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BIOACCUMULATION OF HEAVY METAL CONCENTRATION IN BARNACLE *STRIATOBALANUS TENUIS* FROM KASIMEDU FISHING HARBOUR, CHENNAI COAST, SOUTH EAST INDIA

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ABSTRACT
The marine environment has been contaminated due to anthropogenic activities including increasing discharge of industrial and domestic waste leading to elevated concentrations of heavy metals that pose a serious threat to aquatic ecosystems. These metals exhibit toxicity and can bioaccumulate to various trophic levels. In this study, the accumulation of heavy metals in the barnacle *Striatobalanus tenuis* was assessed to evaluate the extent of contamination in the coastal waters of Kasimedu, Chennai. Kasimedu is the major fishing hub significantly impacted by sewage mixing and oil spill by harbour related activities. Barnacles were collected from the boat hulls at Royapuram Fishing Harbour and soft tissues were analyzed for heavy metal concentrations using Atomic Absorption Spectrophotometry and direct mercury analyzer. The results revealed high concentration of mercury (Hg) 19.28 ± 17.02 µg/g, indicating pollution in the area. Among the other metals, zinc (Zn) showed the highest accumulation of 0.68 ± 0.03 µg/g, followed by Cu, Ca, Cr, Ni and Pb in decreasing order. The presence of these metals especially mercury and zinc strongly suggest the effects of industrial effluents and sewage discharge. The study highlights the bio accumulative capacity of barnacle *Striatobalanus tenuis* supporting its capacity as a sentinel species for monitoring heavy metal pollution in coastal ecosystems.

***Keywords:** *Barnacle, Heavy metal, Pollution, Bio monitor, Marine ecosystem, Crustaceans*

INTRODUCTION

The natural environment has been contaminated through the release of waste from industries like mining as they dispose of high levels of metal waste in the environment. Heavy metal plays a major role in the pollutants as they are not easily degradable. They originate from natural processes or with the influence of humans (Tan *et al*., 2021). The metals are dangerous to the humans when it comes in direct contact with skin (Liu *et al.,* 2020). As past few decades, the impact of the heavy metal pollution in the marine ecosystem has appeared to be impact worldwide (Romano *et al*., 2021). The Chennai city's marine water bodies are contaminated through many natural and anthropogenic ways, heavy metals like arsenic, selenium, lead, chromium, copper, cadmium, zinc, manganese and mercury combine with seawater by waste water discharge from power plant, petroleum industry, solid waste landfills and storm drain outfall, automobile emissions (Madhusudana *et al.,* 2020). Heavy metals remain ongoing pollutants in water-based environments.

The occurrence of trace metals in marine environments has an ability to accumulate in the organisms from the various tropic levels of marine food webs thereby it causes an impact in the biogeochemical cycle. When the accumulated substance is toxic, it becomes an environmental problem. Toxicity may occur in the marine species through the food chain when the bioaccumulated species is consumed by another species

(Heng *et al*., 2004). Heavy metals have huge attraction for the sulphur and sulphur bond proteins, it also stops the activity of the enzymes in the marine environment (Al-Mohanna *et al.,* 2001). According to ecological science, heavy metals are defined as the metals and metalloids where they contaminate, toxic, and harmful to the living organisms (Ali and Khan, 2018). Due to the toxicity of the heavy metals, it is divided into two forms (de Almeida *et al*., 2022). First it includes the essential biology metals such as copper (Cu), chromium (Cr), nickel (Ni), and zinc (Zn) (Jan *et al*., 2015). The above metals are required in minimal amount for the metabolic functions, but it is toxic when it is in high concentration (Silva Pinheiro *et al*., 2020). Secondly there are non-essential heavy metals such as aluminium (Al), arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg), and silver (Ag), which are toxic to the environment at very low concentration (de Almeida *et al*., 2022).

Biological organisms are unable to degrade the metals as it is present in the body and also in the environment (Amaral and Rodrigues, 2005). It is to be noted that high concentration of heavy metals affect the different taxonomic groups of marine groups like corals (Biscéré *et al*., 2015), fish (Cui *et al*., 2020), macroalgae (Wen and Zou, 2021), microalgae (Zhang *et al*., 2020), molluscs (Cao *et al*., 2018), and polychaetes (Nielson *et al*., 2019), are primarily impacted in terms of their growth and development, photosynthesis, gametogenesis, and antioxidant systems (Pinsino *et al*., 2010; Matranga *et al*., 2011). Marine molluscs such as oyster mussels are considered as bio monitors for heavy metals, because they have capacity to accumulate metals (Jung and Zauke, 2008). The sedentary and filter feeders are in wide range of distribution in the marine ecosystem, their presence in the coastal area indicates the contaminants in water and they also have the ability to accumulate them. To assess the abundance and availability of metals in the marine environment, researchers study the bioaccumulation of metals in the tissues of marine organisms, which led to the development of the bio-indicator concept (Kucuksezgin *et al*., 2006).

