Determination of Potentially Toxic Elements in Muscles of Selected Contaminated Freshwater Fish Species and Implications on Human Health

Heavy metals contamination assessment in Muscles of Selected Contaminated Freshwater Fish Species and Implications on Consumer's Health

Heavy Metals Contamination and Bioaccumulation in Commonly Consumed Fish Species in an Urban River of Bangladesh and Implications on Consumer's Health

Introduction

The continuous influx of metal(loids) derived from anthropogenic activities and natural pedogenic processes pose an objective threat to the ecosystems that are endowed with freshwater reservoirs. Environmentally toxic elements are present; characteristically, they are freely dissolved and are readily taken up by aquatic animals in freshwater. Consequences may ensue in the form of biomagnifications in large food chains, as metals pose considerable toxicity by the process of bioaccumulations in tissues (Zhou et al., 2020). Potential toxic elements (PTEs) loading in surface water bodies is a chief concern of environmental management in global contexts (Karvelas et al., 2003; Jolly et al., 2023a). In developing nations, limnic bodies may often be used as a convenient means of discharging wastes that act as a major polluting factor, and are a result of prioritizing management practices at the expense of the wellbeing of the environment. Bangladesh is particularly vulnerable to such pollutant loading, in regions where the practice of release of untreated effluents into water bodies is often overlooked to reduce costs (Uddin and Jeong, 2021).

The threat of potential toxic elements to aquatic ecosystems and by extension, humans, has been intensifying in recent decades (Bhuiyan et al., 2011; Jolly et al., 2023a). While natural processes release heavy metals at a measurable rate, the influence of anthropogenic activities can accelerate that process in a detrimental fashion. Industrialization and exponentiating urbanization exacerbate heavy metal pollution. To that point, urban sewage and the formation of industrial effluent-mineral-complexes, particularly from those derived of mineral extraction, water treatments, metal molding and coating, battery technology, nuclear plant effluents and tanneries contain notable amounts of PTEs and toxicological compounds (Karvelas et al., 2003; Bhuiyan et al., 2011; Ahsan et al., 2019; Beni and Esmaeili, 2020).

Once PTEs, specifically the heavy metals enter a river channel with active basin pedoturbation, they stabilize to become non-degradable contaminants (Mokarram et al., 2020). Consequently, as the heavy metals continue to accumulate in river waters, physiological problems for the health of ecosystems may ensue. These metals tend to accumulate along the food chain through bioaccumulation, and with a high residence time tend to result in chronic and acute toxic effects on aquatic fauna and human health (Tchounwou et al., 2012; Gautam et al., 2016; Jolly et al., 2023b). Toxic heavy metals such as Pb, Cd, Hg, Ni, Cr, Cu, Zn, and As pose significant dangers to biota. Even at low concentrations, water contaminated with the mentioned metal(loids) is deemed highly poisonous and carcinogenic (Chaturvedi et al., 2015; Gautam et al., 2016).

Fish populations play a crucial role in the fluvial ecology and the biodiversity in Bangladesh. But potential toxic elements (PTEs)-contaminated fish pose serious health hazards. Presence of toxic heavy metals (THMs) can cause a decline in fish populations. THMs have potential to act as neurotoxins and play a role in causing deformities (Tchounwou et al., 2012; Jolly et al., 2023b). Furthermore, consumption is a major route of human exposure to toxic elements, particularly through diets that rely heavily on fish, making fish an important indicator for studying heavy metal pollution (Ali et al., 2019; Jolly et al., 2023b; Mendoza et al., 2023).

