Comparative Study of Toxins and Heavy Metals Levels Detected in The Gills Tissue and Sediments of Gills from Marine and Freshwater Fishes

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Abstract:
The marine and freshwater ecology has been greatly impacted by the increased water pollution seen in aquatic life. Water pollutants greatly affect the fish's anatomy and physiology. Heavy metals are one such water pollutant that shows detrimental effects on biotic life. This study aims to quantify the toxins in the gill deposition and tissue samples from two fish samples each from freshwater and marine water. Various toxins were analyzed, including phosphate, sulphate, and heavy metals such as Lead, Cobalt, Manganese, Iron, Copper, and Nickel. The study shows the presence of heavy metal in the gills which could lead to lesions and discolouration compared to healthy fish. The differences in species and water bodies indicate the varying concentrations of potential toxins and heavy metals in gills and the accumulation of these probable toxins in freshwater and marine fishes. It helps lay the groundwork for detecting possible pollutants in two water bodies and the high rise of toxicity in water. This study indicates that the quality of water in different water bodies and the fish consumed poses significant risks to human health, with potential risk of hazard looming, as fish could be considered environmental biomonitoring tools.

Keywords: Heavy metal, Toxicity, Sediment analysis, water pollution, gills sediment.

Introduction:

The aquatic ecosystem is considered to be a natural indicator of environmental health. Due to the increase in urbanization and industrialization, the contamination of water has been drastically increased. Previous studies have demonstrated the presence of various contaminants in both marine and freshwater environments, which usually originate from anthropogenic activities e.g. Industrial discharge (Bukola *et al.*, 2015). The contaminants include heavy metals and other pesticides and toxins. (Singh *et al*., 2022) Various toxins and heavy metals and their potential to impact the aquatic ecosystem and human health are major threats to the environment. (Ullah *et al*., 2017)

The metallic elements referred to as "heavy metals" are characterized by their high atomic weights and densities, which are at least five times greater than that of water (Idowu, 2022). These elements, such as lead, cadmium, mercury, iron, copper, and arsenic, are widely used in various industries, households, agriculture, medicine, and technology, leading to their ubiquitous presence in the environment (Nwankwoala *et al.,* 2022). Human activities, including mining, urbanization, and industrial processes, have significantly increased the number of heavy metals released into the atmosphere and aquatic systems compared to natural sources (Ibrahim *et al.,* 2017, Wang, 2022). As noted by Xu *et al*., (2022), heavy metals have the ability to persist in the environment for extended periods without undergoing rapid degradation.

Heavy metals are introduced into the aquatic environment through a variety of sources, including bedrock and atmospheric decomposition (L. Wan., 2010). Sediments (Bloesch & Swiss Federal Institute of Aquatic Science and Technology (Eawag, Dubendorf, Switzerland, 2009) typically consist of loose clay, sand, dirt, and various pollutants, including heavy metals, that are deposited in water. These sediments play a crucial role in the ecosystem and have a significant impact on the trophic states of aquatic environments (Kjelland *et al*., 2015). Pollution is a major global concern that greatly affects the health and well-being of both people and the environment. Pollutants, which can be dangerous solids, liquids, or gases, are produced in excess as a result of various human activities, particularly due to rapid industrialization and technological advancements in the modern era (Ukaogo *et al.,* 2020) (Manisalidis *et al.,* 2020). The presence of heavy metals and other pollutants poses a serious threat to the health of humans and aquatic habitats. (Hoang et al., 2021) These harmful chemicals have the potential to cause a wide range of negative effects, including organ damage, cardiovascular disorders, and even death, and their bioaccumulation in the food chain presents a significant risk (Bawuro *et al.,* 2018). The complexity of heavy metal pollution in aquatic environments arises from the tendency of pollutants to easily attach to suspended solids and sediment particles, greatly affecting their bioavailability and mobility within the ecosystem. Through biomagnification in the food chain, heavy metals can accumulate in aquatic organisms and ultimately pose a direct risk to human health when contaminated seafood is consumed (Bawuro *et al.,* 2018)

