern Ocean food web. *Environ*. 2021;275(15):116620.
11. Azevedo LS, Pestana IA, Almeida MG, Nery A, Bastos WR, Souza CM. Mercury biomagnification in an ichthyic. the food chain of an Amazon floodplain lake (Puruzinho Lake): Influence of seasonality and food chain modeling. *Ecotoxicol Environ Saf*. 2021;207:111249.
12. Bjorklund G, Dadar M, Mutter J, Aaseth J. The Toxicology of Mercury: Current Research and Emerging Trends. *Environ Res*. 2017;157:545–54.
13. Mason RP, Choi AL, Fitzgerald WF, Hammerschmidt CR, Lamborg CH, Soerensen AL, et al. Mercury biogeochemical cycling in the ocean and policy implications. *Environ Res*. 2012;119:101–17.
14. Pinto EP, Paredes E, Bellas J. Influence of microplastics on the toxicity of chlorpyrifos and mercury on the marine microalgae Rhodomonas lens. *Sci Total Environ*. 2023;857:159605.
15. Nyholt K, Jardine TD, Villamarin F, Jacobi CM, Hawes JE, Campos-Silva JV. High rates of mercury biomagnification in fish from Amazonian floodplain-lake food webs. *Sci Total Environ*. 2022;833:155161.
16. Vöröš D, Díazsomoano M, Geršlová E. Mercury contamination of stream sediments in the North Bohemian Coal District (Czech Republic): mercury speciation and the role of organic matter. *Chemosphere*. 2018;211:664–73.
17. Visha A, Gandhi N, Bhavsar SP. Assessing mercury contamination patterns of fish communities in the Laurentian Great Lakes: a Bayesian perspective. *Environ Pollut*. 2018;243(A):777–89.
18. Condini MV, Haus H, and DJR. Mercury concentrations in dusky grouper Epinephelus marginatus in littoral and neritic habitats along the Southern Brazilian coast. *Marine Poll Bull*. 2017;115(1):266–72.
19. Elsayed H, Erhan Y, Al-Ansari. Methylmercury bioaccumulation among different food chain levels in the EEZ of Qatar (Arabian Gulf). *Reg Stud*. 2020;37:101334.
20. Soares JM, Gomes JM, Anjos MR. Mercury in fish from the Madeira River and health risk to Amazonian and riverine populations. *Food Res Int*. 2018;109:537–43.
21. Farina M, Rocha JB, Aschner M. Mechanisms of methylmercury-induced neurotoxicity: evidence from experimental studies. *Life Sci*. 2011;.
22. Sanfeliu C, Sebastia J, Cristofol R, Rodriguez-Farre E. Neurotoxicity of organomercurial compounds. *Neurotox Res*. 2003;5:283–305.
23. Crespo-Lopez ME, Sa ALD, Herculano AM, Burbano RR, Nascimento JLD. Methylmercury genotoxicity: A novel effect in human cell lines of the central nervous system. *Environ Int*. 2007;3:141–146.
24. Tchounwou PB, Ayensu WK, Ninashvili N, Sutton D. Environmental exposure to mercury and its toxicopathology implications for public health. *Environ Toxicol*. 2003;18:149–175.
25. Rae D, Graham L. Benefits of Reducing Mercury in Saltwater Ecosystems: A Case Study. *BiblioBazaar*. 2012;.
26. Arctic Monitoring and Assessment Programme (AMAP). *AMAP: Oslo*. 2009;.
27. Seigneur CP, Karamchandani K, Lohman K, Vijayaraghavan. Multiscale modeling of the atmospheric fate and transport of mercury. *Journal of Geophysical Research*. 2001;.
28. Shia RL, Seigneur C, Pai P, Ko M, Sze ND. Global simulation of atmospheric mercury concentration and deposition fluxes. *Journal of Geophysical Research*. 1999;.
