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Implications of Mercury Pollution in Water

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Abstract

Mercury is a very dangerous pollutant that is highly bioaccumulating. Mercury has no biological function, is potentially toxic, and causes severe damage to the body's metabolic and physiological functions. The aquatic regime is a severely affected area where mercury is the most common pollutant affecting aquatic flora and fauna. Mercury primarily targets the body's nervous system, but can damage any tissue and organ. In fish, mercury has been documented to affect various organs such as the brain, muscles, immune system, immune response, and reproductive system. Since mercury is ingested by fish and transferred to other vertebrates through the food chain, it affects not only aquatic life but also humans through bioaccumulation. Therefore, knowledge of the toxicological effects of mercury on fish is one of the research objectives in the field of fish farming.

Keywords: *Mercury, Pollution, Aquatic regimes, Fish.*

Introduction

Heavy metals naturally present in the environment are essential to life but can become toxic through accumulation in organisms (Awasthi et al., 2018; Kumar et al., 2022b, 2022a; Ratn et al., 2018). As, Ca, Cr, Cu, Ni, Pb and Hg are the most common heavy metals which are deteriorating the environment. Mercury, lead and cadmium are of major concern because of their ability of bioaccumulation and biomagnification in the atmosphere (Kumar et al., 2019).

The heavy metal mercury (Hg) has been used for centuries as a medicine and poison, and is currently used for many commercial purposes. Lately, attention has shifted to this metal due to environmental concerns. Some of the particular sources of Hg exposure that have been disclosed include consumption of contaminated seafood, use in dental amalgam, and involvement in traditional medicine and rituals. Hg is a toxic heavy metal that is widely distributed in nature (Suhendrayatna et al., 2019). Hg occurs in several chemical forms with complex nature and chemistry. Hg can produce a variety of clinical manifestations.

Hg and its derivatives are one of the most common pollutants in the environment. As Hg is bioaccumulated in the higher vertebrates living in aquatic regimes it is equally harming the human population as well. Therefore, knowledge about the toxicological effects of Hg on fish is one of the goals of research in fish farming and aquaculture.

Since Hg is absorbed and bioaccumulated in fish it causes an adverse effect on aquatic regimes as well as to human health through biomagnification. Mercury overdose is responsible for the alterations in marine and freshwater animals, ultimately decline in aquatic animals, and drastically affecting the whole groups of other aquatic vertebrates (Al-Sulaiti et al., 2022). Thus, the information on Hg toxicity on fish has become very important in research applied to fish aquaculture.

Material and Methods

Estimation of Mercury in the environment

India is the second largest country in the mercury pollution worldwide with an approximate discharge of 144.7 tonnes Hg/year. Mercury pollution in India is pointing towards lethal conditions due to the release of unwanted pollutants having a range of Hg from 0.058 to 0.268 mg/L. The mercury pollution in India is increasing day by day but data on its potential to harm aquatic flora and fauna is still obscure hitherto.

Table 1. Maximum permissible limit of mercury in the environment

Heavy Metal	Permissible limit of Hg in environment according to EPA and WHO					
Mercury (Hg)	Ground water	Fresh water	Drinking water	Terrestrial	Human blood	Fish
	2 ppb	2ppb	2ppb	1 mg/kg	0.7 ppb	0.46

Measurement of mercury in water, sediments, plants and fish tissues

- **Sample preparation for sediments**

Moisture content from sediments samples will be removed by air drying then crushing and sieving of the samples will be done. 2 g of sieved samples will be digested with 20ml of tri-acid mixture nitric acid: sulphuric acid: perchloric acid in the ratio of 5:1:1. The mixtures will be left overnight and then heated for four to five hours at 80°C. A clear solution will be obtained and filtered through filter paper and stored in 100 ml bottle.

- **Sample preparation for Plants**

The plant samples were dried, grinded and sieved before digestion. 5 ml (HNO_3 (4): $HCLO_4$ (1) mixture will be added to 1 g of weighed dried plant powder. Heating will be done for one hour. The sample will be cooled and volume will be marked up to 50 ml. digestion of samples will be done with concentrated nitric acid (5 ml), cooled and filtered through filter paper. The volume will be maintained up to 100 ml with ddH_2O (APHA., 2012).

- **Sample preparation for fish tissue**

Acid digestion of dried fish samples will be done by adding high purity 70% HCI04, concentrated HNO_3 and concentrated H_2SO_4 in 1:5:1 ratio to 500mg of each sample for autolysis and digestion. Transparent solution will be obtained after heating the samples at 80 ^{0}C. The digested samples will be diluted with ddH_2O.

