Vidhyabharti International Ibterdisciplinary Research Journal

BIOACCUMULATION OF HEAVY METALS IN AQUATIC LIFE: A LITERATURE REVIEW

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ABSTRACT

The poisoning of aquatic systems with heavy metals as a result of natural human sources has grown into a global problem that is threatening ecosystems and natural communities. A result of these findings, this research investigates the repercussions of metal bioaccumulation in aquatic organisms. Cadmium is thought to accumulate in aquatic species through a range of organs, including the gills, liver, stomach, and intestines, according to current estimates. These dangerous heavy metals are brought to the public's attention because of the harm they can cause.

Keywords: Bioaccumulation, Heavy metals, Aquatic life, ecosystem.

1. Introduction

Heavy metals are chemical elements having a high density, which are dangerous or lethal even in trace amounts. Mercury (Hg), chromium (Cr), thallium (Tl), and lead are examples of heavy metals (Pb). Heavy metals are naturally found in the earth's crust. Their level of quality won't deteriorate. Because of their toxicity, heavy metals can accumulate in the body and cause problems with bioaccumulation. Bioaccumulation, on the other hand, is the process through which a chemical's concentration in a living creature increases over time. When compounds are taken up and stored quicker than they can be broken down (metabolised) or expelled, they build up in living organisms. Acid rain destroying soils, industrial and consumer waste polluting rivers and groundwater can all lead to water contamination.

Metals that can't be absorbed by the body build up in organs and soft tissues. The human body absorbs heavy metals from industrial and agricultural surroundings through food, drink, air, and skin absorption. Asthma episodes in children and adults are common. Most youngsters are exposed to these substances by eating or drinking them (Roberts, 1999). Children who eat non-food objects (such dirt or paint chips) or touch contaminated soil are at risk of ingesting hazardous quantities due to their frequent hand-to-mouth behaviour (Schachter et al., 2020). Exposure through radiological treatments, improper dosage or monitoring during feeding, broken thermometers, or self-harm attempts is rarer. (Chartier al., 2014).

Heavy metal pollution is linked to a variety of illnesses, including organic mercury poisoning in Japanese, cadmium poisoning in Taiwanese, and arsenic acid pollution in humans in the United States and Europe (Rahman & Singh, 2019). Heavy metal pollution is also a major cause of asthma caused by air pollution in the United States and Europe. In marine ecosystems, there are numerous internal and external linkages that can change over time, making them very complex and dynamic. Pollutants that enter estuaries and inshore waters cause major problems, endangering aquatic life and activities and even causing mass fatalities. Heavy metal buildup in marine environments is one of the most serious contaminants.

Several heavy metals have been distributed through water and beach transport. Water systems can be seriously harmed by activities that release large amounts of heavy metals into the environment into the ecosystem (Masindi & Muedi, 2018). Poisoning by heavy metals can have major consequences for the ecological balance and aquatic species richness of the recipient ecosystem (Kolarova & Napiórkowski, 2021). Fish are particularly vulnerable to pollution since they are water-dependent creatures (Avni & Jagruti, 2016). Many fish are utilised in aquatic ecosystem health evaluations due to the fact that toxins build throughout the food chain and cause severe harm or death (Bhateria & Jain, 2016). According to the Environmental Protection Agency (EPA), heavy metals enter waterways through atmospheric deposition or erosive processes such as mining waste or human-caused geological substrate erosion. Metal pollutants in aquatic systems are typically soluble or suspended, and they either settle to the bottom or are consumed by organisms before being cleaned up. Toxic metal accumulation in the organs of marine species causes long-term metal-related disorders, putting the aquatic biota and other organisms in danger. Because fish are a major aquatic organism in the food chain, toxic metals can accumulate in them. Toxic metals for fish include Fe, Zn, Pb, Cd, Cu, and Mn, all of which can harm them directly or in combination. These (potential) contaminants move up the food chain through processes and routes known as bioaccumulation and bio magnification, which demonstrate a greater capacity for bioaccumulation in the species exposed to them. Hazardous chemicals are retained for longer in food chains with increasing concentrations than in those with lower concentrations. "Individual metals and metal complexes, such as "heavy metals," have been shown to be toxic to humans. Many of these metals are only required in trace amounts to sustain life. When consumed in large quantities, however, they become poisonous. They can accumulate in biological systems and pose a serious health risk " (OSHA, 2004).