29. Lamborg CH, Fitzgerald WF, Donnell J, Torgersen T. 2002.
30. Lindberg S, Bullock R, Ebbinghaus R, Engstrom D, Feng X, Fitzgerald W, et al. 2007.
31. Driscoll CT, Mason RP, Han HM, Jacob D, Pirrone N. 2013.
32. Hsu-Kim H, Eckley CS, Acha´D, Feng X, Gilmour CC, Jonsson S, et al. 2018.
33. Obrist D, Kirk JL, Zhang L, Sunderland EM, Jiskra M, Selin NE. 2018.
34. Environment A. Arctic Monitoring and Assessment Programme, Oslo, Norway/UN Environment Programme, Chemicals and Health Branch. Geneva, Switzerland; 2018.
35. Zhang H, Zhou Y, Liu T, Tian X, Zhang Y, Wang J, et al. Mercury release behaviors of Guizhou bituminous coal during co-pyrolysis: Influence of Chlorella. *J Environ Sci*. 2022;119:23–32.
36. Dastoor A, Angot H, Bieser J, Christensen JH, Douglas TA, Burger-Boavida LH, et al. Arctic mercury cycling. *Nat Rev Earth Environ*. 2022;3(4):1–17.
37. Guédron S, Tolu J, Brisset E, Sabatier P, Perrot V, Bouchet S, et al. Late Holocene volcanic and anthropogenic mercury deposition in the western Central Andes. *Sci Total Environ*. 2019;3(4):1–17.
38. Global Mercury Assessment. UNEP- Chemicals; 2002. Available from: https://www.unep.org/topics/chemicals-and-pollution-action/pollution-and-health/heavy-metals/mercury/global-mercury-2#:~:text=UNEP%20produced%20its%20first%20Global,3)%20focused%20on%20atmospheric%20emissions..
39. Pang Q, Gu J, Wang H, Footnotes S. Personal communication with experts Telmer, Veiga, and Spiegel- All involved in the UNIDO/UNDP/GEF Global Mercury Project. *50 I Sci*. 2008;p. 1–12.
40. Submission to UNEP in response to the March 2006 request for information on mercury supply, demand, and trade. *Nat Resou Def Coun*. 2006;p. 1–95.
41. Jain RB. Effect of pregnancy on the levels of urinary metals for females aged 17-39 years old: data from National Health and Nutrition Examination Survey 2003-2010. *J Toxicol Environ Health A*. 2003;76(2):86–97.
42. Wang W. 2012.
43. Sunderland EM. Mercury exposure to domestic and imported estuarine and marine fish in the U.S. . *Seafood Market*. 2007;115(2):235–42.
44. Raymat HG, Liu GL, Liriano C, Li Y, Shi YY, Jiang J. Elemental mercury; Its unique properties affect its behavior and fate in the environment mercury. *Environ Pollut*. 2017;229:69–86.
45. Chen L, Zhang W, Zhang Y, Tong Y, Liu M, Wang H, et al. Historical and Future trends in the global source-receptor relationship of mercury. *Sci Total Environ*. 2018;610(11):24–31.
46. Mercury pollution is a special issue. *AMBIO*. 2007;.
47. Stern G, Macdonald RW, Outridge PM, Wilson S, Chételat J, Cole A, et al. How does climate change influence Arctic mercury? *Sci Total Environ*. 2012;.
48. Lavoie RA, Jardine TD, Chumchal MM, Kidd KA, Campbell LM. Biomagnification of Mercury in Aquatic Food Webs: A Worldwide Meta-Analysis. *Environ Sci Technol*. 2013;.

49. Marnane I. Mercury, a Persistent Threat to the Environment and Health. *European Environment Agency*. 2018;p. 25–25.
50. Li J, Chen B, Chen G, Wei W, Wang X, Ge J, et al. Tracking mercury emission flows in the global supply chains: A multi-regional input-output analysis. *J Clean*. 2017;.
51. Li Y, Li D, Song B, Li Y. The potential of mercury methylation and demethylation by 15 species of marine microalgae. *Water Res*;p. 2022–2022.
52. Siedlewicz G, Korejwo E, Szubska M, Grabowski M, Kwasigroch U, Bełdowski J. Presence of mercury and methylmercury in Baltic Sea sediments, collected in ammunition dumpsites. *Mar Environ Res*;p. 2020–2020.
