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Heavy Metal Evaluation in Commonly Consumed Fishes (*Boleophthalmus boddarti* and *Mugil cephalus*) from Panvel creek, District Raigad, Maharashtra, West Coast of India

Leena N. Meshram [a*] and Amisha A. Bhagat [a]

[a] Department of Zoology, Mahatma Phule Arts, Science & Commerce College, Panvel, Dist. – Raigad, Navi Mumbai – 410 206, Maharashtra, India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The present study aimed to monitor heavy metal concentrations in commonly consumed fishes, Mudskipper (*Boleophthalmus boddarti*) and Mullet (*Mugil cephalus*) from Panvel Creek, District Raigad, Maharashtra, West Coast of India using the US-EPA Method and analysis by Inductively

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**Corresponding author: Email: reply.leena@gmail.com;*

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Coupled Plasma Atomic Emission Spectroscopy (ICP- AES). Concentrations of Cadmium (Cd), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), and Zinc (Zn). It is reported that the extent of metal concentrations in muscle, gills, and liver tissue of fishes is varied considerably. In mudskipper, the hierarchy of the metals can be ranked as: Hg > Cu > Ni > Zn > Pb > Cd; whereas in mullet, it is in the order of Hg > Zn > Cu > Ni > Pb > Cd. Exceptionally high levels of heavy metals were observed in mullet and are attributed to the habitat and feeding behavior of this species. Comparatively, lower levels of metals are recorded in mudskippers and may be due to the diet, feeding habits and migration routes. The coastal communities along the Panvel creek are dependent on unprocessed marine fish. Therefore, consumption of contaminated marine food is the major route of human exposure to toxic elements. This study recommends the periodic monitoring of coastal water, sediment, and marine biota for the extent of bioaccumulation of metals. Further, the findings of the present work should be used as baseline data for future assessment of metal pollution in the marine biota from Panvel creek and also for the better management of the coastal ecosystem and the safety of human beings.

Keywords: Bioaccumulation; biomagnification, fishes; heavy metals; mudskipper; mullet; Panvel creek.

1. INTRODUCTION

Heavy metals (HM) are toxic metals and above a normal level can affect the quality, safety and marketability of seafood (Priya et al., 2020). They have atomic weight higher than 40.04 and specific density >5g/cm (Salam et al., 2019; Norouzi, 2020). Metals enter the aquatic environment either through natural sources (geological erosion) or by anthropogenic activities (agricultural activities, industrial activities, tourism, transportation, etc.) (Simionov et al., 2019). Metals are categorized into essential HM (Co, Cu, Fe, Mg, Se, Vn, Zn) important in physiological and biological processes of organisms; and non-essential HM (Al, As, Bi, Cd, Hg, Pb, Pt, Sb, Sn) which are potentially toxic, even at very low concentration (Yousif et al., 2021).

Though metals are naturally occurring elements in the environment, human activities, such as tannery, textile, electroplating, mining, dyeing, printing, photography, and pharmaceutical industry effluents are dumped directly into rivers, toxins of which finally contaminates the coastal ecosystems (Hossain et al., 2022; Bat et al., 2017). Wastes containing toxic HM, pose a serious threat worldwide due to their accumulative properties, inherent persistence, non-biodegradability, and harmful effects (Huseen & Ahmed, 2019). Contamination by toxic metals not only endangers aquatic life but also poses a serious risk to human health (Garai et al., 2021; Barua & Barua, 2024).

Creeks, estuaries and coastal area receive significant anthropogenic inputs from both point and non-point upstream sources (Yunus et al., 2015). HM pollution in the coastal area has been recognized as a serious environmental concern (Agbugui & Abe, 2022). Rapid socio-economic growth and population explosion have increased the discharge of various organic and inorganic contaminants in the coastal environments (Gayathri & Revathi, 2013). These pollutants contaminate the seafood and pose a serious concern for its safety and health of human consuming the seafood (Samantara et al., 2023).

