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Pollution Profile of the Panvel Creek, Raigad, Maharashtra, India: Analysis of the Heavy Metal Contamination

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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 concentration of heavy metal levels (Cd, Cu, Hg, Ni, Pb, and Zn) were assessed in water samples from Panvel creek, District Raigad, Maharashtra, West Coast of India. The heavy metals were analysed by using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). Results of the study reveal that, Cu, Ni, Zn, and Hg were detected in water samples of Panvel creek whereas Pb and Cd were not reported. Levels of Cu range from not detectable to 0.037 ppm whereas concentration of Ni varies from not detectable to 0.048. Zn is the only metal which is consistently detected at both the sites during all seasons whereas its values were moderately high (0.108 ppm) during the monsoon at both sites. Highest values were recorded for Hg, especially during the pre-monsoon. Highest levels of Ni and Zn were detected at both sites during monsoon season whereas Cu, Pb, Hg and Cd were not detected during monsoon at all sites. Further, Cu and Zn were detected during post-monsoon, while other metals such as Ni, Pb, Hg and Cd remain not

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detectable. Zn was only heavy metal detected at both sites during all sampling seasons while Pb and Cd were absent from the water samples during all the seasons at all sites. Average concentration of heavy metals reported in Panvel creek was found to be in the order of Hg>Zn>Ni>Cu>Pb>Cd. Therefore, the coastal water from the Panvel creek is polluted by heavy metals. Absence of heavy metals like Pb and Cd is attributed to the waste discharged in the creek are free from these metals and is also beneficial to the coastal biota of the creek. Consistent occurrence of Cu, Ni, Zn, and Hg in Panvel creek should not be ignored considering their impact on the ecosystem and marine biota.

Keywords: Anthropogenic threats; heavy metals; marine water; Panvel creek; pollution.

1. INTRODUCTION

Bandara and Manage [1] reported that; heavy metals (HM) are a group of metals and metalloids with a higher density, and are persistent organic pollutants. Examples of HM are Aluminium (Al), Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Nickel (Ni), Tin (Sn), and Zinc (Zn) [2]. Major sources of HM contamination in the environment include effluents from geological, pharmaceutical, industrial, agricultural, atmospheric, domestic, smelters, foundries, mining, and other metal-based industrial operations. HM exhibit widespread distribution, high hydrophobicity, prolonged persistence, and cause negative effects on the environment and human health at low concentrations [3].

According to Venkateswarlu and Venkatrayulu [4]; non-essential metals are regarded as markers of anthropogenic influence in the marine environment. Because of their toxicity and capacity to bioaccumulation in marine environment, they can cause hazardous effects on the fragile coastal region. Twenty potentially hazardous trace elements were detected in coastal water samples of Mahakam Delta, Kutai Kartanegara District, East Kalimantan, Indonesia. Metals, such as Cd, Hg, and Pb are toxic to living organisms even at low concentrations [5].

Rao et al [6] noted that; activities such as aquaculture, habitat destruction & fragmentation, oil and gas, pollution, shipping, and tourism and development are the main causes of coastal destruction and also are the main sources of metal pollution of the creeks and estuaries [7]. Marine ecosystem is contaminated with the HM produced from atmospheric deposition, geologic weathering, or industrial waste effluents. Some metals (Cu, Co, Zn, Fe, and Mn) play a crucial role in enzymatic and biological activity, but their elevated levels exert negative impact on marine fauna and human [8].

Sabarina et al [9] recorded that; creeks and estuaries receive significant anthropogenic inputs from point and non-point sources, metropolitan areas, tourism activities and industries. HM pollution in coastal area has been recognized as a serious environmental concern. Due to urbanization and industrialization, the coastal zones have become the natural sink for the release of HM rich effluents. In aquatic environment, HM deposit into the sediments, enter the marine trophic levels and pose a serious threat to coastal ecosystem with marine flora and fauna [10].

