Bioaccumulation of heavy metals in *Metapenaeus monoceros* (Fabricius-1798) from Krishnankotta (Kodungallur), Moolampilly (North & South), Vallarpadam of Central Kerala.

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Abstract:
Anthropogenic activities led to the contamination of estuaries of Central Kerala to a great extent. Heavy metals disposed to estuaries through industrial discharge, yard runoff, agricultural activities and storm drains shows a bioaccumulation in the tissues of aquatic animals. In the present study *Metapenaeus monoceros*, the speckled shrimp and associated water and sediments were collected from four different sites of Central Kerala Division, to gauge the accumulation of heavy metals. Atomic Absorption Spectrophotometer was performed for the analysis of heavy metals like Pb, Fe, Cd, Cr, Mg and Zn in muscle tissue of *Metapenaeus monoceros*. The results revealed that the level of heavy metals accumulation in the muscle tissue of *Metapenaeus* follows in descending order of Mg > Zn > Fe > Pb > Cr > Cd during the period from March 2021 to June 2022. The mean cluster of heavy metals in water at all trail places follows in descending order of Mg > Zn > Fe > Pb > Cr > Cd. Elemental analysis of sediment samples revealed that mean value of Mg and Fe were found to be higher. While mean values of Cd and Cr are within the permissible limit. Study indicates the ability of crustaceans to accumulate heavy metals to detectable levels. Knowledge of heavy metals concentration in biota, water samples and sediments are important both with respect to nature management and human consumption of shrimp.

Keywords : *Metapenaeus monoceros*; Heavy metals; Bio accumulation; Krishnankotta; Moolampilly; Vallarpadam.

1. INTRODUCTION

Shrimp is one of the most commonly consumed decapod. It is the most sought-after sea-food rich in protein, low in saturated fat and with a good nutrient profile. The lower atherogenic (0.36) and thrombogenic (0,29) indices of shrimp shows its cardioprotective nature (De Oliveira e Silva, et al., 1996). But the pollution of aquatic environment with heavy metals pose a serious threat to nutritional food security and also to the blue economy of the country. Metapenaeus monoceros has both ecological and economic importance in the marine environment due to its sensitivity to pollution, affordable price and wide popularity as a seafood delicacy (Shahina Banu, et al., 2016). Metals are continually released into aquatic ecosystem from natural to anthropogenic sources. Non-degradable heavy metals even in trace amount can cause serious threats due to its toxicity in aquatic ecosystems through assimilation, deposition, bioaccumulation, long persistence and biomagnification in the food chain which can create human health hazards (Swaroop S Sonone, et al., 2021). Besides their carcinogenic effects, heavy metals cause liver disorders, cardiovascular anomalies, kidney failure and death in the case of extreme situation (Mehmet Fatih CAN, et al., 2021). Being a top trencherman in aquatic food chain, Metapenaeus sp is normally more susceptible to the accumulation of heavy metals from different sources including water, sediments and food. Hazardous metals like Cd, Pb, Cr, Hg, Zn, Cu, Ni, As, etc. even in trace amount is highly toxic to animals (Paul B Tchounwou, et al., 2012). The main purpose of this study is to systematically investigate the concentration of heavy metals in surface water, sediments and tissue of Metapenaeus monoceros.

2. MATERIALS AND METHODS

2.1 Sampling sites

Four different areas of central Kerala division were selected as the sampling sites. Station I was, the brackish water shrimp farm of Agency for Development of Aquaculture (ADAK), Krishnan Kotta, Poyya at Pallippuram village of Kodungalloor Taluk, Thrissur District (10.2152° N, 76.2508° E). This scientifically managed semi-intensive shrimp culture system is a

