IMPACTS OF MERCURY TOXICITY IN AQUATIC ECOSYSTEM: A REVIEW

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Abstract

Mercury is highly noxious heavy metal. It exists in three forms: Elemental, organic, and inorganic. All forms of mercury have proven to induce toxic impacts on the living beings. It has ability to accumulate in the different tissues of the body and magnifies its concentration from lower to higher trophic level. Mercury has been introduced to aquatic body mostly via different anthropogenic activity. Thermal power plants which uses coal as the main fuel is identified as primary source of mercury contamination in air. From air it gets deposited on land surface and finally washed to water body. The aquatic plants and animals are the process through which it enters the food web. In Aquatic ecosystem, organisms get exposed easily and consume mercury that deposits in their gills, liver, kidney or gonadal tissues. Hg has its potential impacts at both either acute or chronic exposure level. The severity of toxicants depends upon duration of exposure, method of exposure and amount of dose. The present study gives an insight of toxic impacts of mercury in aquatic ecosystem.

Keywords: Mercury, Toxicity, Environment, Heavy Metals,

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Introduction

Mercury (Hg) is considered among most poisonous heavy metal and is present in the environment as deadly toxic pollutant. United States Environmental Protection Agency (EPA) and Agency for Toxic Substance and Disease Registry (ATSDR) has listed the mercury as third most dangerous substance for the environment after lead and arsenic (Pack et al., 2014). Natural and anthropogenic activities transport and redistribute this heavy metal to the atmospheric soil and water ecosystem (Munthe et al., 2001). Aquatic ecosystem has been exposed to a number of toxicants. Anthropogenic activities like industrial effluents, extensive use of synthetic insecticides, pesticides, fungicides and fertilizers along with mining have generated major threat for the survival of aquatic life (Witeska et al., 2014). Maintaining the quality of water in Sultanpur National Park can be achieved by limiting the use of pesticides and fertilisers in nearby areas, which is posing enormous threat to the birds species of that area (Kumar Sumit; Das B.K; Kumari Khushbu; Kush Avi, 2023)

Mercury is a unique heavy metal that exists in all three forms in nature as: Elemental mercury, Organic mercury and Inorganic mercury. All these three forms of mercury have three different toxic potential. Hg exists in three oxidation states: Hg° (metallic), Hg+ (mercurous salt) and Hg++ (mercuric salt). Metallic mercury exists as dense, silvery white and shiny metal whereas it covalently binds with carbon atom to form organo-metallic compound. Methyl mercury is considered most common source as well as most toxic form among organic compound of mercury (Clarkson & Magos, 2006). Methyl mercury is converted from inorganic mercury by few anaerobic bacteria found in the sediment of aquatic bodies like lakes, oceans, ponds, and wetlands (Compeau & Bartha, 1985). The industrial discharge entering the waterbody is also converted to methyl mercury polluting the aquatic ecosystem. Lower trophic organisms easily take up methyl mercury and introduces it to the food chain. Microorganisms such as anaerobic sulphate – reducing bacteria, iron reducers and methanogens methylate inorganic (Amlund et al., 2007)((Nøstbakken et al., 2015). Once entered in food chain, it starts showing tendency of bioaccumulation and enters the body of aquatic organism specially in fishes (Mahaffey, 1999).

There are many other sources of organic mercury such as fossil fuel emission, battery factory discharge, incineration of medical wastes, dental amalgam, teething powder, germicidal soap, some instruments like thermometer, barometer, and sphygmomanometer (Guzzi & La Porta, 2008). Another organic form of mercury, which is considered as most toxic mercury compound is dimethylmercury as its few microlitre can cause death if spilled on gloves or hands. It is also capable to induce mental retardants, blindness, neurological defects, abnormal muscle tone and loss of hearing (Goldman & Shannon, 2001). Mercury has tendency to accumulate in the tissue though the rate of its excretion is slow enough (Tchounwou et al., 2003).

Mercuric chloride ($HgCl_2$) is another toxic inorganic compound of mercury. It is corrosive in nature. Gastrointestinal tract disintegrates if it is taken orally, with symptoms of vomiting, nausea and diarrhoea. Besides, alteration in central nervous system and behavioural pattern were also observed due to mercury toxicity (Brigden et al., 2002). The bioaccumulation of mercury in fish may also be influenced directly or indirectly by a number of variables, such as age of individuals or other factors that are related to size or weight of the individual (Kumari & Chand, 2021)

According to a report by Sinha et al., (2007), the pattern of mercury concentration in Ganga River ecosystem, Varanasi were found in following proportion: water < sediments < benthic macro-invertebrates < fish. The pattern of bond formation of mercury was stated in following order water < fish < sediments < large aquatic invertebrate with increasing tendency (Duzzin et al., 1988).