Fish are affected by heavy metals through genetic and enzymatic effects that lead to alterations at the structural levels of the organs, negating ideal functionality (Luczyńska et al., 2018; Mendoza et al., 2023). Consequently, this may affects immune responses and increases their susceptibility to potential diseases. Fish have three pathways to absorb THMs through contact, their (I) epidermal surface, (ii) gills, and (iii) through ingestion (Luczyńska et al., 2018; Ali et al., 2019). However, the inferred rate of accumulation depends on the species of THMs and the effective absorbance and surface area of the fishes’ organs, such as livers, kidneys, pyloric caeca and gills accumulating higher concentrations of these toxic materials compared to muscles (Bawuro et al., 2018; Jolly et al., 2023b; Mendoza et al., 2023). Consequently, fish are often treated as a means for a rudimentary index for the freshwater systems to identify the toxic element pollution level and subsequently the hazardous impacts on human health (Swanson et al., 2012; Varol et al., 2017; Bawuro et al., 2018; Luczyńska et al., 2018; Rahman et al., 2022). Elevated metal concentrations can cause lethal or chronic effects on fish (Luczyńska et al., 2018) and thus, indicate the contamination status of the fluvial ecosystem and influence the aquatic trophic levels through further biomagnifications (Rahman et al., 2022). Given the diverse accumulation and amplification of metals, which exhibit significant variation across fish species, and the persistent nature of contamination, regular monitoring of potential toxic element (PTE) levels in fish and other aquatic organisms is crucial from an environmental and food safety standpoint.

In addition to their role in freshwater ecosystems, fish constitute a significant dietary component for a considerable proportion of the global population (Varol et al., 2017; Luczyńska et al., 2018; Mendoza et al., 2023). Their role as a vital protein source, reaching 16% of the global population's non-plant intake of protein, and a major source of beneficial polyunsaturated fatty acids (Nordhagen et al., 2020; Haseeb et al., 2022). It constitutes a major source of formative nutrients for the population, additionally supplying lipids and Omega-3 fatty acids (n-3 PUFAs). The inclusion of fish due to its omega-3 fatty acid content, has shown positive effects on cardiovascular function, fetal development, and in the treatment of Alzheimer's (Swanson et al., 2012; Luczyńska et al., 2018).

The impact of bioaccumulation of heavy metals in marine and aquatic foodstuff is particularly detrimental to developing countries like Bangladesh. As fish accounts for 55% of animal protein intake at 18.1 kg consumed every year, per person (FAO, 2016), thus, the discovery of epi-tolerable levels of heavy metals in fish species has raised concerns regarding the appropriateness of fish to be part of a healthy diet (Castro-González and Méndez-Armenta, 2008). Fish muscle being the primary edible fraction (Bawuro et al., 2018; Luczyńska et al., 2018), most studies on human exposure to these toxic elements through fish focus on the muscle accumulation of the metals (Ali et al., 2020; Jolly et al., 2023b; Rahman et al., 2022). Consumption of fish muscles with heavy metal toxicant loading can cause various adverse effects and health concerns in humans, including the risk of cancer, pulmonary disorders, hepatic shutdown, renal damage, cardiovascular problems, immunological effects, neurological damage, and fetal development impairments (Tchounwou et al., 2012; EFSA, 2014; Anyanwu et al., 2018; Mitra et al., 2022).

A tributary of the Jamuna River, the Dhaleswari River, is approximately 160 km long and flows through the central subaxis of the country, originating from Tangail in the northwest. The flow bifurcates into two separate streams, one retaining the name Dhaleswari, which eventually merges with the second stream to become the Shitalakshya River in Narayanganj. This river is highly adversified by heavy metal inundation due to its proximity to Hemayetpur’s tannery industrial estate, with geographically adjacent steel mills and dyeing factory clusters (Wahiduzzaman et al., 2022). Thus, it is crucial to assess the ecotoxicity and pollution effects of the site on the contingent aquatic population, whose livelihoods are severely affected by the river.

In addition to evaluating the pollution status of the contaminated site, it is essential to understand the associated risks to human health and quantify the output of pollutants in order to implement effective mitigation strategies (Jolly et al., 2023b). While several studies have focused on investigating the effects of heavy metal pollution on fish species in this river (Wahiduzzaman et al., 2022; Lipy et al., 2021), there exists a knowledge gap regarding the human health risks associated with consuming these fish. Few studies have explored the possible sources of metals in the urban river. Finally, although extensive investigations have been carried out in the past to determine the potential origins of metal contaminants in water, sediment, and soil through various studies (Bhuiyan et al., 2011; Jolly et al., 2023a,b,c; Shorna et al., 2021), the application of chemometric techniques for source apportionment in fish species remains relatively rare.