Fish, shrimps and crabs accumulate many contaminants in their tissues and can bio-magnify them (Ahmad & Al-Mahaqeri, 2015; Biswas et al., 2023). These organisms were considered as excellent bio-indicators to measure the abundance and availability of metals in the aquatic environments (Celine et al., 2017; Chuan Ong Meng et al., 2018). Further, fish are considered as biomarkers of heavy metals contamination in aquatic ecosystem due to their higher trophic level, negative impact of metals on their behaviour, and fishes are important constituent of human food (Barua & Barua, 2024).

Coastal fish, mussels, shrimps and crabs contain high levels of heavy metals discharged from industrial effluents and wastes from human activities (Suyatna et al., 2017; Sankar et al., 2018; Raval et al., 2017). Fishes are the major seafood and are excellent source of essential minerals, high-value protein, polyunsaturated omega-3 fatty acids, and vitamins (Carvalho, 2018). The HM from aquatic organisms can be transferred to the human after consuming the contaminated resources and the consequences can deteriorate the human health (Mukherjee & Kumar, 2011; Sangur et al., 2021).

Fishes can uptake the HM from the environment primarily through gills, food, and skin (inhalation and ingestion) (Elbeshti et al., 2018). Due to bioaccumulation, biomagnification, and non-biodegradable nature of HM, they are mostly cytotoxic, cause severe damage, carcinogenic, and are lethal for most organisms (Anand & Kumarasamy, 2013). HM contamination in fish and other aquatic organisms depend upon geographic location, species and fish size, feeding pattern, solubility of chemical and their persistence in the environment (Priya et al., 2020; Hossain et al., 2022).

HM pollution of marine aquatic ecosystem is globally a rising concern and possesses a dangerous threat for human health (Vardi & Chenji, 2020; Biswas et al., 2012; Bat et al., 2012). Toxicity of HM due to consumption of contaminated fish results in Alzheimer's disease; damage or reduced mental and central nervous system function; damage to blood composition, lungs, kidneys, bones, liver and other vital organs; lower energy levels; multiple sclerosis; muscular dystrophy, and Parkinson's disease (Batvari et al., 2015; Isangedighi & David, 2019).

Consumption of marine fishes contaminated with HM acts as a connecting pathway for the transfer of toxic HM in human beings (Kumar et al., 2012). It is a need of the hour to monitor the metal contaminants in sea foods to understand their hazard levels. Worldwide many studies have been conducted to assess the metal contamination in different edible fish species (Garai et al., 2021; Agbugui & Abe, 2022; Samantara et al., 2023; Jatav et al., 2023).

Therefore, the objective of this study was to estimate the concentration of HM (Cd, Cu, Hg, Ni, Pb, and Zn) content in the commonly consumed fish species in the region of Panvel creek, Dist. Raigad, Maharashtra, west coast of India. Results of the present study would also serve as a baseline data for future impact assessment.

2. MATERIALS AND METHODS

2.1 Study Area

The present study was undertaken at Panvel creek, Dist. Raigad, Maharashtra, west coast of India (Fig. 1). The creek is located in the Raigad District (Lat. 18° 30' 56.88'' N & Long. 73° 10' 55.92'' E) situated in the Konkan region of Maharashtra. Raigad district is characterized with average annual precipitation of 3,884 mm and mean temperature range is 17.7-31.8°C. Panvel is the most populated and cosmopolitan Tahsil and is the entry node of Navi Mumbai.

Panvel Taluka (Lat. 18° 59' 26.5668'' N & Long. 73° 7' 0.6384'' E) with the population of 750,236 (Census of India, 2021), has average annual precipitation of about 2,740.6 mm and temperature range is 22.6-34.2ºC. It is surrounded by Karjat Taluka in East, Uran Taluka in West and Ambarnath Taluka in the North; the mountains of Matheran to the east, south east and outer regions.

Geographically, Panvel is located near the Panvel creek which opens up in the Thane creek. Kalundre river flows across the city in the south-west region and opens up into Panvel creek. Panvel with a population of 180,464 (Census India 2011) is a highly populated city due to its closeness to Mumbai. It is situated on the banks of Panvel creek and is also surrounded by mountains on 2 sides.

2.2 Study Location

The Panvel creek (Lat 18º 58' 26.895'' N to 18º 59' 58.432'' N & 73º 1' 43.74'' E to 73º 6' 48.269'' E) is the tributary of Thane creek (Fig. 1). The creek is tide-dominated and the tides are semi-diuranal. The average tide amplitude is 2.28 m. The flood period lasts for about 6-7 h and the ebb period lasts for about 5 h. The average annual precipitation is about 3884 mm and the temperature range is 12-36ºC. The relative humidity remains between 61% and 86% and is highest in the month of August.