Fu and Xi [11] noted that; agriculture, cement plants, coal and energy bases, ship breaking/recycling, tanneries, textiles, etc. are the primary sources of contamination of the environment with HM. At very low levels of exposure, HM are hazardous to the physical and chemical functions of animals and can damage their several organs such as brain, liver, and reproductive organs [12]. HM contamination of the coastal environment is of great concern and cause adverse effects on marine health. Therefore, monitoring and assessment of HM from the coastal environmental protection is essential for management and planning of coastal ecosystem [13].

According to Bandara and Manage [1]; HM contamination of the environment occurs either by natural sources (volcanic eruptions and weathering) or by industrial sources (coal combustion in power plants, high-tension lines, metal refineries, microelectronics, nuclear power stations, paper processing industries, petroleum combustion, plastics, textiles, and wood preservation). Anthropogenic metal contamination in coastal and marine environments has toxic effects on aquatic living organisms; destroy natural ecosystems, and significant health risks to humans through consumption of contaminated seafood [14].

Mahalakshmi et al [15] revealed that; due to rapid industrialization and economic development in coastal region, heavy metals are continuing to be introduced to coastal environment around the world. Auto emissions, dredging activities, garbage dumps, industrial discharges, oil spills, and sewage effluents are some of the major sources of metal pollution of marine ecosystem [16]. Discharge of hot effluents in the coastal water by thermal plant and industries deteriorates quality of coastal water and also affects the planktons and benthos [17].

Mohamed et al [18] reported that; due to long-lasting presence, toxicity, tendency to build up, and ability to strengthen biological effects, HM are harmful even at low concentration. Tidal currents and other movements of coastal water change the levels of HM and they are spread easily [19]. Heavy metal pollution is a great concern for the environment and human health, especially in developing countries. Due to anthropogenic activities, deep buried HM in the earth's crust have now been exposed in the air, agricultural soil and drinking water [20].

Jobaer et al [21] documented that, coastal water contaminated with heavy metals can cause changes in the physical, chemical, and biological properties of the water, and can also affect the behaviors and survival of marine organisms. Contamination of the marine environment by HM has been a major concern since they constitute a potential risk to a number of flora and fauna species, including humans, through food chains [22]. Assessment of the concentration levels of heavy metals in water is addressed to provide crucial information for environmental risk evaluations [23].

At present, Panvel creek is used as a natural sink to release the domestic waste, industrial effluent, urban run-off, and wastes of seafood industries. As a result, many toxic HM should be introduced into the creek which may affect the health coastal ecosystem and deteriorate the water quality. Further barring few reports [14, 16], no bibliographic data is available on comprehensive studies on the concentration of HM in coastal water of Mumbai and Navi Mumbai. Hence the present study is undertaken.

The aim of this study was to determine the heavy metals concentrations (Cd, Cu, Hg, Ni, Pb, and Zn) in water from Panvel creek of the Panvel creek in pre-monsoon, monsoon and post-monsoon season. The results obtained from this study would provide information for background levels of metals in the water of Panvel creek, contributing to the effective monitoring of environmental quality.

2. MATERIALS AND METHODS

2.1 Study Area

Geographically, Raigad District (previously known as Colaba District) (Lat. 18° 30' 56.88'' N & Long. 73° 10' 55.92'' E) with the population of 2,634,200, is one of the districts in Konkan division of Maharashtra. The district is bounded by Mumbai Harbour to the northwest, Thane district to the north, Pune district to the east, Ratnagiri district to the south and the Arabian Sea to the west. Raigad District occupies an area of approximately 7,152 km², and has average annual precipitation as 3,884 mm. The mean temperature range is from 17.7-31.8°C. Raigad district is subdivided into 13 talukas, such as Alibag, Raigarh, Karjat, Khalapur, Mahad, Mangaon, Mhasla, Murud, Panvel, Pen, Roha, Shrivardhan, Sudhagad and Uran.

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.