53. Capo E, Feng C, Bravo AG, Bertilsson S, Soerensen AL, Pinhassi J, et al. Expression Levels of hgcAB Genes and Mercury Availability Jointly Explain Methylmercury Formation in Stratified Brackish Waters. *Environ Sci Technol*. 2022;.
54. Bravo AG, Cosio C. Biotic formation of methylmercury: A bio-physico-chemical conundrum. *Limnol Oceanogr*. 2019;.
55. Capo E, Broman E, Bonaglia S, Bravo AG, Bertilsson S, Soerensen AL, et al. Oxygen-deficient water zones in the Baltic Sea promote uncharacterized Hg methylating microorganisms in underlying sediments. *Limnol Oceanogr*. 2021;.
56. Li P, Wang R, Kainz MJ, Yin D. Algal Density Controls the Spatial Variations in Hg Bioconcentration and Bioaccumulation at the Base of the Pelagic Food Web of Lake Taihu. *China Environ Sci Technol*. 2022;.
57. Quiroga-Flores R, Guédron S, Achá D. High methylmercury uptake by green algae in Lake Titicaca: Potential implications for remediation. *Ecotoxicol Environ Saf*;p. 2021–2021.
58. Ulus Y, Tsui MT, Sakar K, Nyarko A, Aitmbarek P, Ardón NB, et al. 2022.
59. Lanza WG, Achá D, Point D, Masbou J, Alanoca L, Amouroux D, et al. Association of a Specific Algal Group with Methylmercury Accumulation in Periphyton of a Tropical High-Altitude Andean Lake. *Arch Environ Contam Toxicol*. 2017;.
60. Skrobonja A, Gojkovic Z, Soerensen AL, Westlund PO, Funk C, Björn E. Uptake Kinetics of Methylmercury in a Freshwater Alga Exposed to Methylmercury Complexes with Environmentally Relevant Thiols. *Environ Sci Technol*. 2019;.
61. Kuklina I, Kouba A, Boric M. Accumulation of heavy metals in crayfish and fish from selected Czech reservoirs. *BioMed Res Int*. 2014;.
62. Soerensen AL, Schartup AT, Gustafsson E, Gustafsson BG, Undeman E, Björn E. Eutrophication Increases Phytoplankton Methylmercury Concentrations in a Coastal Sea-A Baltic Sea Case Study. *Environ Sci Technol*. 2016;.
63. Selin NE. Global Biogeochemical Cycling of Mercury: A Review. *Annu Rev Environ Resour*. 2009;.
64. Krabbenhoft D, Norling P, Wood-Black F, Masciangioli T. Water and Sustainable Development: Opportunities for the Chemical Sciences-A Workshop Report to the Chemical Sciences Roundtable. *National Academy of Sciences*. 2004;.
65. Sams CE, Methylmercury. Contamination: Impacts on Aquatic Systems and Terrestrial Species, and Insights for Abatement. In: Advancing the Fundamental Sciences: Proceedings of the Forest Service National Earth Sciences Conference; 2004.
66. Cavicchioli R, Ripple WJ, Timmis KN, Azam F, Bakken LR, Baylis M, et al. Scientists' warning to humanity: Microorganisms and climate change. *Nat Rev Microbial*. 2019;.
67. Ighalo JO, Dulta K, Kurniawan SB, Omoarukhe FO, Ewuzie U, Eshiemogie SO, et al. Progress in Microalgae Application for CO2 Sequestration. *Clean Chem Eng*;p. 2022–2022.
68. Even C, Hadroug D, Boumlaik Y, Simon G. Microalgae-based Bioenergy with Carbon Capture and Storage quantified as a Negative Emissions Technology. *Energy Nexus*;p. 2022–2022.
69. Lena D, Casini G, Lucarini I, Pulgar MD, Aguzzi JS, Caproni A, et al. Chemical characterization and nutritional evaluation of microalgal biomass from large-scale production: A comparative study of five species. *Eur Food Res Technol*;p. 2020–2020.
70. Faucheur L, Campbell S, Fortin PG, Slaveykova C, I V. Interactions between mercury and phytoplankton: Speciation, bioavailability, and internal handling. *Environ Toxicol Chem*. 2014;33:1211–1224.