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tide fed area which is not an industrial belt and anthropogenic interferences are remarkably less in this area. Station II was Moolampilly North at Kochi of Ernakulam district (10.0451° N, 76.2636° E). Distance between station I and station II is 28.5 km. Station III was Moolampilly south at Kochi of Ernakulam district (10.0394° N, 76.2638° E). Distance between station II and station III is about 4 km. Moolamilly is an island in Kochi surrounded by river Periyar. It is only 6 km from Eloor suburb of Kochi. Eloor is an island of 14.21 km^2 formed between two distributaries of river Periyar and is the largest industrial belt of Kerala with over 300 chemical companies like, Fertilizers and Chemicals Travancore (FACT), Indian Rare Earths Ltd., Hindustan Insecticides Ltd. and industries manufacturing chemical – petrochemical products, rare-earth elements, rubber processing chemicals, fertilizers, Zinc/Chromium compunds and leather products (Ambily, A.P., Menon, J., 2019.). Untreated or partially treated industrial effluents are discharged into the perinnial river Periyar. This industrial belt is the 35th most toxic hotspot in the world (Nimisha and Sheeba, 2004). Station IV was Vallarpadam (9.9994° N, 76.2537° E) near to International Container Transhipment Terminal (Fig. 1). Acidity and toxicity of water is high in this area as ships periodically release sewage and bilge water often contaminated with oil. Dredging increases the cloudiness of water and disturb the contaminated bottom sediment which is threatening to aquatic organisms
(U.S. EPA, 2020; Newell, et al. 1998; Verma, et al.2020).