For present investigations, two study sites, namely Site I – Karanjade (18°58'54.87911"N, 73°6'24.15522"E) and Site II (Chinchpada) (18°59'56.8" N 73°05'17.9"E) separated approximately by 10 km were selected. These sites were selected on the basis of their strategic locations and vicinity to on-going anthropogenic activities (Fig. 2).

- **Site I – Karanjade:** Located near the public transport bridge joining the Karanjade with Old Panvel. It is in the vicinity of human settlement and experiences tremendous pressure of increasing population, urbanization, small-scale industries, public transport, disposal of municipal waste, aquaculture ponds, and settlement of small fishing crafts with derailing nets. Intertidal area is characterized with rocky substratum with sparse vegetation.

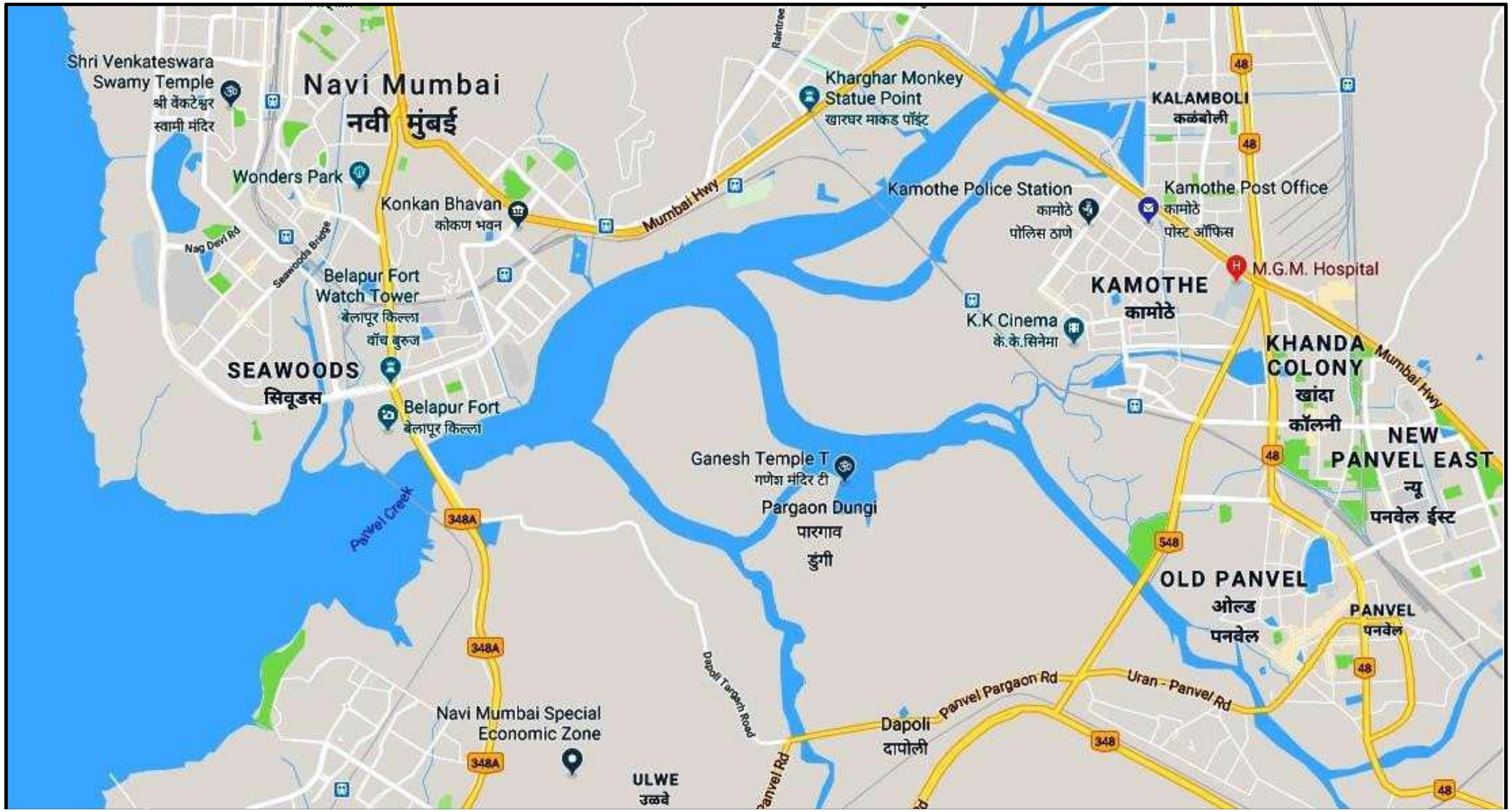
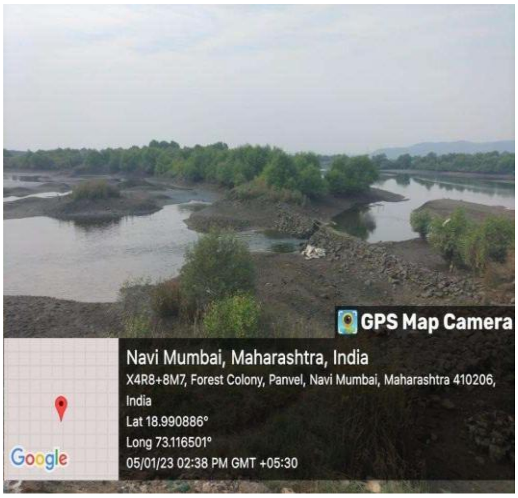