Compounds of mercury infect fishes or aquatic organisms through gills, general body surface or digestive tract resulting in reduction of cellular adaptive immunity, inducing histo-pathological anomalies, alters the metabolism of glucose, lipids and fats (Mandour et al., 2012). The effects of mercury and other heavy metals on fish health and bioaccumulation have also been studied by researchers (Garai P et al., 2021). These accumulated heavy metals in aquatic ecosystem not only have an impact on fish population but also move up the food chain or web to the next trophic level. Trophic transmission of these components from aquatic to terrestrial ecosystem brings negative impacts on human health as a result the risk of developing diseases like cancer, neurological disorder increases (Chen et al., 2019). The principle aim of this review is to focus the deleterious impact of mercury toxicity which is continuously increasing mainly by anthropogenic activities even after many conventions towards its mitigation.

Toxic Impacts of Mercury on Aquatic organisms

Mercury is extremely poisonous to fish, even at sublethal concentration that alters the structure, biochemistry and physiology of nervous system. Due to its ability to pass the blood-brain barrier, it gets accumulated in the nervous tissues of fish. By altering the arrangements of purines, pyrimidines and nucleic acids, mercury changes the physical characteristics and structural integrity of cell membrane (Baatrup, 1991). The chronic exposure of mercury shows signs of injury and necrosis to the kidney tubule of Clarias (Kumari, 2021). Hepatological changes and oxidative stress in the gonads were observed in zebra fish exposed to inorganic mercury. Additionally, mercury exposure interfered with the transcription of genes in the Hypothalamic-Pituitary-Gonadal (HPG) axis leading to alteration in sex hormones.

Gymnotous carapo, a tropical fish, displayed hypersensitivity to Hg poisoning in its male reproductive system. Mercuric chloride caused disorder to seminiferous tubule, clogging of blood arteries, growth of interstitial tissues and decreased the quantity of germ cells and sperms (Vergilio, C. S. et al., 2013). A comparative haematological (Chand et al., 2021) and biochemical (Chand et al., 2020) study of two different species of control group of fresh water air breathing fish Clarias has been done by researchers. These obtained reference ranges can be used as sensitive index to track later changes in fish pathophysiology caused by a variety of factors or stressed caused by xenobiotics. It will also help in keeping track of fish health and the state of aquatic bodies' pollution. Researchers examined how mercury in water at various temperatures affected grass carp's haematological and mercury metabolism. They demonstrated the strong relationship between the effects of water temperature, mercury exposure and time on haemoglobin concentration, haematocrit value, hexokinase, pyruvate kinase and malate (Li et al., 2021).

Mercury has strong affinity for proteins so, more than 90% of all mercury accumulates in fish muscle (Bradley et al., 2017). High level of mercury has been identified in muscle as well (Giblin & Massaro, 1975). Additionally, the liver serves as a location for the detoxification, storage and translocation of mercury (Evans et al., 1993). Fishes being the best indicators for accessing the state of an aquatic ecosystem and physiological changes (Rajkumar, 2016). Fishes appear to be most significant source of mercury in human hence, they may be considered as a bio-indicator to access its potential impact on the human health (Fitzgerald et al., 2007). Fishes are most susceptible to heavy metal contamination because they are unable to escape the negative effects of aquatic pollutants (Saleh & Marie, 2015).

Since, the liver is important metabolic centre, any abnormalities in hepatic tissue histopathology affect the liver function and results in fish mortality. Any damage in hepatic tissue ultimately leads to variety of physiological problems including fish mortality (Mahboob et al., 2020). In a study, Clarias batrachus was exposed to different concentration of mercury and the treated hepatic tissues were examined under TEM. As a result, the major veins of hepatic tissues were blocked by eosinophilic inclusions, haemorrhagic clots and bile. It also showed the symptoms of bile atresia. Other signs of portal cirrhosis include hepatic cellular necrosis, nodular regeneration along with disturbed hepatic cytoarchitecture (Kumari, 2021).