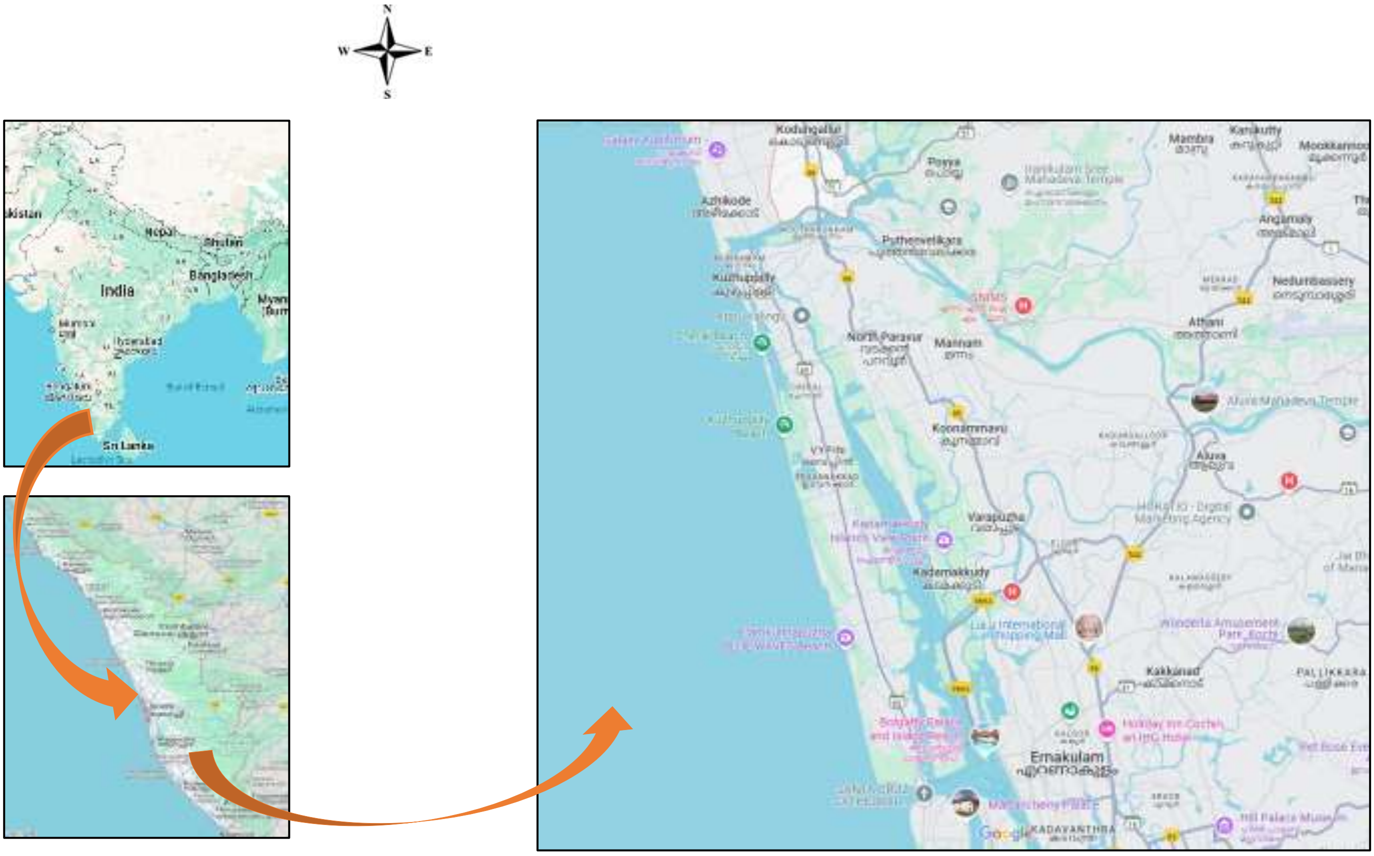

Fig.1. Sampling locations in the Central Kerala Division

2.2 Sample collection

Study was carried out from March 2021 to June 2022. Shrimp samples were collected from all four sampling sites in the early morning hours. After washing with distilled water, shrimps were carried to Central Instruments Laboratory of Kerala Veterinary and Animal Sciences University, Mannuthy, in sealed, labelled and iced condition. Surface water samples for heavy metal analysis were also collected from four sampling sites from March 2021 to June 2022. Samples were transported to Department of Veterinary Public Health and Central instruments laboratory of Kerala Veterinary and Animal Sciences University. Water samples collected in sterilized bottles were filtered through What's man filter paper and kept in refrigerator until further analysis. The samples were subjected to analysis directly. Sediments were collected from four sampling site from March 2021 to June 2022. Samples from each site is kept in separate polythene bags and taken to Radiotracer Laboratory of Kerala Agricultural University, Vellanikkara.

2.3 Digestion procedure for tissue samples

10 gm of shrimp muscle was weighed using electronic micro weighing scale. Weighed sample is mixed with 8 ml of con. HNO_3 and placed in a microwave high pressure digester for 1 hour. Digested samples were diluted to 20 ml using deionized water. The diluted solutions were mixed using a vortex mixer. Diluted samples were directly initiated into atomic absorption spectrometry. The blanks were executed corresponding with all analysis and the blank values were lesser than 0.50% of sample signals.

2.4 Digestion procedure for sediment samples

Sediment samples collected from 4 sampling sites were first air dried, then placed in electric oven at a temperature of 40 °C approximately for 30 minutes. They were then homogenized having been previously ground and sieved through sieves of stainless steel 2 mm mesh. A 0.1g sample is weighed out and transferred to reaction vessel. 