Panvel is located in Raigad district of Maharashtra in Konkan region and is a node of Navi Mumbai city. Geographically, Panvel is near Panvel creek which opens up in 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

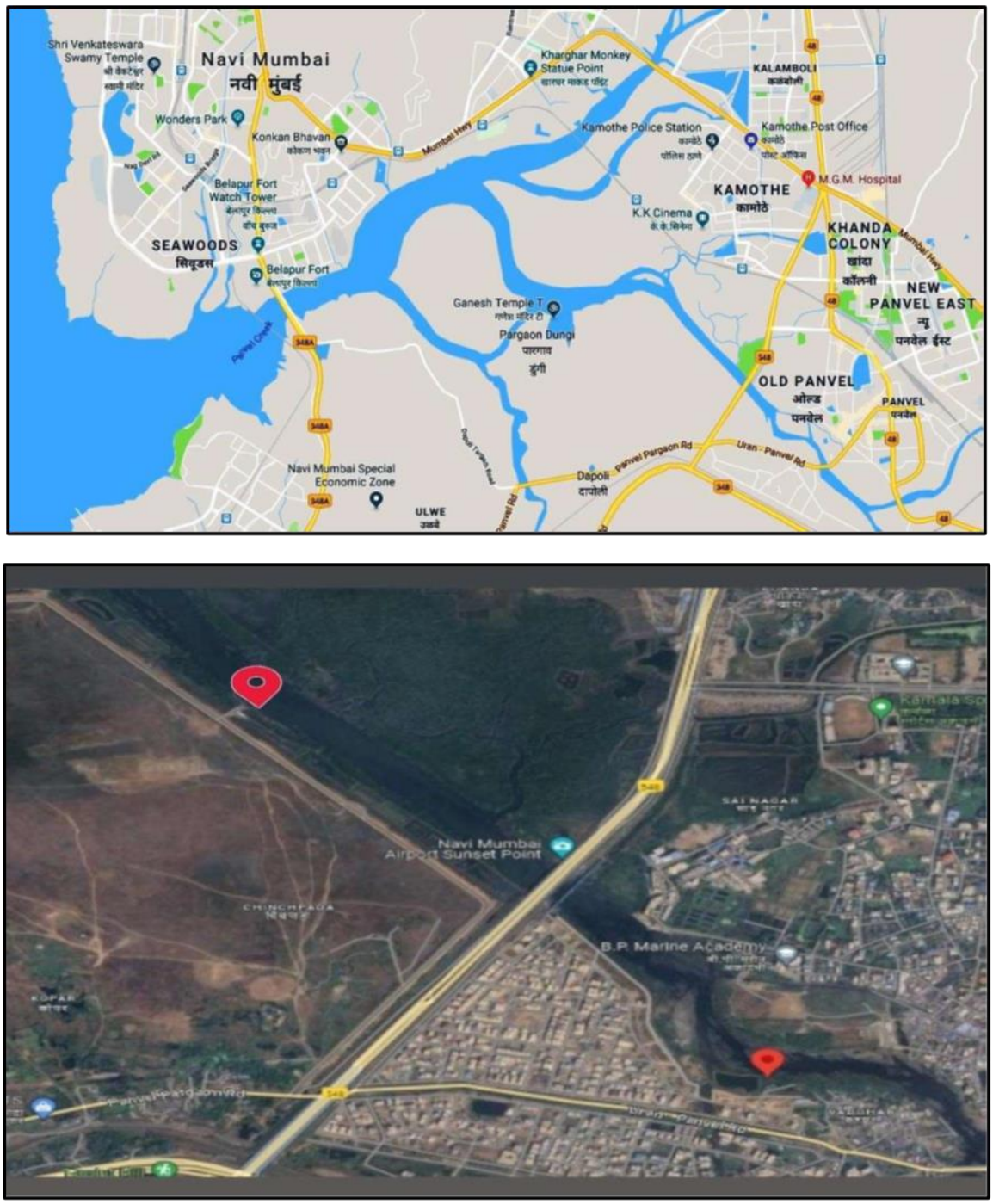


Fig. 1. Location map & satellite image of study area (Source: Google Map)

ebb period lasts for about 5 h. The average annual precipitation is about 3884 mm of which about 80% is received during July to September. The temperature range is 12-36ºC, whereas 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 (Old Panvel) (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 for on-going construction of Navi Mumbai International Airport, industries, airport related infrastructural facilities and different anthropogenic activities along the entire coastal area.