As marine crustaceans, barnacles (Thecostraca) stand out for being highly diverse, regularly observed, and ecologically essential across the globe. However, they deviate from almost all other Crustacea in that only the larval stages (naupliar and cypridoid) are free-living, whereas the adults are permanently sessile as either suspension feeders or parasites (Benny *et al*., 2021). They are microphagous feeders as they absorb metal rich particles and can easily pass through volumes of water by the cirri which enhance the uptake of high metal, therefore it is considered as bioindicators (Rainbow, 1995). Due to their ability to thrive in diverse coastal environments with different degrees of pollution, barnacles are considered effective biofilters and are widely used as reliable biotracers (Barbaro *et al*., 1978). In the present study barnacle *Striatobalanus tenuis* was used as sentinel organism to access the heavy metal concentrations in the tissues which helps them to serve as bio accumulating candidate species for monitoring the quality of coastal waters.

MATERIALS AND METHODS

Study Area

The Royapuram fishing harbour, also known as Chennai fishing harbour or Kasimedu fishing harbour is located at 13°06'14.51"N latitude and 80° 17' 37.18" E longitude in the Royapuram are of Chennai, Tamil Nadu. This harbour is situated along the Bay of Bengal acts as a key site for marine fisheries, particularly for fish and crustacean landings. Kasimedu, a coastal settlement in northern Chennai near the port, serves as a prominent hub for fishing activities and houses one of the largest fish markets in the region. It is located approximately 8 km north of Chennai Central, at 13.126475° N and 80.297466° E. The site experiences considerable environmental contamination due to its proximity to the Chennai Port and the influx of pollutants via numerous city drainage outlets and occasional oil discharges (Madhusudana *et al*., 2020). For the purpose of heavy metal analysis, barnacles adhering to boat hulls were manually scraped and their soft tissues collected

them to serve as bio accumulating candidate species for monitoring the quality of coastal waters.

MATERIALS AND METHODS

Study Area

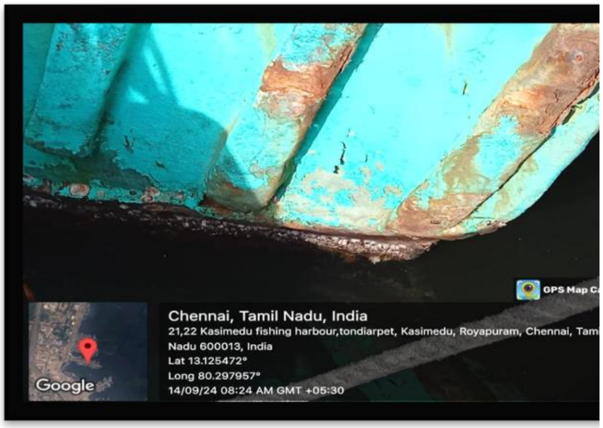

Figure 1. Barnacle (*Striatobalanus tenuis*) attached

Figure 2. Map showing study area on boat hull

Barnacle Identification

The conventional method of identifying species is through morphological traits, particularly shell structure which plays a key role in its classification. The class Thecostraca comprises of 65 families, 367 genera and 2116 species distributed among three subclasses: Facetotecta (12 species), Ascothoracida (114 species) and Cirripedia (1990 species). The Cirripedia subclass includes Thoracica, Acrothoracica, and Rhizocephala, with Thoracica noted for their specialization in suspension feeding. These barnacles possess an external covering composed of mineralized plates, which are integral parts of the cuticle. Unlike typical arthropods, these plates are not shed during moulting but are retained and continue to grow in both surface area and thickness. Between these plates, the cuticle undergoes regular moulting in narrow regions, producing parallel growth marks known as 'cuticular slips' (Anderson, 1994; Blomsterberg *et al*., 2004). Barnacles belonging to this genus often exhibit distinct striations on their shells, which serve as a key identifying feature.

Heavy metal analysis

Barnacle samples collected from Kasimedu were placed in polyethene bags and stored in an ice box. For heavy metal analysis, the soft tissues of barnacles were dissected from the hard shells, the soft tissues were dried in the hot air oven at 60°C for 24 hours until it got completely dried. The dried tissues were then ground into a fine powder using a mortar and pestle. Replicate sets of powdered tissue samples were prepared to ensure data reliability and statistical accuracy. To ensure reliable and representative data, sampling was performed according to established protocols. Before analysis, each sample was individually measured for opercular aperture dimensions and weighed for total fresh weight. Sample dissolution and measurement constitute vital steps in the analysis. The process of dissolving samples in chemical analysis is called destruction, which changes the shape of a solid sample into a solution ready to be measured on measurements using AAS, spectrophotometry.