Table 1. Common types of heavy metals

Metal Name	Description
Arsenic	The ATSDR's "Top 20 List" says arsenic is the most prevalent acute heavy metal poisoning in adults. It is also released during the manufacture of chemicals and glass. Insecticides contain arsenic, which produces arousine gas. Arsenic in water threatens shellfish, cod, and haddock globally. Poisoned rats, fungicides, and wood preservatives are culprits. Blood, kidneys, CNS, digestive system, skin (Roberts, 1999).
Lead	The ATSDR's "Top 20 List" includes Lead. It is the most common harmful exposure in kids (Roberts, 1999). Pipelines, drains, and soldering supplies use it. Mold, mildew, and mildew are issues for millions of pre-1940 homes that contain lead (e.g., in painted surfaces). Every year, over 2.5 million tonnes of lead are produced. It's mostly batteries. The rest goes to cable covers, plumbing, and fuel additives. The compound is also used to make insecticides and PVC plastics.
Mercury	Mercury comes on third rank, it is naturally created by volcanic eruptions. Inorganic mercury is elemental mercury. All three industries produce a lot of mercury (Gworek et al., 2020). Due to wind and rain carrying it, it accumulates in lakes and rivers (Budnik & Casteleyn, 2019). Paints used mercury-based fungicides until 1990. However, ancient paint supplies and painted surfaces still exist. Aluminium dental amalgam contains mercury. Many scientists assume dental amalgam contains mercury (Homme et al., 2014). They are still available. These include algaecide, childhood illnesses, and vaccinations. Most people inhale mercury. GIT readily absorbs organic mercury (90-100%) but also inorganic mercury at high doses (7-15 percent). The brain and kidney are targets (Roberts, 1999).
Cadmium	It is a by-product of lead and zinc mining. ATSDR ranks it 7th. It's in nickel cadmium batteries and PVC plastics. Cadmium-containing pesticides and fertilisers have been identified in the soil. Cadmium in shellfish Cadmium is in smoke. Tooth alloys, electroplating, motor oil, and exhaust Cadmium absorbs 2–7% of what is consumed in the GI tract. Inhalation contributes for 15% to 50% of respiratory absorption. Heart, liver, kidneys, lungs, bones (Roberts, 1999).

Iron	Iron is a dangerous heavy metal to eat, especially in young children, due to the possibility of serious poisoning. Due to its fast absorption in the gut, iron is most commonly ingested. Abrasion improves absorption. It happens when kids mistake red-coated ferrous sulphate tablets or adult multivitamins for candy. Childproof packaging has decreased overdose deaths. For iron containing 250 mg or more, use child-proof bottle closures to reduce accidental ingestion and overdose. Iron is present in iron pipes and cookware. Heart, liver and kidneys (Roberts, 1999).
Aluminium	Despite not being a heavy metal, aluminium is the third most abundant element (specific gravity: 2.55-2.80). Aluminium ToxFAQs Aluminium foil, aluminium cookware, cans, ceramics, and pyrotechnics all include it. Is in pyrotechnics and water (ATSDR ToxFAQs for Aluminium). Around 20 years ago, researchers began looking for a link between aluminium and Alzheimer's disease. Aluminium has been detected in non-brain Alzheimer's tissue, but consumers are advised to avoid it. Several groups and individuals have been banning all aluminium cookware, storage containers, and even water (Roberts, 1999). Aluminium poisoning can harm the brain, kidneys, and gut.