- **Karanjade (Old Panvel):** Located near the public transport road bridge joining the Karanjade with Old Panvel. It is located in the vicinity of human settlement and was experiencing a tremendous pressure of growing population, urbanization, small-scale industries, public transport, disposal of municipal waste, aquaculture ponds, and settlement of small fishing crafts with derailing nets. Panvel creek at this site is characterized with rocky substratum with less coastal vegetation.

- **Chinchpada:** Located about 5 Km away from the site I and is comparatively less polluted site characterized by 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 fishermen 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 Digestion Process

Present study was conducted during the year 2022 and HM from surface water assessed during pre-monsoon, monsoon, and post-monsoon. Standard method prescribed by Binning and Baird [24] was followed for assessment of HM from surface water samples.

Surface water samples from the selected sites along Panvel creek were collected in an acid washed polyethylene bottles and immediately preserved by addition of few drops of concentrated nitric acid. 25 ml of acid preserved water samples were taken in a 100 ml beaker, 5 ml of concentrated nitric acid (HNO_3) was added in it and the sample was evaporated in the hot plate for 15 to 20 minutes. After evaporation, again 5 ml of concentrated nitric acid and 10 ml of concentrated sulphuric acid were added, and the sample was evaporated until a dense white flame appears. After cooling, the sample was diluted up to 50 ml with de-ionized water. A blank was also digested using the de-ionized water as a reference material. The concentration of HM (Cd, Cu, Hg, Ni, Pb, and Zn) was studied by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). Statistical analysis has been done by one way ANOVA. The data set was tested for homogeneity of variance and for normal distributes. For all statistical tests, probability of $p<0.05$ was considered significant.

3. RESULTS AND DISCUSSION

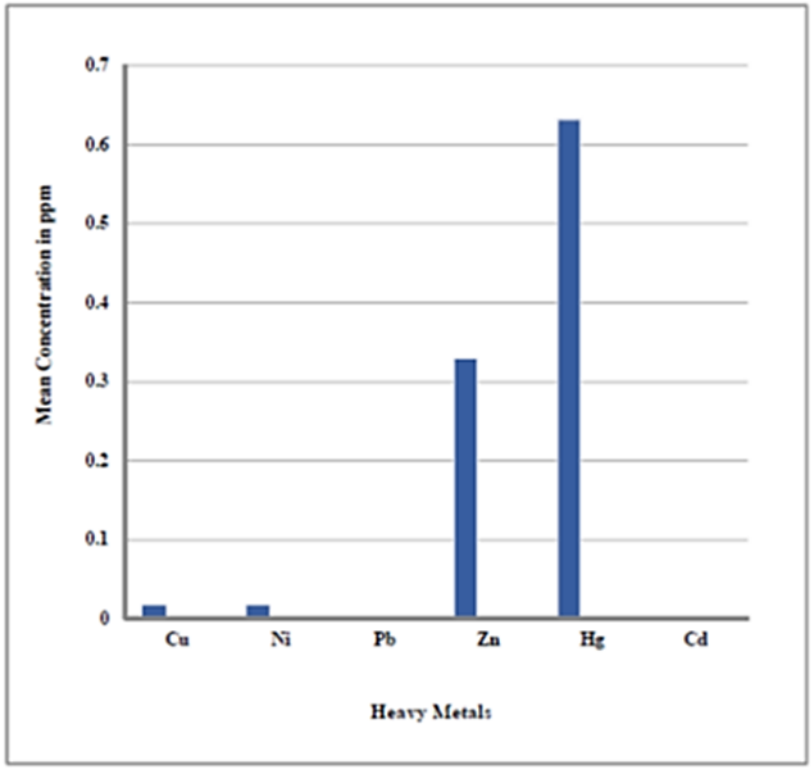
Results on assessment of levels of HM concentration in water samples from Panvel creek were presented in Table 1 and Fig. 2. It is observed that, Cu, Ni, Zn, and Hg were detected in water samples of Panvel creek whereas metals such as Pb and Cd were not reported. Zn was found to be the only HM among six HM present in water samples of both the sites during all the seasons: pre-monsoon, monsoon and post-monsoon. Among all the HM studied, highest concentration was noted for Hg (0.632 ppm) whereas concentration of Pb and Cd was found to be very negligible. Average concentration of HM reported in Panvel creek was found to be in the order of Hg>Zn>Ni>Cu>Pb>Cd.