Studies such as Manciocco *et al.,* 2014, have focused on the impact of environmental contaminants on aquatic species. For example, Ogbeide et al. 2019, explored the comparative gill and liver pathology of Tilapia Zilli, Claris gariepinus Neochanna and Neochanna diversus in the Owan River in Nigeria to assess the ecological risks that these species face in areas affected by pesticides. This research provides valuable insights into how pollutants affect different fish species, emphasizing the importance of monitoring and managing water quality to protect aquatic life. Demirezen & Uruç, 2006b, demonstrated the impact of trace metals found in the water on various organs of selected edible fish species. Additionally, the research of Pandey & S., 2014, revealed that imbalances in aquatic environments, characterized by elevated levels of trace metals, sulphates, phosphates, and other compounds, have detrimental effects on both aquatic ecosystems and human health, especially when contaminated fish are consumed as part of the diet. Furthermore, Kumar et al. 2020, evaluated the seasonal pollution of heavy metals (Cu, Cr, Zn, Cn, Cd and Pb) in three sites of Gogabil Lake during 2018 and 2019, as well as in fish tissues (liver, gills, and muscles) and sediments, showing that higher levels of total metal concentration in water were observed during summertime. Conversely, levels were higher in sediments during the winter, except for Pb and Zn.

Excessive amounts of nutrients, such as nitrogen and phosphorus, have the potential to cause Eutrophication, a phenomenon that can have detrimental effects on aquatic ecosystems. Eutrophication is characterized by an overgrowth of algae, leading to a reduction in dissolved oxygen levels in the water, which can negatively impact the survival of fish and other aquatic organisms (Patil *et al.,* 2022). Fluctuations in pH resulting from different pollutants can have ecotoxicological consequences and influence the general well-being of fish (Zak *et al.*, 2021, Morales *et al.,* 2018).

The utilization of fishes and other marine organisms as natural biological indicators has been recognized as a crucial tool for environmental monitoring in various research studies. For instance, De Brito Carvalho *et al*. (2020) demonstrated that an increased frequency of branchial lesions in fish from Sepetiba Bay serves as an indication of water contaminants, such as heavy metals and solvents, which are causing stress to the aquatic organisms. The authors suggest that histological alterations in fish tissues can be valuable indicators for assessing environmental pollution. Our research contributes to this field by conducting a comprehensive analysis of toxins and heavy metals in gills tissue and gill sediments of both freshwater and marine fish species. Understanding the distribution and levels of toxins and heavy metals in marine and freshwater environments is essential for effective environmental management and conservation. The concentration of metals in water is influenced by geological processes, while human activities introduce significant quantities of these metals into the aquatic environment. The fish species selected for this study, along with the conducted tests, serve as important indicators of the impact on human health, as well as the future of aquatic life and the overall environment.

In research conducted by BOSE et al. (2013), it was observed that the fish exhibited irregular swimming patterns characterized by sudden darting movements, diminished reflexes, impaired balance, and awkward swimming behaviour upon exposure to various heavy metals. This investigation aids in the evaluation and estimation of the atypical levels of heavy metals and potential toxins in the aquatic environment, as well as the potential repercussions on both aquatic organisms and human health.

Materials and Method

Sample Collection and Preparation

The research involved the examination of marine and freshwater fish species, obtained from local markets and transferred to the laboratory in sterile ice containers to avoid contamination and guarantee safe transportation. The specimens were sourced from the fish markets in Malad and Gorai regions, which are well-known markets supplying freshly caught fish to different parts of the city. Two freshwater species, Rohu (Labeo rohita) and Catla (Catla catla), as well as two marine species, King Mackerel (Scomberomorus guttatus) and Indian Croaker (kathala axillaris), were chosen for evaluation. These species are common and sold on a large scale and are an essential part of the diet of many people.

The samples underwent cleaning and dissection to eliminate gill sediments through washing with distilled water, followed by placement in sterile petri dishes for further examination. The gill tissues were isolated and sectioned using standard sterile surgical scissors to prevent potential cross-contamination from the fish. The gill tissue was weighed and subjected to treatment with 10% KOH to digest the tissues for the isolation of contaminants.

The gill sediment was processed with Aqua Regia (3:1), consisting of 35% HCl and 70% HNO3, and digested on a sand bath for thorough digestion. The gills and sediment samples were filtered using Wattman Filter No.1 and subjected to analysis. The Inorganic Phosphates and Sulphates test was adopted from Chemical and Biological Methods for Water Pollution Studies. The samples were analyzed in triplicates to ensure accuracy and minimize the margin of error.