2. How does heavy metal contaminate into the water

It's critical to keep toxic trace metals out of our waterways and soils. Natural water bodies, sediments, and soils are polluted by metals after they have been released into the environment from anthropogenic and natural sources. As a result of volcanic eruptions and other industrial pollutants returning to the ground, heavy metals discharged into the atmosphere are contaminating water and soils. Metals stay in the environment for long periods of time, causing biota accumulation or leaching into the groundwater. There are significant implications for human health if biota and groundwater are contaminated with hazardous heavy metals. Investigating heavy metal concentrations and distribution in riverine ecosystems is critical for determining the extent of pollution by these elements (Islam et al., 2018). All of these variables have an impact on heavy metal dynamics and biogeochemical cycling in the environment.

Water, according to some, is a necessity for human survival. Water is a universal solvent because it dissolves both inorganic and organic pollutants. The freshwater and marine ecosystems are both at risk from contaminated runoff. Drinking water and soil contamination by heavy metals damages plants, animals, and people because of particulate matter (Rezania et al., 2016). Heavy metals are lethal to aquatic life even at low concentrations (Pacle Decena et al., 2018). These chemicals have the ability to change the histopathology of tissues. Aquatic environments are teeming with heavy metal pollution from myriad sources. Mining effluent is where heavy metals that end up in water get their start (Zhuang et al., 2013). Surface and groundwater, as well as agricultural runoff and industrial effluent, are contaminated with high levels of heavy metals. Surface and groundwater pollution are both exacerbated by untreated industrial effluent discharge (Afzal et al., 2018). Because of heavy metals' persistence, bioaccumulation, and biomagnification in food chains, heavy metal pollution of water bodies is a global issue (Rajaei et al., 2012).

3. Bioaccumulation of heavy materials among aquatic animals

Metal uptake by aquatic species occurs in two stages. In the first case, quick surface adsorption occurs, while in the second, gradual metal transport occurs within the cell (Abbas et al., 2014). It is the rate-limiting step in epithelial metal transport. A carrier protein or metal ion diffusion through the cell membrane aids intracellular transit (Brezonik et al., 1991).

- **Metal gill absorption**

Metals in water attack gill surfaces first, with the gill surface microenvironment, phospholipids create an epithelial membrane covered in mucus. Environmentally important pH values (pH>5) result in negatively charged

 ISSN 2319-4979

gill surfaces and probable gill-metal interaction sites (Gill-Metal Interaction Sites, GMIS). The pK value of the external gill surface epithelial components is 3.6. (de Paiva Magalhães et al., 2015). In equilibrium, the pK value is 1 when both anion and conjugate concentrations are 1. (HA). Many approaches have been developed to anticipate complexation patterns since the degree of metal interaction with biological complexes varies substantially between metals.

"Metal electronegativity" is a measure of a metal's propensity to form ionic vs covalent bonds. Thus, metal binding to gill surfaces may be mediated via ionic interactions with epithelial tissue (Cook-Auckram, 2019). They may operate as metal sensors because they have oxygen-rich cores. Conversely, covalent interactions occur between nitrogen or sulfur-rich chemicals, such as sulphydryl (Cook-Auckram, 2019).

- **Metals plasma uptake**

In the blood, metals are transported by binding to plasma proteins. Bentley (1991) discovered a serum albumin with strong zinc affinity in channel catfish (Ictalurus puntatus) (Zn). There are steric variables that influence access to non-sulphydryl, non-electrostatic sites such as imidazole groups that alter Zn binding specificity, as shown here. If this protein was present, more competitive metals would lose plasma binding sites. Because of this, this protein kept physiologically active "free" Zn at low doses. Crichton (2016) found that nearly all Zn associated to plasma proteins is easily exchangeable. The protein transferrin binds iron in plasma to prevent it from leaching (Bentley, 1991). A high ambient Cu level boosted the production of copper-binding protein MT in Anguilla anguilla gill tissue, according to Noel-Lambot et al. (1978).