- **Determination of metal concentration**

Atomic absorption spectrophotometer (Model AAS-4141, ECIL, India) using acetylene - air flame will be used for the estimation of mercury in different samples.

Experimental design on fish

- **Determination of LC_{50} in fish species**

For the calculation of 96 h LC_{50} of mercury standard methods under OECD guidelines for fish acute bioassays (OECD203, 92/69/EC, method C1) and the standard protocols of APHA, (2012) were used for *Channa punctatus*. Firstly, approximate toxic range of mercury will be identified on ten well-acclimatized fish. Different concentrations of mercury (0.1, 1.0, 10, 100, and 1000 mg/L) will be given to fishes in different aquaria till 96 h in a semi-static bioassay system. The range of toxicity of mercury will be noted. After having approximate toxic range, logarithmic series of ten nominal concentrations (0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4 mg/L) were given to fish for determination of the LC_{50} value of mercury.

- **Experimental set up in the laboratory**

Healthy specimens of fishes will be selected and acquired with the aid of fishermen from aquatic habitats. Fish will be transferred to the laboratory and prophylactic treatment with 0.05% $KMnO_4$ solution for 2–5 min will be given to protect against external infections if any (Awasthi *et al.*, 2018). Acclimatization of fish will be done for 10 to 15 days and fishes will be fed with fish food available in market twice a day. Feeding will be stopped one day before the starting of the experiment. (OECD, 2019). Overall, 135 fish will be kept at random into three groups in triplicates in separate aquaria, each having 15 fish, the group I will be served as control, group II - 96 h-LC_{50}/20, group III – 96 h-LC_{50}/10 of mercury. At one time, the aquaria will be cleaned daily to prevent waste and debris (Palermo et al., 2015). After that exposure period will be selected and 3 fish from every triplicate were anesthetized by using 0.1% (v/w) diethyl ether, their blood and tissues will be collected for the estimation of different biomarkers of toxicity.

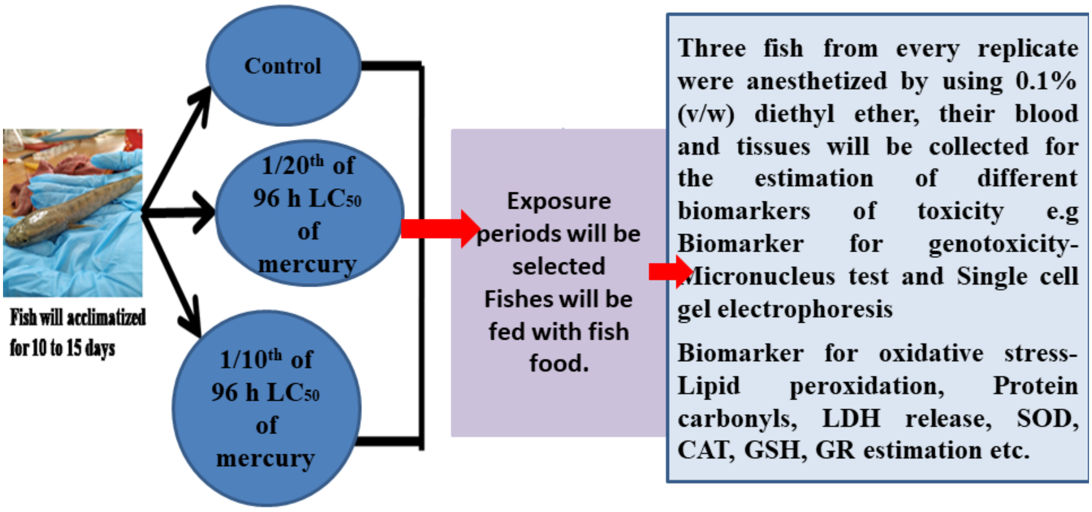

Diagram 1: Representation of experimental set up for toxicity test of mercury on fish

Harmful effects of mercury on aquatic fauna

Pollution is negative feedback from the environment that affects living organisms. The aquatic environment is also not spared from the bad effects of pollution. Recently, interest has shifted to rivers and estuaries as they are considered a major source of pollutants in coastal seas and oceans. Humans are responsible for the pollution of the oceans, which directly or indirectly have introduced hazardous waste into the marine environment. Estuaries and rivers are not spared, as a result of which the adverse effects have paved the way for human health hazards. Hg and its derivatives are one of the most common pollutants in the aquatic environment. Hg affects aquatic ecosystems and humans through bioaccumulation. Therefore, knowledge about the toxicological effects of Hg on fish is one of the goals of research in fish farming.