Fig. 1. Location Map of study area (Source: Google Map)

Sampling stations at Site I (Karanjade) during pre-monsoon and monsoon



Site I (Karanjade): during post-monsoon Site II (Chinchpada) during pre-monsoon

Sampling stations at Site II (Chinchpada) during monsoon and post-monsoon

Fig. 2. Types of habitats and Sampling stations along Panvel creek, Dist. Raigad

Mudskipper (*Boleophthalmus boddarti*) Mullet (*Mugil cephalus*)

Gills tissues Liver tissues Muscles tissues

Tissues of Mudskipper (*Boleophthalmus boddarti*) under study

Gills tissues Liver tissues Muscles tissues

Tissues of Mullet *(Mugil cephalus)* under study

Fig. 3. Sample fishes and tissues of fishes assessed for heavy metals

- **Site II - Chinchpada:** Separated by about 5 Km from the site I and is comparatively less polluted. Coastal area exhibits extensive mud flats with dense mangrove vegetation. Fishing activity is routinely conducted at this site and is the main source of livelihood for the local community. This site is very near to the on-going construction of Navi Mumbai International Airport, and was subjected with pressure of dredging, land filling and earth moving on the large scale.

2.3 Sample Collection

Edible fish species of Mudskipper (*Boleophthalmus boddarti*) and Mullet (*Mugil cephalus*) were randomly acquired from different fish landing centers in the study area (Fig. 3). Fishes were identified by following standard literature of Day (Day, 1878). Adult fish samples that were commonly consumed by the coastal population were selected for the present study. Fish samples were preserved in an icebox and transported to the laboratory, where they were thoroughly cleaned with ultrapure water, weighed, measured, photographed for the record, and kept frozen at -20ºC until further processing.

2.4 Sample Preparation

Fish samples were thawed, thoroughly cleaned with ultrapure water, and dissected to separate liver, muscles and gills. Samples were dissected with corrosion-resistant stainless steel knives, blades, and accessories. Dissected and separated tissues were then lyophilized for 72 h for complete removal of the moisture content. The dried samples were then grounded and homogenized to the powdered form to be used for further analysis.

2.5 Research Design

1 g of powdered sample was digested in concentrated acid. To the sample, 9 ml of freshly prepared acid mixture of 65 % HNO_3 and 37 % HCl was added. Then, the mixture was boiled gently over a water bath (95°C) for 4 -5 h (or until the sample had completely dissolved) (US-EPA Method (US-EPA, 1995)). HM from the samples were analysed by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP- AES). Triplicates of each sample were processed for metal analysis and the average values were considered.