- **Absorption of metals by the liver**

According to this study, fish have a liver that controls metals like mammals (Heath, 1987). Metal exposure generates MT, which then binds metals to protein targets (Rubino, 2015). Pickering (1993) asserts that fish use the stress response to avoid or overcome potentially harmful circumstances. It appears that all types of environmental stress have a basic characteristic. Activated sympatheticochromaffin system, HPI axis secretes corticosteroids into circulatory system, and hypothalamic-pituitary-interrenal axis. That is true. As a result of increased oxygen carrying capacity and intermediate metabolism, catecholamine production helps fish survive. It has been shown that catecholamines cause glycogenolysis, gluconeogenesis, and lipid mobilisation in fish liver (Ardeshir et al., 2017). Most likely, further adaptive changes in liver tissue are caused by catecholamines (or to hormones such as growth hormone or cortisol). Stress hormone secretion may have triggered internal metal fluxes, freeing naturally bound metals from the liver. This is a fascinating theory, these metals were probably excreted by bile or kidney.

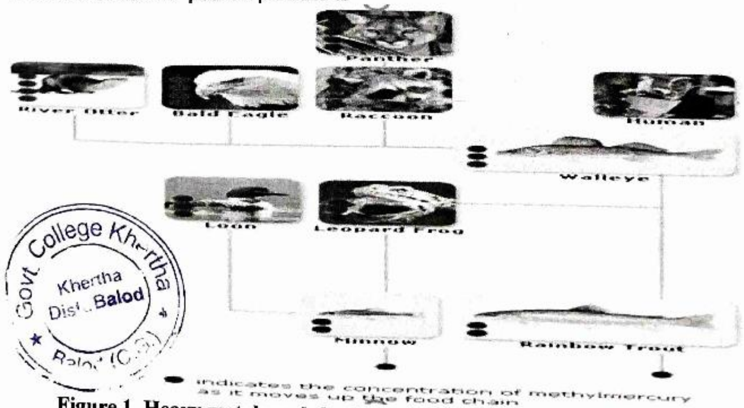

Figure 1. Heavy metals and the food chain (source: Baby et al., 2010)

4. Water pollution control with heavy metals

Most widely used processes for the removal of metals from water are chemical precipitation (which involves adding lime to the water) and solvent extraction (which involves using water to separate the metal ions from the water) (Yadav et al., 2020). Each method's steps are outlined in the following sections.

- **The process of reverse osmosis:** Toxic metals are removed from contaminated water using a semi-permeable membrane and a high pressure greater than the osmotic pressure. This approach has the drawback of being prohibitively expensive.
- **Electrodialysis:** separates heavy metals (ions) using semi-permeable selective membranes for ions. Electricity between two electrodes causes cations and anions to move to their respective electrodes. The alternation of cation and anion permeable membranes forms salt cells. Metal hydroxides block the membrane..
- **Ultrafiltration:** Porous membranes are used to remove heavy metals in pressure-driven membrane processes. Due to this process's ability to generate sludge, it has some drawbacks.
- **Ion-exchange:** Metal ions in diluted solutions are exchanged with ions trapped on an exchange resin by electrostatic forces in this procedure. High costs and incomplete elimination of some ions are some of the drawbacks.
- **Precipitation of chemicals:** Precipitation of metals involves the use of coagulants such as alum, lime, iron salts, and other organic polymers. As a result, a significant volume of hazardous sludge with poisonous chemicals is generated during the process.
- **Phytoremediation:** Phytoremediation is the process of cleaning up sites contaminated with heavy metals by using specific plants. The drawbacks include the fact that metal removal takes a long period, and that the plant needs to be regenerated for additional biosorption.
- Due to drawbacks such as incomplete metal removal, high reagent and energy requirements, and the generation of toxic sludge or other waste products that must be carefully disposed of, a cost-effective treatment method to remove heavy metals from aqueous effluents is now required to overcome these issues.
- **Biosorption:** Biological materials with metal binding capacities have been studied in the hunt for innovative methods of removing harmful metals from wastewaters. Biosorption is the ability of biological materials to absorb heavy metals from wastewater metabolically or physicochemical. Metal biosorbents can be made from algae, bacteria, fungi, and yeasts. Biosorption has a number of advantages over more traditional treatment approaches, including the following Efficiency at a low cost; The use of fewer chemicals; In addition, no additional nutrients are required, and the biosorbent regenerates; There is a chance that the metal can be recovered (Lutzu et al., 2020).