2.0 ml of concentrated nitric acid and 5.0 ml of concentrated hydrochloric acid were then added to each vessel. Complete preparation of the sample was done by carefully uncapping and sealing each vessel in a fume hood. Vessels then placed in the rotor. At the end of the microwave program, the vessels were allowed to cool for a minimum of 25 minutes before removing them from the microwave system. The vessels were carefully uncapped in fume hood. To remove the particulates, the digests were filtered through Whatman No. 41 filter paper and the filtrate was collected in a 100-mL volumetric flask, the volume was adjusted to 100 ml with 0.5% HNO3. The digests were then analyzed for Fe, Zn, Pb, Cr and Cd by Atomic Absorption Spectrometry. For the extraction of available Mg, 5 gm. of sediment samples were thoroughly mixed with 25 ml of neutral normal ammonium acetate for 5 minutes and filtered immediately through a dry Whatman No. 42 filter paper. First few ml. of the filtrate was discarded. From the soil extract, Mg was estimated by Atomic Absorption Spectrophotometry. Atomic Absorption Spectrophotometry of laboratory blanks were also done at each time.

2.5 Analysis of water samples.

Water samples were collected in good quality screw capped high density pre-sterilized polypropylene bottles each of one litre capacity, labelled properly and analysed for heavy metals by Atomic absorption Spectrometer (AAS). The blanks were executed corresponding with all analysis using distilled water.

3.RESULTS

3.1 Heavy metals in muscle tissue of Metapenaeus monoceros.

The study found highest concentration of Mg. Concentration of Mg varied between 515.200 ± 197.990 mg/kg (site 1) and 2.167 ± 0.047 mg/kg (site 4). (Fig.2) Concentration of Zn varies between 199.407 ± 6.213 mg/kg (site 4) and 8.800 ± 0.877 mg/kg (site 3) (Fig.3). The concentration of Fe varied between 88.020 ± 59.029 mg/kg (site 2) and 4.970 ± 1.160 mg/kg (site 1) (Fig.5). While that of Pb is between 6.180 ± 0.198 mg/kg (site 1) and 0.420 ± 0.001 mg/kg (site 4), (Fig.4) Cd varied between 4.273 ± 0.094 mg/kg (site 2) and 0.047 ± 0.009 mg/kg (site 1), (Fig.7) and Cr between 3.673 ± 1.028 mg/kg (site 2) and 0.010 ± 0.001 mg/kg (site 2) (Fig.6). Levels of Zn and Pb observed to be relatively higher during summer compared with rainy season. In the study, highest concentration of Fe is found post monsoon seasons ie., in August concentration of Fe was 83.963 ± 9.478 and in November it was 88.020 ± 59.029. Concentration of Fe was lowest during pre-monsoon periods ie., in January, March and in the beginning of June. Levels of Cr and Cd were highest during November.