The specimens underwent a thorough cleaning process and were dissected to eliminate gill sediments through rinsing with distilled water. Subsequently, they were transferred to sterile petri dishes for further examination. The gill tissues were carefully removed and sectioned using standard sterile surgical scissors to prevent any potential cross-contamination from the fish. The weight of the gill tissue was measured and then treated with 10% KOH to facilitate the digestion of the tissues for the purpose of isolating contaminants.

In a separate process, the gill sediment was subjected to treatment with Aqua Regia (3:1), which consists of 35% HCl and 70% HNO3, and was digested over a sand bath to ensure thorough digestion. Both the gills and sediment samples were filtered using Wattman Filter No.1 and subsequently analysed. The Inorganic Phosphates and Sulphates. (Chemical and Biological Methods for Water Pollution Studies)

Sample Analysis

The samples were analysed in triplicates to ensure accuracy and minimize the potential for error. In order to analyse the presence of heavy metals, an Atomic Absorption Spectrometer was employed, and the metals analysed included Pb, Cu, Co, Mn, Ni, and Fe. These were then compared to the permissible levels of heavy metals as per CPCB.

Result and Discussion

Toxins present in Freshwater

The data presented in Table 1 summarizes the levels of toxins in gill sediment and gill tissue of freshwater fishes. The concentration of Iron was notably high, with 20.731mg/L in gill sediment and 0.589mg/L in gill tissue, surpassing the permissible levels for fish (Javed & Usmani, 2013). This elevated level of iron toxicity can potentially lead to fish mortality, as indicated in the study by Filho (2019), and respiratory issues due to physical clogging from iron accumulation (Dalzell & Macfarlane, 1999). Lead levels were also found to be higher than the recommended limits for fish, at 0.0689 mg/L (Javed & Usmani, 2013). The heavy metal concentrations in fish samples followed the order Fe > Mn > Cu > Pb > Co > Ni in gill sediment, while in gill tissue, the order was Fe > Cu > Pb > Mn > Co > Ni.

Iron, being a heavy element, can accumulate in water body sediments, be ingested by fish, and eventually enter the human food chain. The prevalence of heavy metal contamination is well-documented, with anthropogenic activities like industrial processes and improper waste disposal being major contributors to the release of heavy metals, including iron, into water sources. Once in the aquatic environment, these metals can swiftly enter sediments, posing a direct threat to benthic organisms and potentially moving up the food chain.

The widespread presence of heavy metal pollution is a known issue, with human activities such as industrial operations and inadequate waste management being key sources of heavy metal release into water bodies, including rivers. Once these metals enter the aquatic environment, they can swiftly accumulate in sediments and move up the food chain.

Toxins present in Marine fish

The gill sediment of fish revealed heavy metal concentrations in the order Fe > Mn > Co > Zn > Cu > Pb > Ni, while the gill tissue showed the following order: Mn > Co > Cu > Pb > Ni > Fe. The continuous threat of pollutants such as phosphates, sulphates, and heavy metals to the ecosystem can negatively impact aquatic life.

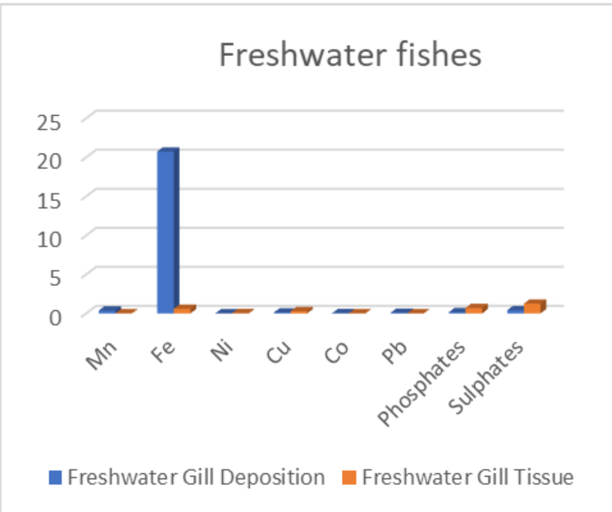
Human-caused activities, including the release of industrial effluents, mining operations, and agricultural runoff, contribute to the presence of these toxins in waterways. Consequently, these contaminants can accumulate in fish tissues, leading to various physiological and biochemical abnormalities that can severely harm aquatic life. The gills, being the main respiratory organs of fish, are particularly vulnerable to exposure to these pollutants. (Briffa *et al.*, 2020, Huseen & Mohammed, 2019, Aris & Tamrin, 2020, Mehana *et al.*, 2020