5. Conclusion

The high concentration of heavy metals could be harmful to aquatic and human health. Heavy metal pollution in the ecosystem has the potential to harm marine species at the cellular level, which could have a negative impact on the ecological balance. Heavy metals are absorbed by aquatic organisms in three ways: through the skin, gills, and food. Aquatic microorganisms collect metals, which are then ingested by small fish as an added bonus. For the second time today, predatory fish exhibit higher levels of aggression than their prey. Those that live at the end of the food chain must deal with trophic level enrichment, when they excrete less than they take in. Enrichment has taken place. In order to eliminate heavy metal contamination in aquatic environments, it is necessary to implement preventive measures.

Reference

1. Baby, J., Raj, J. S., Biby, E. T., Sankarganesh, P., Jeevitha, M. V., Ajisha, S. U., & Rajan, S. S. (2010). Toxic effect of heavy metals on aquatic environment. International Journal of Biological and Chemical Sciences, 4(4).
2. Roberts JR.1999. Metal toxicity in children. In Training Manual on Pediatric Environmental Health. Emeryville CA: Children's Environmental Health.
3. Schachter, A. E., Gailey, A., Egendorf, S. P., & Mielke, H. W. (2020). Mechanisms of children's soil exposure. Current problems in pediatric and adolescent health care, 50(1), 100742.
4. Chartier, Y. (Ed.). (2014). Safe management of wastes from health-care activities. World Health Organization.
5. Islam, M. S., Proshad, R., & Ahmed, S. (2018). Ecological risk of heavy metals in sediment of an urban river in Bangladesh. Human and ecological risk assessment: an international journal, 24(3), 699-720.
6. Rezania, S., Taib, S. M., Din, M. F. M., Dahalan, F. A., & Kamyab, H. (2016). Comprehensive review on phytotechnology: heavy metals removal by diverse aquatic plants species from wastewater. Journal of hazardous materials, 318, 587-599.
7. Ahmed, M. K., Parvin, E., Islam, M. M., Akter, M. S., Khan, S., & Al-Mamun, M. H. (2014). Lead-and cadmium-induced histopathological changes in gill, kidney and liver tissue of freshwater climbing perch Anabas testudineus (Bloch, 1792). Chemistry and Ecology, 30(6), 532-540.
8. Zhuang, P., Li, Z. A., McBride, M. B., Zou, B., & Wang, G. (2013). Health risk assessment for consumption of fish originating from ponds near Dabaoshan mine, South China. Environmental Science and Pollution Research, 20(8), 5844-5854.
9. Afzal, M. S., Ashraf, A., & Nabeel, M. (2018). Characterization of industrial effluents and groundwater of Hattar industrial estate, Haripur. Advances in Agriculture and Environmental Science: Open Access (AAEOA), 1(2), 70-77.
10. Rajaei, G., Mansouri, B., Jahantigh, H., & Hamidian, A. H. (2012). Metal concentrations in the water of Chah nimeh reservoirs in Zabol, Iran. Bulletin of environmental contamination and toxicology, 89(3), 495-500.
11. Rahman, Z., & Singh, V. P. (2019). The relative impact of toxic heavy metals (THMs)(arsenic (As), cadmium (Cd), chromium (Cr)(VI), mercury (Hg), and lead (Pb)) on the total environment: an overview. Environmental monitoring and assessment, 191(7), 1-21.
12. Masindi, V., & Muedi, K. L. (2018). Environmental contamination by heavy metals. Heavy metals, 10, 115-132.
13. Kolarova, N., & Napiórkowski, P. (2021). Trace elements in aquatic environment. Origin, distribution, assessment and toxicity effect for the aquatic biota. Ecohydrology & Hydrobiology.
14. Avni, P., & Jagruti, B. (2016). Determination of genotoxic effect of azo dye CI RR 120 on fish Catla catla. Biotechnological Research, 2(2), 77-80.
15. Bhateria, R., & Jain, D. (2016). Water quality assessment of lake water: a review. Sustainable Water Resources Management, 2(2), 161-173.
16. Osha. 2004. Safety and Health Topics: Toxic Metals. U.S. Dept. of Labor, Occupational Safety and Health (OSHA).
17. Gworek, B., Dmuchowski, W., & Baczewska-Dąbrowska, A. H. (2020). Mercury in the terrestrial environment: a review. Environmental Sciences Europe, 32(1), 1-19.
18. Budnik, L. T., & Casteleyn, L. (2019). Mercury pollution in modern times and its socio-medical consequences. Science of The Total Environment, 654, 720-734.
19. Homme, K. G., Kern, J. K., Haley, B. E., Geier, D. A., King, P. G., Sykes, L. K., & Geier, M. R. (2014). New science challenges old notion that mercury dental amalgam is safe. Biometals, 27(1), 19-24.
20. Pacle Decena, S. C., Sanita Arguelles, M., & Liporada Robel, L. (2018). Assessing Heavy Metal Contamination in Surface Sediments in an Urban River in the