3. RESULTS AND DISCUSSION

Variations of Cd, Cu, Hg, Ni, Pb, and Zn content in gills, liver and muscle tissues of mudskipper (*Boleophthalmus boddarti*) and mullet (*Mugil cephalus*) are presented in Table 1 & 2.

In mudskipper, the individual metals in mudskipper can be ranked as: Hg > Cu > Ni > Zn > Pb > Cd based on their concentration. The average range of levels of HM in various tissues varies from non-detectable to 17.36 ppm. For individual HM, the detected range is, Cu (0.10-9.943 ppm), Ni (0.028-6.108 ppm), Pb (ND-1.208 ppm), Zn (1.567-3.98 ppm), Hg (ND-17.36 ppm), and Cd (ND-0.095 ppm). For all the tissues, higher values of HM were detected in pre-monsoon than the post-monsoon. Among all the tissues, exceptionally higher values were reported for Hg (14.761-17.36 ppm) during pre-monsoon; whereas during post-monsoon, values of Hg were non-detectable.

Similar with Hg, higher values during pre-monsoon were also noted for Cu and Ni. Interestingly Pb remains non-detectable in all tissues during pre-monsoon whereas Hg is not reported in all tissues during post-monsoon. During pre-monsoon, highest values of Cu and Ni were reported in liver, while gills exhibit the higher values of Hg during pre-monsoon. Among all detected HM, lowest values were noted for Ni (0.028 ppm) and Cd (0.07 ppm). Cu, Ni, and Zn are the only metals which are consistently reported in all tissues of mudskipper, both during pre- and post-monsoon (Table 1).

In mullet, the values of individual metals can be ranked as: Hg > Zn > Cu > Ni > Pb > Cd. Among the different tissues under investigation, average range of levels of HM varies from non-detectable to 52.016 ppm. For individual HM, the detected range is, Cu (0.083-6.653 ppm), Ni (0.042-0.365 ppm), Pb (ND-0.355 ppm), Zn (1.511-11.78 ppm), Hg (ND-52.016 ppm), and Cd (ND-0.011 ppm). In agreement with the values of Hg, in mullet also, still higher values of Hg in the range of 10.05-52.016 were reported during pre-monsoon.

Table 1. Levels of HM in tissues of mudskipper (*Boleophthalmus boddarti*)

Collection season	Fish tissue	Concentration of heavy metals (ppm)					
		Cu	**Ni**	**Pb**	**Zn**	**Hg**	**Cd**
Pre-monsoon	Liver	9.943	6.108	ND	1.89	14.761	0.095
	Gills	0.233	0.028	ND	1.924	17.36	ND
	Muscle	0.123	0.041	ND	1.567	15.244	ND
Post-monsoon	Liver	0.253	0.122	ND	1.796	ND	0.07
	Gills	0.81	0.232	ND	3.98	ND	ND
	Muscle	0.10	0.267	1.208	1.715	ND	ND

ND = Not detectable

Table 2. Levels of HM in tissues of mullet (*Mugil cephalus*)

Collection season	Fish tissue	Concentration of heavy metals (ppm)					
		Cu	**Ni**	**Pb**	**Zn**	**Hg**	**Cd**
Pre-monsoon	Liver	3.678	0.042	ND	10.191	10.05	0.044
	Gills	0.256	0.101	ND	4.085	21.314	0.011
	Muscle	0.221	0.125	ND	2.153	52.016	ND
Post-monsoon	Liver	6.653	0.09	ND	11.78	ND	ND
	Gills	0.083	0.137	0.355	3.013	ND	ND
	Muscle	0.099	0.365	ND	1.511	ND	ND

ND = Not detectable

For mullet, Pb remains non-detectable in all tissues during pre-monsoon and during post-monsoon, it was recorded only in gills. Hg and Cd were not detected during post-monsoon in all tissues under study. Cu, Ni, and Zn were consistently reported for both the seasons in all tissues. Higher values of Hg (52.016 ppm in muscle) were followed by Zn (11.78 ppm in liver) and Cu (6.653 ppm in liver). In mullet values on individuals metals in different tissues is ranked as muscle > gills >liver (Table 2).