It is observed that, concentration of Cu ranges from not detectable to 0.037 ppm in water samples from both sites. Higher concentration of Cu was recorded in pre-monsoon (0.037 ppm at Site I and 0.036 ppm at Site II), whereas in monsoon it was not detectable at both the sites. Concentration of Ni varies from not detectable to 0.048 and highest values were recorded at Site I during monsoon. Slightly higher Ni was recorded during monsoon at both the sites whereas it is not detectable during post-monsoon at both sites. At both the sites, recorded values for the Pb are not detectable.

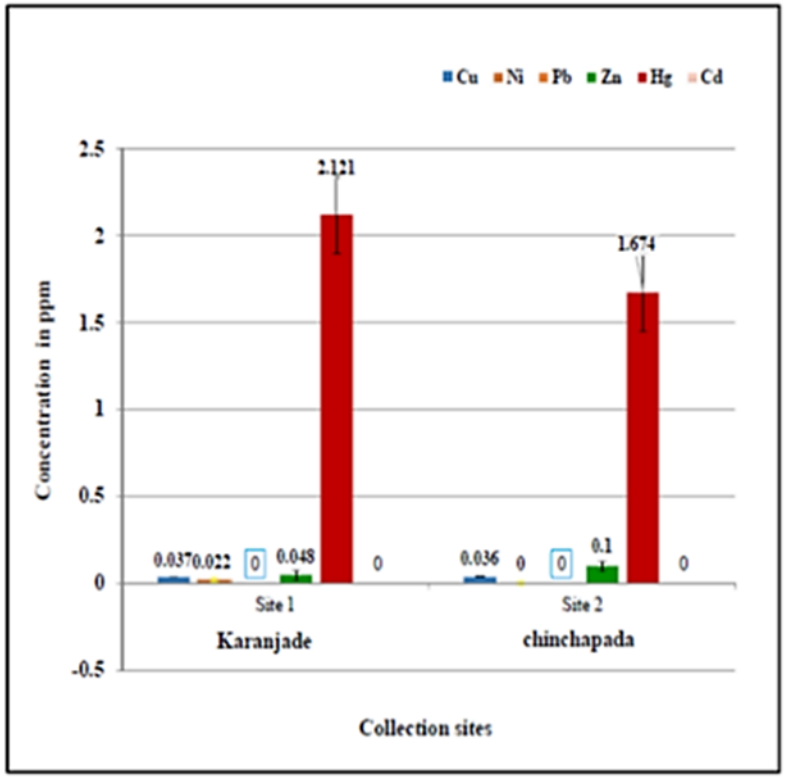
Table 1. Concentration of HM (ppm) detected in surface water from Panvel creek

Collection season	Sampling site	Concentration of heavy metals in ppm					
		Cu	Ni	Pb	Zn	Hg	Cd
Pre-monsoon	Site I: Karanjade	0.037	0.022	ND	0.048	2.121	ND
	Site II: Chinchpada	0.036	ND	ND	0.1	1.674	ND
Monsoon	Site I: Karanjade	ND	0.048	ND	0.108	ND	ND
	Site II: Chinchpada	ND	0.034	ND	0.108	ND	ND
Post-monsoon	Site I: Karanjade	0.017	ND	ND	0.017	ND	ND
	Site II: Chinchpada	0.016	ND	ND	0.042	ND	ND