The amount of Hg in fish and other seafood depends on the type and level of pollution. A 1998-2005 study recorded 27% of fish from 291 rivers in the United States contained high level of mercury (Scudder et al., 2011). Another study found that a fishes caught from the coast of New Jersey had Hg levels greater than 0.5 ppm— levels that initiates the health issues in people who regularly have canned fish in their diet (Burger and Gochfeld, 2011). High concentrations of Hg have been found in fish stocks, especially in coastal areas in India. Mumbai, Kolkata, Karwar and North Koel are some of the worst affected areas. In Mumbai, the Hg content of fish is 0.03-0.82 mg total Hg/kg dry weight (dw); Crabs have a total of 1.42-4.94 mg Hg/kg mercury compared to a limit value of 0.5 mg/kg. Hg levels in oysters in Karwar ranged from 0.18 to 0.54 mg/kg body weight.

Several studies have shown that in a well-known response to oxidative stress, Hg initiates a disbalance in the production of ROS and decreasing their level by the antioxidant system. ROS production after exposure to Hg has been described in fish. In fact, Hg combines with the thiol group of GSH, which can lead to GSH deficiency and oxidative stress. Therefore, several studies have identified changes in the antioxidant system caused by Hg exposure. Recently, Hg exposure increased ROS levels and decreased the antioxidant potential of serum mucus in *Sparus aurata*, while increasing SOD, CAT, and GR activity in the liver (Guardiola et al., 2016).

Among other mutagenic properties, $HgCl_2$ adversely effect on tubulin. $HgCl_2$ interferes with tubulin polymerization, resulting in chromosomal shrinkage at metaphase, delayed centromere cleavage, and slower anaphase movement. Investigation of cytogenetic endpoints like MN formation, chromosomal breakage and exchange of sister chromatids proves a sensitive genetic test to detect genotoxic chemicals and mutagens in the environment at subtoxic levels. In recent years, rapid advances in agriculture and industry have led to widespread mercury pollution from the use of organic and inorganic mercury fungicides in agriculture, entering aquatic ecosystems through rain leaching and direct disposal of sewage and industrial effluents into rivers. Fish liver exposed to mercury chloride exhibits biochemical and histopathological changes with extensive cellular degeneration that can be caused by cumulative toxicity (Trivedi et al., 2022). In rats, mercury is known to increase hepatic cholesterol synthesis (Wu et al., 2013). Acid and base phosphatases are lysosomal hydrolytic enzymes and increased hepatic levels in fish may be due to hepatocyte degeneration and lysosomal rupture, leading to their accumulation in the liver (Trivedi et al., 2021).

Conclusion

Absorption of harmful heavy metals occurs in the fish's body, which is unsafe for human consumption because the bioaccumulated heavy metals have been transferred to humans. An unpolluted aquatic environment can provide humans with the best quality seafood. Fish that are economically important are more susceptible to heavy metal pollution in water bodies. This study covers the toxicological effects of mercury on the environment and fish. The data is extremely useful and provides an overview of heavy metal toxicity in aquatic environments and provides a baseline for the scientific community and government officials involved in health risk assessment and environmental pollutant management to guide best practices for restoration and protecting the health of human ecosystems.

References

Al-Sulaiti, M.M., Soubra, L., Al-Ghouti, M.A., 2022. The Causes and Effects of Mercury and Methylmercury Contamination in the Marine Environment: A Review. Curr. Pollut. Reports 8, 249–272. https://doi.org/10.1007/s40726-022-00226-7

APHA, AWWA, WEF, 2012. Standard Methods for the Examination of Water and Wastewater, 22nd ed. APHA 800 I Street, NW, Washington, DC 20001-3710.

Awasthi, Y., Ratn, A., Prasad, R., Kumar, M., Trivedi, S.P., 2018. An in vivo analysis of Cr 6+ induced biochemical, genotoxicological and transcriptional profiling of genes related to oxidative stress, DNA damage and apoptosis in liver of fish, Channa punctatus (Bloch, 1793). Aquat. Toxicol. 200, 158–167. https://doi.org/10.1016/j.aquatox.2018.05.001

Branco, V., Canário, J., Lu, J., Holmgren, A., Carvalho, C., 2012. Mercury and selenium interaction in vivo: Effects on thioredoxin reductase and glutathione peroxidase. Free Radic. Biol. Med. 52, 781–793. https://doi.org/10.1016/J.FREERADBIOMED.2011.12.002

Burger, J., Gochfeld, M., 2011. Mercury and selenium levels in 19 species of saltwater fish from New Jersey as a function of species, size, and season. Sci. Total Environ. 409, 1418–1429. https://doi.org/10.1016/J.SCITOTENV.2010.12.034