71. Garnero PL, Monferran MV, Ángeles Delos, Bistoni M. Uptake, tissue distribution and elimination in a native fish species Astyanax eigenmanniorum exposed to inorganic mercury. *Aquat Toxicol*;.
72. Tang W, He M, Chen B, Ruan G, Xia Y, Xu P, et al. Investigation of the toxic effect of mercury on Microcystis aeruginosa: Correlation between intracellular mercury content at single cells level and algae physiological responses. *Sci Total Environ*;p. 2023–2023.
73. Satoh M, Hitachi Y, Yoshioka A, Kobayashi M, Oyama YS, Al-Ghanim KA, et al. Determination of cellular levels of nonprotein thiols in phytoplankton and their correlations with susceptibility to me Mahboob. *Z Impact of Water Pollution on Trophic Transfer of Fatty Acids in Fish*. 2019;.
74. Beauvais-Flück R, Slaveykova VI, Cosio C. 2017.
75. Quevedo-Ospina C, Arroyave C, Peñuela-Vásquez M, Villegas A. Effect of mercury in the influx and efflux of nutrients in the microalga Desmodesmus armatus. *Aquat Toxicol*. 2023;.
76. Dranguet P, Cosio C, Faucheur SL, Beauvais-Flück R, Haus AF, Worms IA, et al. Transcriptomic approach for assessment of the impact on microalga and macrophyte of in-situ exposure in river sites contaminated by chlor-alkali plant effluents. *Water Res*. 2017;.
77. Wu Y, Wang WX. Thiol compounds induction kinetics in marine phytoplankton during and after mercury exposure. *J Hazard Mater*. 2012;.
78. Who. 2008.
79. Wu Y, Wang WX. Accumulation, subcellular distribution and toxicity of inorganic mercury and methylmercury in marine phytoplankton. *Environ Pollut*. 2011;.
80. Chevrollier LA, Koski M, Søndergaard J, Trapp S, Aneto DW, Darpaah G, et al. Bioaccumulation of metals in the planktonic food web in the Gulf of Guinea. *Mar Pollut Bull*. 2022;.
81. Ha E, Basu N, Bose-O'reilly S, Drea, Mcsorley JG, Sakamoto E, et al. Current progress on understanding the impact of mercury on human health. *Environmental Research*. 2016;p. 419–433.
82. Khatiwada B, Hasan MT, Sun A, Kamath KS, Mirzaei M, Sunna A, et al. Proteomic response of Euglena gracilis to heavy metal exposure-Identification of key proteins involved in heavy metal tolerance and accumulation. *Algal Res*. 2020;.
83. Choi AL. Methylmercury exposure and adverse cardiovascular effects in Faroese whaling men. *Environ Health Perspect*. 2009;117(3).
84. Tokuomi H, Minamata, Japan K, Med J, Pal J, Shukla BN, et al. A review of the role of fish in human nutrition with special emphasis on essential fatty acids. *International Journal of Fisheries and Aquatic Studies*. 2018;.
85. Vergilio CS, Cev C, Melo E. Accumulation and histopathological effects of mercury chloride after acute exposure in tropical fish Gymnotus carapo. *J Chem Health Risks*. 2012;2(4):1–8.
86. Vieira LR, Gravato C, Soares A. Acute effects of copper and mercury on the estuarine fish Pomatoschistus microps: linking biomarkers to behavior. *Chemosphere*. 2009;76(10):1416–27.
87. Camargo MM, Martinez CB. Histopathology of gills, kidney, and liver of a Neotropical fish caged in an urban stream. *Neotrop Ichthyol*. 2007;5(3):322–7.
88. Adams DH, Sonne C. Mercury and histopathology of the vulnerable goliath grouper, Epinephelus itajara, in US waters: a multi-tissue approach. *Environ Res*. 2013;126:254–63.
89. Jasim MA, Azirun MS, Yusoff I. Bioaccumulation and histopathological changes induced by the toxicity of mercury (HgCl2) to tilapia fish Oreochromis niloticus. *Sains Malaysiana*. 2016;45(1):119–27.
90. Macirella R, Brunelli E. Morphofunctional alterations in zebrafish (Danio rerio) gills after exposure to mercury chloride. *Int J Mol Sci*. 2017;.