Samples	Mn (mg/L)	Fe (mg/L)	Ni (mg/L)	Cu (mg/L)	Co (mg/L)	Pb (mg/L)	Total Phosphorous (mg/L)	Sulphate (mg/L)
Gill sediment	0.3646	20.731	0.0177	0.1077	0.0277	0.0689	0.15	0.4
Gill tissue	0.0081	0.589	0.036	0.272	0.0199	0.0041	0.6915	1.25

Table 1. Toxins present in freshwater fishes

Samples	Mn (mg/L)	Fe (mg/L)	Ni (mg/L)	Cu (mg/L)	Co (mg/L)	Pb (mg/L)	Phosphate (mg/L)	Sulphate (mg/L)
Gill sediment	0.0684	3.6288	0.0023	0.0042	0.0434	0.0229	1.5	0.7
Gill tissue	0.19205	0.0237	0.02645	0.0862	0.10645	0.0755	3.0	1.0

Table 2. Toxins present in marine fishes



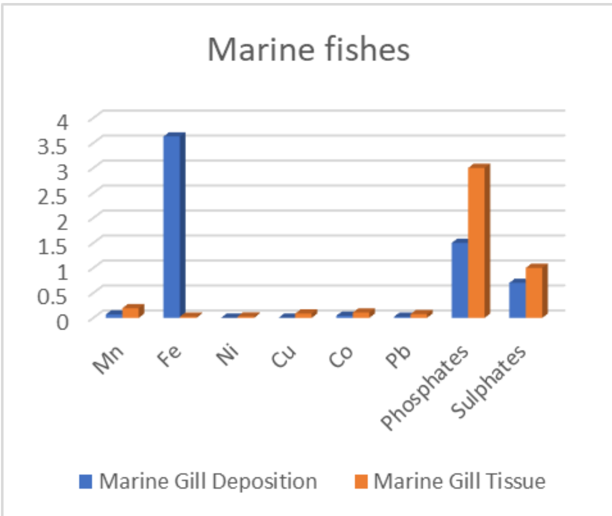


Figure 1. Comparative toxin analysis of freshwater and marine fishes

Conclusion

Heavy metals are frequently found in our environment. Nevertheless, contamination and various human-induced activities, like industrial discharges, surface runoff, and improper waste disposal, can result in the accumulation of these metals in ecosystems, making them potential poisons and lead to toxicity. Pesticides are one of the most common sources of heavy metals. Pesticides are extensively utilized due to urbanization and agricultural practices aimed at enhancing crop yields. The expanding population has led to an increased reliance of pesticides to meet the high demand in food production, consequently escalating the levels of heavy metal toxicity. Iron, the most prevalent metal in the environment, is a crucial macronutrient for organisms. Nonetheless, even a slight rise in its concentration can lead to toxicity.

The presence of iron in fish gill sediments indicates high levels of this metal in water, which can seep into the gills of fish. Elevated levels of iron have been noted in freshwater fish, hinting at surface runoff from nearby fields treated with pesticides. Furthermore, increased levels of other poisons, such as lead, have been identified, frequently surpassing permissible thresholds. This study demonstrates that water pollution with poisons results in their existence in fish. Steps need to be taken to diminish pollution in rivers and lakes, which is a major cause of poison accumulation in freshwater fish. This study offers valuable insights into the comparison of poison presence in freshwater and marine ecosystems. Further research is necessary to pinpoint other toxins that could contribute to heavy metal buildup. To boot a deeper understanding of the underlying mechanisms that govern heavy metal accumulation in the body is essential to develop effective strategies for reducing exposure to toxic metals and promoting their safe elimination. Such research should also explore the potential synergistic effects of different toxins, as well as their impact on various organs and systems in the human body.

By expanding our knowledge in these areas, we can better protect the health of individuals and communities exposed to heavy metal pollution. Expanding our understanding of the long-term effects of heavy metal exposure and the development of new technologies to detect and remove these pollutants from the environment can further enhance our ability to safeguard public health.

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