Kidney serves to maintain electrolyte and water balance inside the body (Ortiz et al., 2003). Its primary purpose is to excrete nitrogenous wastes. It is considered as key organ for detoxifying and getting rid of metallic contaminants although it is main location where metallic compounds accumulate (von Burg, 1995) over chronic exposure. Kumari (2021) mentioned in her thesis about impacts of chronic and acute mercury toxicity in renal tissues of Clarias batrachus (Linn.). The mercury impacts were observed in renal tissue under TEM as degeneration in collecting tubule. In addition, podocytes, constricted endothelial cell and glomerular capillaries exhibited some degenerative characteristics. The structure of cuboidal epithelial cells and the line distinguishing the cells in the collecting tubules were gone. Additionally, the tubular shrinkage in nearly all renal tubules, predominantly in PCT & DCT, produced evidence of acute tubular necrosis. Haemorrhagic clots clog the lumen of the DCT. The inter-tubular gap had significant lymphocyte infiltration and the basal lamina displayed discontinuity. The lumen of collecting tubules revealed an abundance of inflammatory cells, pus, fibrous clots, fusiform vesicles, autophagic organelles and autophagic apoptotic organelles (Kumari, 2021).

Analysis of blood parameters is thought to be a useful method for determining the health of fishes since it offers accurate and first-hand information about any inadequacies, chronic stress, and metabolic anomalies (Baghizadeh & Khara, 2015).

Fishes exhibit an oxidative stress response when metal ions are present in excess amount, which results in the generation of reactive oxygen species (ROS) (Lushchak, 2016). Redox-inactive metals, such as mercury, cadmium, arsenic, lead and nickel bind to sulfhydryl groups (-SH) of proteins involved in antioxidant defence mechanism and weakens them (Stohs & Bagchi, 1995). In fishes, increased ROS generation results in oxidations of lipids and proteins, DNA damage and bring changes in cellular redox state (Sevcikova et al., 2011). By analysing the production of oxidative stress, fishes are worldwide used as bioindicators of metals in the environment, however, actual form of biomarkers and mechanisms of their action need to be examined further (Sevcikova et al., 2011).

High level of sewage contamination is reported in Ganga and the national aquatic animal of India, the Gangetic dolphin perceives threat from heavy metals (B. Das et al., 2023b). Ganga water is carried through pipeline up to Rajgir from Hathidah (Patna) and is used as town water supply for Rajgir, and Gaya. It is to be ensured that the water is free from mercury toxicity(Kumar & Das, 2023). Even the wetlands which are rich in biodiversity and have a great environmental value have threat of mercury. Heavy contamination due to pesticide and chemical fertiliser possess mercuric threat to the living species. Kabartal wetland is the first Ramsar listed wet land of Bihar in India. It is the largest fresh water ox-bow lake of Asia formed from old Burhi Gandak river(B. Das et al., 2023a). Many migratory birds from Siberia flock this wetland(Kumari et al., 2023a).

Discussion

Many species of aquatic environment are in grave danger of extinction due to the rise in mercury levels in water bodies in recent years. Additionally, because mercury is a heavy metal, it tends to collect in the fatty portions of fish tissues and through the food chain may enter the liver, posing a major risk to human health. The current work sheds light on the systematically harmful effects of mercury exposure on aquatic life. According to biochemical and haematological research, mercury is fatally poisonous to the aquatic organism even at low doses, it may pose serious threat to the fish's biochemical, haematological, histopathological and stress tolerance profile. To better understand the molecular mechanisms underlying the toxico-kinetics of mercury toxicity in fish and to develop detoxifying strategies to enhance the general health of this important commercial fish, more research is required. According to WHO guidelines, actions at the local, national, and international levels are required to minimise or eliminate environmental emissions of mercury and its constituents (WHO, 2021). Some of the measures adopted to prevent heavy metal toxicity including Mercury is worth mentioning. At Patna in India under 'Namamai Ganga Mission' river front development has been done along the river Ganga. Separate idol immersion pool has been created at Barharwa ghat, where water is filled and idols are immersed during puja season. This water is pumped out and river is protected from contamination (B. K. Das et al., 2020). Migratory birds which feed on Mercury contaminated fishes are threat to the species(Kumari et al., 2023b). The modern industrial area planning has separate provision to deal with industrial effluents being dumped in nearby water bodies. Separate ETP's are created to deal with all the toxic wastes in Industrial area of Rajasthan(Mahatma & Das, 2023).

Conclusion

Mercuric toxicity causes severe health impact on long exposure and its effect on living system are vulnerable to entire eco system. Usage of fossil fuel must be minimised and more dependency on clean and green energy sources are need of hour. We should strive for our children to have best brain and eyes for them to see the fluttering feathers of kingfisher diving deep the blue water.

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