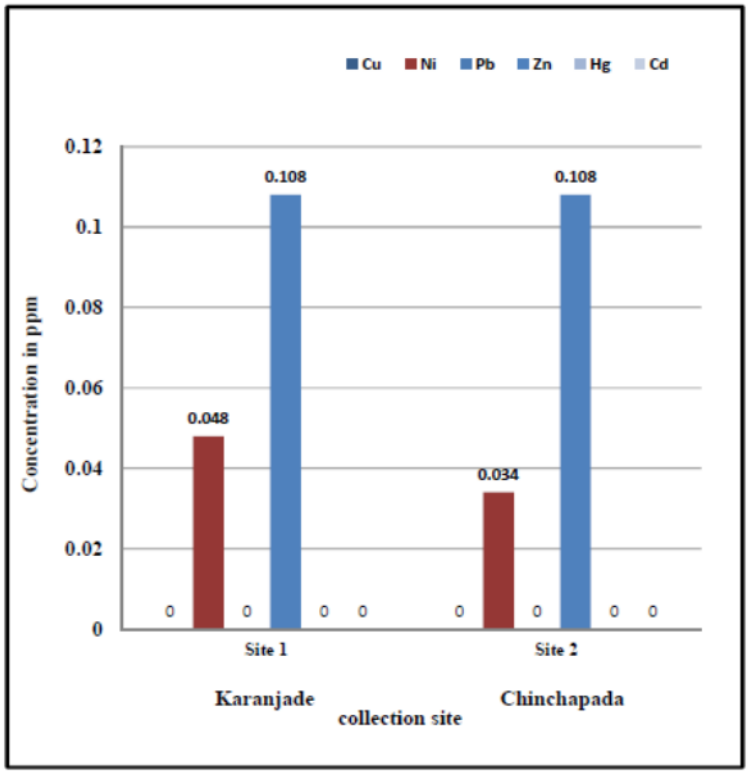
ND = Not detectable



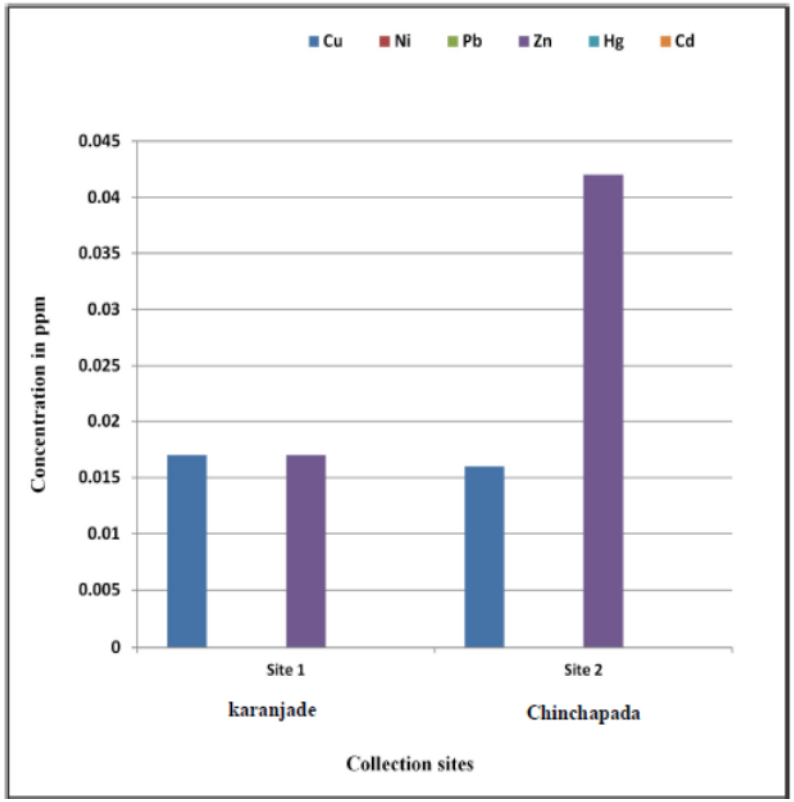
Mean concentration of HM in water



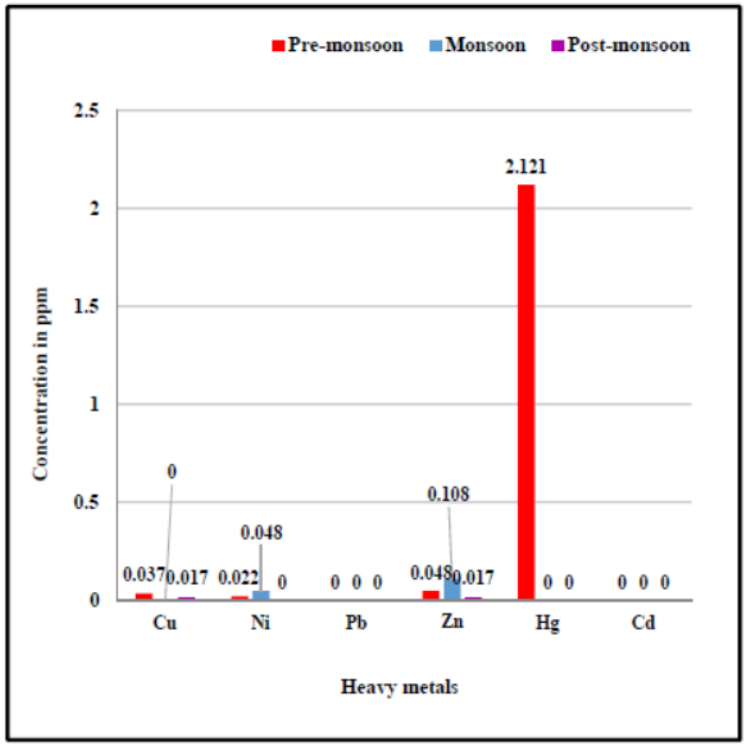
HM concentration at Site I & II during pre-monsoon