91. Pereira P, Korbas M, Pereira V. A multidimensional concept for mercury neuronal and sensory toxicity in fish- From toxicokinetic and biochemistry to morphometry and behavior. *Biochim Biophys*

Acta Gen Subj. 2019;.

92. Berntssen M, Aatland A, Handy RD. Chronic dietary mercury exposure causes oxidative stress, brain lesions, and altered behavior in Atlantic salmon (Salmo salar) parr. *Aquat Toxicol*. 2003;.
93. Peng X, Liu F, Wang WX. Organ-specific accumulation, transportation, and elimination of methylmercury and inorganic mercury in a low Hg accumulating fish. *Environ Toxicol Chem*. 2016;35(8):2074–2083.
94. Leaner JJ, Mason RP. Methylmercury uptake and distribution kinetics in sheepshead minnows, Cyprinodon variegatus, after exposure to CH3Hgspiked food. *Environ Toxicol Chem*. 2004;.
95. 2018. Available from: https://apps.who.int/iris/handle/10665/334181.
96. Assessment of prenatal exposure to mercury: standard operating procedures. Copenhagen;.
97. 2018. Available from: https://apps.who.int/iris/handle/10665/332161.
98. *UNEP 2019 Global Mercury Assessment*. 2018;.
99. Basu N, Horvat M, Evers DC, Zastenskaya I, Weihe P, Tempowski J. A state-of-the-science review of mercury biomarkers in human populations worldwide between. *Environmental Health Perspectives*. 2000;.
100. Eagles-Smith CA, Geld EKS, Basu N, Bustamante P, Diaz-Barriga F, Hopkins WA, et al. 2018. Available from: https://doi.org/10.1007/s13280-017-1011-x.
101. United Nations Environment Programme, International Labour Organization, and World Health Organization. Geneva; 1991. Available from: https://apps.who.int/iris/handle/10665/.
102. Bridges CC, Zalups RK. Transport of inorganic mercury and methylmercury in target tissues and organs. *Journal of Toxicology and Environmental Health-Part B*. 2010;.
103. Roulet M, Lucotte M, Canuel R. Distribution and partition of total mercury in waters of the Tapajos River Basin, Brazilian Amazon. *Science of the Total Environment*. 1998;.
104. Grandjean P, Weihe P, White RF. Cognitive deficit in 7-year-old children with prenatal exposure to methylmercury. *Neurotoxicology and Teratology*. 1997;.
105. Graeme KA, Pollack CV. Heavy metal toxicity, part I: arsenic and mercury. *Journal of Emergency Medicine*. 1998;.
106. Hussain S, Rodgers DA, Duhart HM, Ali SF. Mercuric chloride-induced reactive oxygen species and its effect on antioxidant enzymes in different regions of rat brain. *Journal of Environmental Science and Health-Part B*. 1997;.
107. Su JY, Chen WJ. The effects of methylmercury on isolated cardiac tissues. *American Journal of Pathology*. 1979;.
108. Rhee HM, Choi BH. 1989.
109. Bastos WR, Gomes J, Oliveira RC. 2006.
110. Fillion M, Mergler D, Passos CJS, Larribe F, Lemire M, Guimarães J. A preliminary study of mercury exposure and blood pressure in the Brazilian Amazon. *Environmental Health*. 2006;5:29–29.
111. Guallar E, Sanz-Gallardo MI, Van, Veer P. Mercury, fish oils, and the risk of myocardial infarction. *The New England Journal of Medicine*. 2002;.
112. Yoshizawa K, Rimm EB, Morris JS. Mercury and the risk of coronary heart disease in men. *The New England Journal of Medicine*. 2002;.
113. Houston MC. 2007.
114. Available from: https://www.epa.gov/mercury/health-effects-exposures-mercury.

Author biography

Shweta Gupta, Student https://orcid.org/0000-0003-3363-9882

Upasana Yadav, Assistant Professor https://orcid.org/0000-0003-3363-9882

Cite this article: Gupta S, Yadav U. Biomagnification of mercury in aquatic ecosystem and effect on human being. *J Pharm Biol Sci* 2024;12(1):8-18.