Consequently, this study aims to quantify the non-carcinogenic and carcinogenic risks linked to the consumption of eight commonly found fish species from the Dhaleswari River. Furthermore, the study investigates whether there are significant associations between heavy metal accumulation and the presence of beneficial polyunsaturated fatty acids, particularly omega-3, in the fish species. The following study employs methods of statistical multivariate analysis to identify potential sources and apportionment of heavy metal contamination in the river.

Table: Eight species of the studied fish samples including their feeding and living habit

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| --- | --- | --- |
| Local name | Scientific name | Description of the species |
| Ghagra fish | *Clupisoma garua* | It is a potamodromous species of catfish of the family Schilbeidae, well distributed in Indian subcontinent rivers and freshwater reservoirs. *Clupisoma garua* is herring-shaped fish, tapering gradually toward both ends and abdominal edge partly keeled between pelvic fins and vent. It falls in the category of euryphagous fish, highly carnivorous and predacious in nature, and feeds on insects, molluscs, crustaceans and small fishes in wild conditions. |
| Koi fish | *Anabas testudineus* | The climbing perch is a fish species from the family of Anabantidae, the climbing gouramis. It is native to Asia, found in Bangladesh, India, and China. It is omnivorous more inclined to carnivorous. This predatory species apparently feed on different feeding labels of waterbody, plant matter including algae and rice grains as well as smaller fishes, invertebrates, rotifers, crustaceans, insects, algae, diatoms, etc. |
| Tatkini fish | *Cirrhinus reba* | It's a freshwater cyprinid fish. *Cirrhinus reba* is used to inhabit rivers, reservoirs and streams of Asian countries but is also found in lakes, tanks, ponds, canals, beels and inundated fields. It's an herbivorous fish that actually feeds on plant matters in aquatic environment. The finger lings of *Cirrhinus reba* prefer zooplankton up to a certain length group and intended to consume plant materials in their adult stage. |
| Tengra fish | *Mystus vittatus* | *Mystus vittatus*, the long whiskers catfish, is a species of catfish of the family Bagridae, distributed around India to the Malay archipelago. It is found in Bangladesh, India, Sri Lanka, Pakistan, Nepal, and Vietnam. It is predominately a carnivore, feeding mainly on crustaceans, molluscs, and insect larvae. Primarily a low salinity brackish water cyprinid fish that enters and lives in freshwater. |
| Batashi fish | *Neotropius atherinoides* | Belonging Siluriformes family, it's a tropical labyrinth perch well distributed across Bangladesh, Pakistan, India, Myanmar and Nepal. It is carnivorous. The juveniles feed on crustaceans, plant matter, and insects while the adults feed on zooplanktons and plant matter. It's higher diet breadth on resource use (Levins’ and Hurlbert’s) with zooplankton compared to phytoplankton and total plankton confirmed its zooplanktivore habit. |
| Jatka (juvenile) fish | *Tenualosa ilisha* | It is anadromous, migrating from the sea to freshwater riverine environments to spawn. It is distributed in rivers, tributaries and channels extending over 9,390 km2 as well as in the 118,813 km2 area of the northern Bay of Bengal. Jatka (juvenile) mainly feed on phytoplankton with a small quantity of zooplankton. It also consumes copepods including detritus, algae, mysis, molluscan larvae etc. |
| Rani fish | *Botia Dario* | Belonging loach family Botiidae, Rani fish can be found in the creeks and streams of the northern and eastern regions of Bangladesh (bordering India and Myanmar, respectively). The fish most likely populates the streams that supply the Bengal section of the Ganges River. It is a carni-omnivorous and bottom feeder fish having a preference for animal materials over plant materials. It also consumes mosquito larvae, tubifex, daphnia, and some vegetable foods such as algae wafers. |
| Chanda fish | *Pseudambassis ranga* | The elongate glassy perchlet is a species of freshwater fish in the Asian glassfish family. The species are carnivores and feed on mosquito larvae and worms and eat the scales of other fishes (lepidophagy); the species may have potential use in controlling malaria and parasites. |