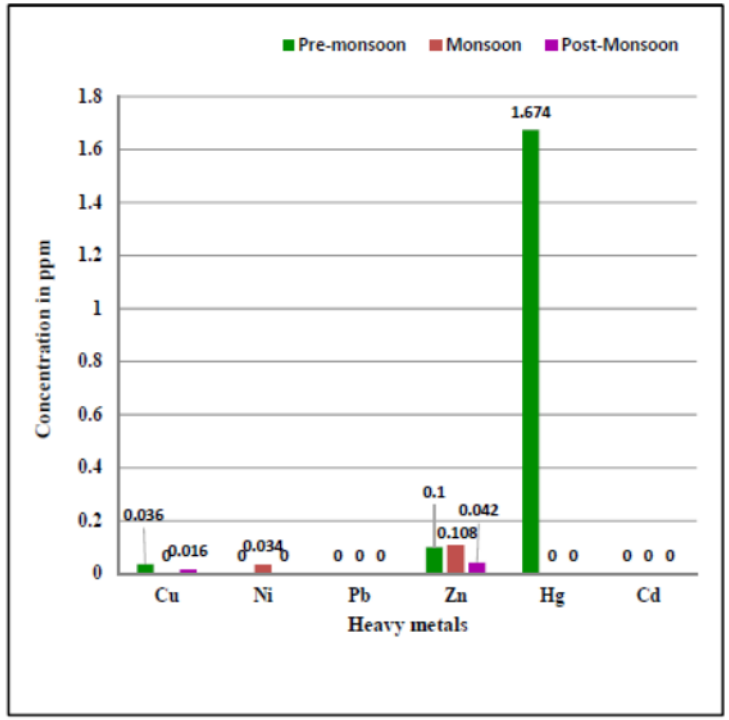
HM concentration at Site I & II during monsoon



HM concentration at Site I & II during post- monsoon



Seasonal HM concentration at Site I (Karanjade)



Seasonal HM concentration at Site II (Chinchpada)