Guardiola, F.A., Chaves-Pozo, • E, Espinosa, • C, Romero, • D, Meseguer, • J, Cuesta, • A, Esteban, • M A, 2016. Mercury Accumulation, Structural Damages, and Antioxidant and Immune Status Changes in the Gilthead Seabream (Sparus aurata L.) Exposed to Methylmercury. Arch. Environ. Contam. Toxicol. 70, 734–746. https://doi.org/10.1007/s00244-016-0268-6

Kimáková, T., Kuzmová, L., Nevolná, Z., Bencko, V., 2018. Fish and fish products as risk factors of mercurexposure. Ann. Agric. Environ. Med. 25, 488–493. https://doi.org/10.26444/aaem/84934

Krabbenhoft, P., D., A., D., 2018. Mercury Contamination of Aquatic Ecosystems.

Kumar, M., Gupta, N., Ratn, A., Yashika, A., Prasad, R., Trivedi, A., Trivedi, P.S., 2019. Biomonitoring of Heavy Metals in River Ganga Water, Sediments, Plant, and Fishes of Different Trophic Levels. Biol. Trace Elem. Res. 1–12.

Kumar, M., Singh, S., Dwivedi, S., Dubey, I., Trivedi, S.P., 2022a. Altered transcriptional levels of autophagy-related genes, induced by oxidative stress in fish Channa punctatus exposed to chromium. Fish Physiol. Biochem. https://doi.org/10.1007/s10695-022-01119-8

Kumar, M., Singh, S., Dwivedi, S., Trivedi, A., Dubey, I., Trivedi, S.P., 2022b. Copper-induced Genotoxicity, Oxidative Stress, and Alteration in Transcriptional Level of Autophagy-associated Genes in Snakehead Fish Channa punctatus. Biol. Trace Elem. Res. https://doi.org/10.1007/s12011-022-03301-8

Mela, M., Neto, F.F., Yamamoto, F.Y., Almeida, R., Grötzner, S.R., Ventura, D.F., de Oliveira Ribeiro, C.A., 2014. Mercury distribution in target organs and biochemical responses after subchronic and trophic exposure to Neotropical fish Hoplias malabaricus. Fish Physiol. Biochem. 40, 245–256. https://doi.org/10.1007/s10695-013-9840-4

Minoia, C., Ronchi, A., Pigatto, P., Guzzi, G., 2009. Effects of mercury on the endocrine system. Crit. Rev. Toxicol. 39, 538. https://doi.org/10.1080/10408440903057029

Morcillo, P., Esteban, M.A., Cuesta, A., 2017. Mercury and its toxic effects on fish. AIMS Environ. Sci. 4, 386–402.

https://doi.org/10.3934/environsci.2017.3.386

OECD, 2019. Test No. 203: Fish, Acute Toxicity Testing, Section 2: Effects on Biotic Systems. Guidel. Test. Chem. 10.

Palermo, F.F., Risso, W.E., Simonato, J.D., Martinez, C.B.R., 2015. Bioaccumulation of nickel and its biochemical and genotoxic effects on juveniles of the neotropical fish Prochilodus lineatus. Ecotoxicol. Environ. Saf. 116, 19–28. https://doi.org/10.1016/j.ecoenv.2015.02.032

Ratn, A., Prasad, R., Awasthi, Y., Kumar, M., Misra, A., Trivedi, S.P., 2018. Zn 2+ induced molecular responses associated with oxidative stress, DNA damage and histopathological lesions in liver and kidney of the fish, Channa punctatus (Bloch, 1793). Ecotoxicol. Environ. Saf. 151, 10–20. https://doi.org/10.1016/j.ecoenv.2017.12.058

Scudder, C.B., Chasar, C.L., Dennis, A.W., Bauch, J.N., Brigham, E.M., Moran, P., Krabbenhoft, P.D., 2011. Mercury in fish, bed sediment, and water from streams across the united states, 1998-2005, U.S Department of the interior U.S Geological Survey.

Suhendrayatna, S., Arahman, N., Sipahutar, L.W., Rinidar, R., Elvitriana, E., 2019. toxics Toxicity and Organ Distribution of Mercury in Freshwater Fish (Oreochromis niloticus) after Exposure to Water Contaminated Mercury (HgII). https://doi.org/10.3390/toxics7040058

UNEP/AMAP Expert group, 2013. AMAP/UNEP Technical Background Report for the Global Mercury Assessment 2013, AMAP/UNEP.