Toxic HM such as Hg, Zn, Cu, Cd, Ni, and Pb were found to be the most accumulating metals in fish tissues particularly during pre-monsoon is attributed to the particular habitats, feeding nature, and the availability of metals in that particular habitat (Zhang et al., 2007). Similar results on HM concentration were reported by Samantara et al (2023) in marine edible fishes from Tamil Nadu coast, Bay of Bengal. Highest values of Cu, Ni, and Zn in all tissues of both the fishes are correlated with the effluents from various industries and mining (Ahmad & Al-Mahaqeri, 2015).

According to Simionov et al (2019); significant differences regarding HM concentration were found between various species. Therefore, high levels of HM in *Mugil cephalus* were attributed to habitat and feeding behavior of this species. Comparatively lower levels of HM recorded in *Boleophthalmus boddarti* was could be due to the diet, feeding habits and migration routes. Results of the study are in agreement with the findings of Suyatna et al (2017) in fish samples from coastal waters of Mahakam Delta, Kutai Kartanegara District, East Kalimantan, Indonesia.

Yousif et al (2021) on their studies on bioaccumulation of heavy metals in fish and other aquatic organisms from Karachi Coast, Pakistan, noted that littoral zone of most of the coasts worldwide is facing issues such as increasing pollution and human-induced environmental changes particularly fishing, coastal aquaculture, waste disposal, industrial activity, agriculture, domestic effluents, salt making, unplanned tourism, etc. resulting in contamination of coastal zones by HM. Consistent occurrence of HM such as Cu, Ni, Zn, and Hg is linked with the increasing anthropogenic activities in the vicinity of Panvel creek (Yunus et al., 2015).

Alina et al (2012) noted that; accumulation of HM in fish tissues depends on numerous factors, such as environmental concentration, environmental conditions such as pH, water temperature, salinity, DO and turbidity. The high concentration of Cu, Ni, and Hg in fish tissues might due to high concentration in seawater originating from the large scale factories that operated at Panvel creek. Similar finding on HM accumulation was reported by Mukherjee and Kumar (2011) in commonly consumed coastal fishes from Bay of Bengal, India.

Therefore results of the present investigation reveals that both the fishes mudskipper (*Boleophthalmus boddarti*) and mullet (*Mugil cephalus* had the largest accumulation of heavy metals (Hg, Zn, Cu, and Ni) in their liver, gills, and muscles (Krishna et al., 2013). Significantly higher levels of Hg reported during pre-monsoon in tissues of both the fishes were ranked as: muscle > gills > liver and is attributed to the release of effluent from chemical plants, chloralkali plants, coal slime water, dental amalgam, leakage from contaminated soils, oil refinery processes, and vinyl chloride monomer plants (Hossain et al., 2022; Beheary & El-Matary, 2018).

Results of the present study is in agreement with the findings of Anand and Kumarasamy (2013) in fish samples along the east coastal region of Valinokkam, Ramanathapuram District, Tamilnadu; Celine et al (2017) in three different fish species from Southeast Coast region of Cuddalore; and Barua and Barua (2024) in commercially significant fish species available in coastal Bangladesh.
Similar findings were reported earlier by Rani et al (2024) with respect to bioaccumulation of heavy metals in commercial fishes (*Mugil cephalus* and *Megalops cyprinoides*) from Adyar estuary, India.

4. CONCLUSION

Results of the present evaluation reveals that; both the fishes mudskipper (*Boleophthalmus boddarti*) and mullet (*Mugil cephalus*) has bio-accumulated the highest concentrations of heavy metals in muscles, gills, and liver; particularly during the pre-monsoon. Among all studied metals, Hg had the highest concentrations in all fish species, followed by Cu, Ni, Zn, Pb, and Cd. Since the coastal population along the Panvel creek is dependent on unprocessed marine fish; consumption of contaminated marine food is the major route of human exposure to toxic elements. Present investigation has also filled the knowledge gap by documenting the metal contamination in the commonly consumed fishes in Panvel region. Results of this study should be used as a baseline data for future assessment of metal pollution in marine biota from Panvel creek and also for the better management of coastal ecosystem and safety of human beings. This study recommends the periodic monitoring of coastal water, sediment, and marine biota for extent of bio-accumulation of metals.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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