Fig. 2. Mean and seasonal concentration of HM in water from Panvel creek

Zn is the only metal which is consistently detected at both the sites during all seasons whereas its values were moderately high (0.108 ppm) during the monsoon at both sites. In post-monsoon the recorded values were slightly lower in the range of 0.017 - 0.042 ppm. During pre-monsoon, still lower values of Zn were detected. Among all the detected HM, highest values were recorded for Hg, especially during the pre-monsoon (2.121 ppm at Site I and 1.674 ppm at Site II). During remaining period of investigation, Hg values remain in the range of not detectable. Cd was not detected at both the sites for all seasons.

It is noticed that, highest levels of Ni and Zn were detected at both sites during monsoon season whereas Cu, Pb, Hg and Cd were not detected during monsoon at all sites. Further, Cu and Zn were detected during post-monsoon, while other metals such as Ni, Pb, Hg and Cd remain not detectable (Fig. 2). Zn was only heavy metal detected at both sites during all sampling seasons while Pb and Cd were absent from the water samples during all the seasons at all sites. Higher levels of Hg were noted during pre-monsoon while it remains not detected during monsoon and post-monsoon seasons.

At Site II, Zn is the only metal detected during all seasons while Pb and Cd were absent from the water samples during all the seasons. Hg was present in higher concentration during pre-monsoon season but was not detected during monsoon and post-monsoon seasons at site II. Ni was detected only during monsoon season at site II.

The highest concentration of Zn reported at both sites in all seasons could be attributed to the release of effluents from the industries manufacturing detergents, fertilizers, painting and dye, rubber, and wood preservative industries [1]. Effluents releasing from industrial belt from Taloja and Patalganga may play major role in releasing Zn containing waste into the creek. Further, release of effluents throughout the year into the creek may be correlated with these findings.

Moderately higher levels of Cu reported in the creek water are may be due to the discharge of industrial wastes from industries engaged in production of electroplating, metal refining and plastic. Not detection of Cu in monsoon is attributed to dilution of the waste due to monsoonal runoff and freshwater influx [9]. Detection of Ni in creek water could be due to discharge of industrial wastes from the factories manufacturing the batteries processing units, galvanization, metal refining, fertilizers, and painting industries [15].

Hermalin and Glory [10] reported that; HM can be introduced into the coastal environment via natural and anthropogenic processes, consequently causing potential danger to the coastal ecosystems. Levels of HM in water depend on physic-chemical parameters of water such as pH, electrical conductance, and salinity. Among all the detected metals, highest levels of Hg detected could be attributed to the effluents released from industries producing chloralkali plants, vinyl chloride monomer plants, coal slime water, oil refinery processes, dental amalgam, chemical plants, and leakage from contaminated soils [21].

Findings of the study are in agreement with the findings of HM in coastal waters by Mehta and Amin [14] coastal water Vasai region, Mumbai; Sabarina et al [9] in seawater Pulau Indah, Selangor, Malaysia; and Rao et al [6] in coastal sea water, east coast of Andhra Pradesh, India. Results of the study suggest that the coastal water from the Panvel creek is polluted by HM. The creek water frequently receives HM contaminants from different industrial sources. Consistent occurrence of Cu, Ni, Zn, and Hg in Panvel creek should not be ignored considering their impact on the ecosystem and marine biota.

4. CONCLUSION

The findings of this study revealed that occurrence of Cu, Ni, Zn, and Hg in creek water indicates that the creek receives industrial wastes containing heavy metals throughout the year. Therefore, if concentration of these heavy metals continues to increase, the toxicity will also increase, thus affecting the entire food chain within the marine ecosystem. It is recommended that, for the protection of coastal ecosystem of Panvel creek, illegal discharges into the tributaries of Panvel creek should be properly monitored. Wastes and effluents from various sources should be properly treated before they are released into the coastal environment near the Panvel creek. This is the first and only original work from the study area, hence results of the study could be taken as baseline data for further assessment of the creek water quality parameters and for its better management.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChaGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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