Philippines. Polish Journal of Environmental Studies, 27(5).

21. Abbas, S. H., Ismail, I. M., Mostafa, T. M., & Sulaymon, A. H. (2014). Biosorption of heavy metals: a review. J Chem Sci Technol, 3(4), 74-102.
22. Brezonik Pl, King So, Mach Ce. 1991. The influence of water chemistry on trace metal bioavailability and toxicity to aquatic organisms. In Metal Ecotoxicology: Concepts and Applications, Newman MC, McIntosh AW (eds) Lewis Publishers Inc: Michigan; 1-26.
23. de Paiva Magalhães, D., da Costa Marques, M. R., Baptista, D. F., & Buss, D. F. (2015). Metal bioavailability and toxicity in freshwaters. Environmental Chemistry Letters, 13(1), 69-87.
24. Cook-Auckram, L. (2019). Heavy metal accumulation in marine fishes in Porirua Harbour.
25. Crichton, R. (2016). Iron metabolism: from molecular mechanisms to clinical consequences. John Wiley & Sons.
26. Bentley PJ. 1991. A high-affinity zinc-binding plasma protein in channel catfish (Ictalurus punctatus). Comp. Biochem. Physiol., 100C(3): 491-494.
27. Noel-Lambot F, Gierday C, Disteche A. 1978. Distribution of Cd, Zn and Cu in liver and gills of the eel Anguilla anguilla with special reference to metallothioneins.
28. Heath Ag. 1987. Water Pollution and Fish Physiology. CRC Press Inc.: Boca Raton; 145.
29. Rubino, F. M. (2015). Toxicity of glutathione-binding metals: a review of targets and mechanisms. Toxics, 3(1), 20-62.
30. Pickering AD .1993. Endocrine-induced pathology in stressed salmonid fish. Fish. Res., 17: 35-50.
31. Ardeshir, R. A., Movahedinia, A. A., & Rastgar, S. (2017). Fish liver biomarkers for heavy metal pollution: a review article. American Journal of Toxicology, 2(1), 1-8.
32. Yadav, M., Gupta, R., Arora, G., Yadav, P., Srivastava, A., & Sharma, R. K. (2020). Current Status of Heavy Metal Contaminants and Their Removal/Recovery Techniques. In Contaminants in Our Water: Identification and Remediation Methods (pp. 41-64). American Chemical Society.
33. Lutzu, G. A., Ciurli, A., Chiellini, C., Di Caprio, F., Concas, A., & Dunford, N. T. (2020). Latest developments in wastewater treatment and biopolymer production by microalgae. Journal of Environmental Chemical Engineering, 104926.