AAS provides a cost-effective and offers an uncomplicated approach. AAS (Atomic absorption spectroscopy) emerges as a frontline technique in this endeavour, offering a precise and sensitive means of heavy metal detection. This method involves the atomization of a sample solution in a flame, followed by absorption of light by the analyte atoms at specific wavelengths. The amount of light absorbed is proportional to the concentration of the analyte, which allows for quantitative analysis. The tissue samples were digested with 10 ml concentrated nitric acid in a hot plate, then it was diluted up to 40 ml with double distilled water and filtered with Whatman filtered paper No. 1. The concentrations of Cd, Cu, Fe, Ni, Pb, Cr and Zn were determined by an air-acetylene flame Atomic Absorption Spectrophotometer (AAS). The data were presented in µg/g dry weight. For Hg, it was analysed using the direct mercury analyser. For this procedure, 1 mg of dried sample was weighed in the cleaned cuvette, then the sample was made to run and values were noted down.

RESULTS AND DISCUSSION

The bioaccumulation of pollutants can occur through direct absorption from seawater, ingestion of suspended particles, from sediments and trophic transfer through food chains. Barnacles, being microphagous feeders, may ingest metal-laden substances (Masala *et al*., 2004). In the aquatic environment, contaminants enter into organism tissues by direct and indirect absorption (Kosnett, 2009), water pores, and water columns, consumption and/or epidermal contact (Ruttkay Nedecky *et al*., 2013). Metal absorption by aquatic organisms through three main pathways, those are the respiratory tract (gills), body surface, and digestive tract, but the ability of fish and invertebrates to accumulate metals depends on physical and chemical characteristics of metals (EPA, 2017). Barnacles act as bioindicators by accumulating pollutants from the surrounding water due to their sessile lifestyle., making them useful for monitoring contaminants like microplastics, heavy metals and other chemicals in coastal environments, particularly when studying changes in water quality and pollution levels, their physical characteristics can also indicate variations in water flow conditions, with different cirri (feeding appendages) developing depending on the current strength.

The present study shows the higher concentration of Hg accumulation in the soft tissues of barnacles due to contamination of water in the Kasimedu area by the mixing of untreated sewage water including domestic waste. The results are in accordance with Shirneshan *et al.* (2012), where the soft tissues of oysters served to be a good indicator of Hg in the aquatic system. When the concentration of mercury in the water and sediment increases, the concentration of mercury is found to have increased in marine organisms by the process of biomagnification (Irawati, 2019). Each organism has a threshold of adaptive ability to accumulate mercury in its body (Li *et al*., 2012). The metal concentrations of Zn were also reported high in barnacles and the results were similar with other studies (Masala *et al*., 2004).

In the current study, among the metals analysed Zn>Cu>Cd>Cr>Ni was found to be higher than the acceptable standard levels. Other metal such as Pb was found in trace amounts and in acceptable limits. Benthic creatures, the biota, the purity of the water, and numerous invertebrates that use sediment as a food source are all adversely affected by heavy metal pollution in sediments. Given that heavy metals bioaccumulate in invertebrates and can reach different trophic levels barnacles serve as essential bio-indicators for monitoring metal pollution and assessing the ecological integrity of coastal waters (Calmuc *et al*., 2021).

The concentration of the heavy metals from the barnacle were analyzed from the atomic absorption spectrophotometer and are tabulated below.

Table 1: Concentration of Heavy Metals

S. No	Heavy Metals	Concentration of Heavy Metals (µg/gm)
1.	Cu	0.41 ± 0.02
2.	Ni	0.13 ± 0.01
3.	Pb	0.02 ± 0.001
4.	Cr	0.14 ± 0.01
5.	Cd	0.17 ± 0.02
6.	Zn	0.68 ± 0.03
7.	Hg	19.28 ± 17.02

(Values are mean ± S.D)

CONCLUSION

The present study was analysed in the barnacle *Striatobalanus tenuis* to evaluate the accumulation heavy metals from the Kasimedu harbour. This shows the high concentration of Hg from the soft tissue of barnacle in the order Zn>Cu>Cd>Cr>Ni, whereas Pb showed low concentrations. Maintaining suitable water quality is becoming a vital need for both aquatic and terrestrial life. Effective evaluation and monitoring of marine environmental status rely on pertinent bio-indicators that deliver essential information. The accumulation of pollutant elements in their body tissues is found to be a valid reflection of pollution levels in specific environments. should conduct the long-term pollution monitoring study in the respective area in order to implement the optimal mitigation measures. The assessment of heavy metal pollution in Kasimedu highlights the need for effective management strategies to control and prevent further contamination and to protect the health of the ecosystem and the people who depend on it.

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