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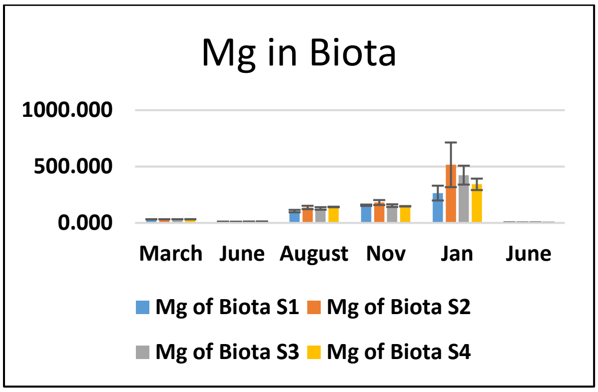

Fig. 2 Concentration of Mg in Biota

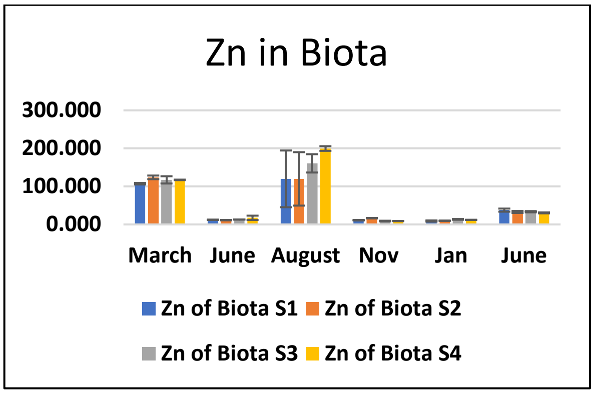

Fig. 3 Concentration of Zn in Biota

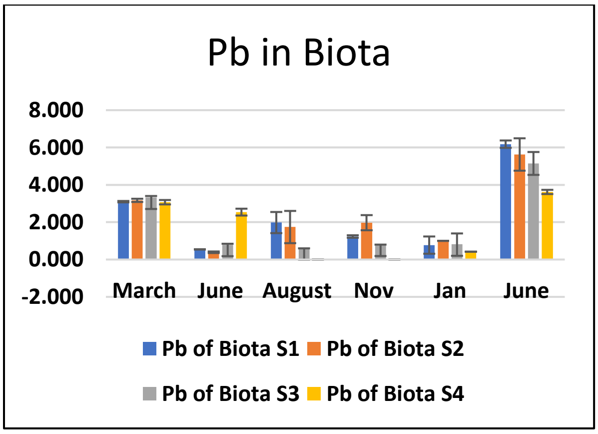

Fig. 4 Concentration of Pb in Biota

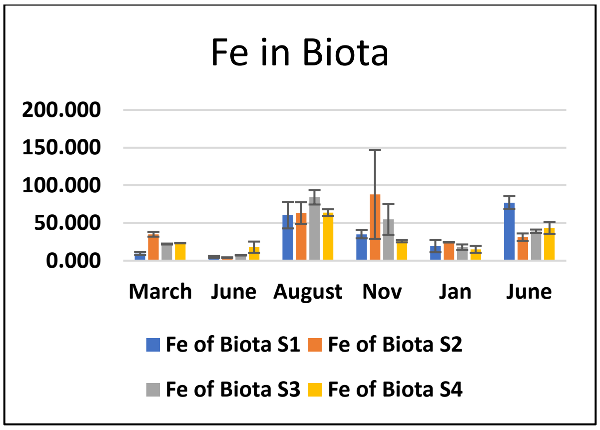

Fig. 5 Concentration of Fe in Biota

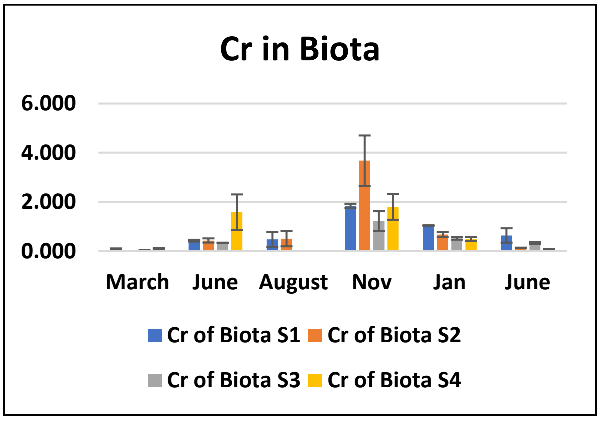

Fig. 6 Concentration of Cr in Biota

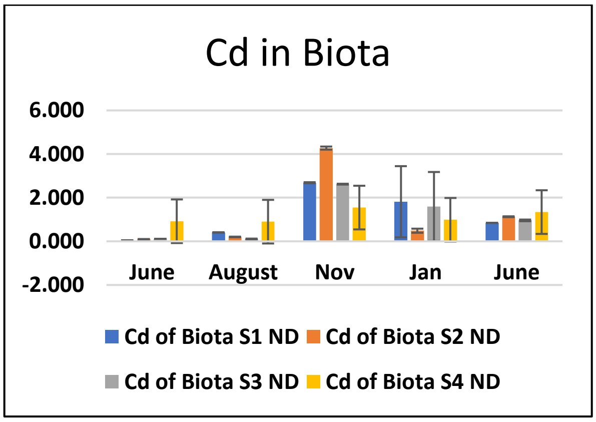

Fig. 7 Concentration of Cd in Biota

3.2 Levels of trace elements in tissues of Metapenaeus and permissible limit by FSSR, 2011.

Observed concentration of heavy metals when compared with the standards of FSSR 2011, concentration of all metals analysed except Fe were above permissible limits recommended in FBSR of Food Safety and Standards Authority of India (FSSAI). Level of Fe in all statistics were observed to be below the maximum limit recommended (Table 1).

Comparing Elemental Analysis in Tissue Sample of Metapenaeus monoceros with recommend limits of FSSR (FSSAI)					
Metals Analysed	**Highest concentrations of metals in tissue sample of Metapenaeus monoceros in each stations**				**Maximum limits for metal contaminants by FSSR (2011) ppm/mg/kg**
	I	**II**	**III**	**IV**	
Fe	76.887 ± 8.523	88.020 ± 59.029	88.963 ± 9.478	63.817 ± 4.297	100 mg/kg
Zn	119.823 ± 74.694	123.733 ± 4.833	160.587 ± 24.004	199.407 ± 6.213	50 mg/kg
Cd	2.686 ± 1.632	4.273 ± 0.094	2.620 ± 1.584	1.340 ± 0.283	1.5 mg/kg
Pb	6.180 ± 0.198	5.627 ± 0.867	5.147 ± 0.613	3.620 ± 0.113	2.5 mg/kg
Cr	1.840 ± 0.085	3.673 ± 1.028	1.213 ± 0.405	1.793 ± 0.519	0.5 mg/kg
Mg	264.533 ± 65.714	515.200 ± 197.990	423.800 ± 83.721	342.133 ± 50.723	390 mg/kg

Table: 1 Comparison of trace element concentrations with maximum limits for metal contaminants prescribed under Food Safety and Standards Regulations (FSSR) 2011,15th August.

3.4 Heavy metal variations in tissue of Metapenaeus between sampling locations.

Concentration of Fe in tissue of Metapenaeus of Station I was lower when compared with its concentration in Stations II and III. Further the levels of Cd and Cr in tissues of Metapenaeus of Station I were also observed to be lower than that of Station II. Level of Mg in tissue of the shrimp of Station I was observed to be lower than its level in Stations II, III and IV. Concentration of Zn, Pb, Cd, Cr in all sites were found to be higher than the maximum recommended limits for human consumption by FAO/WHO. Concentration of Fe in tissue samples of all the sites were below the maximum recommended limits for human consumption by FAO/WHO. While the concentration of were found to be lower in site I and site IV compared to the recommended limits for human consumption. But in site II and site III it was higher than the recommended limits for human consumption by FAO/WHO (Table 2).

Metals analysed	Highest concentration of metals in muscle tissue of Metapenaeus in each station				Maximum recommended limits for human consumption by FAO/WHO
	Station I	Station II	Station III	Station IV	
Zn	119.823 ± 74.694	123.738 ± 4.833	160.587 ± 24.004	199.407 ± 6.213	100 mg/kg
Fe	76.887 ± 8.523	88.020 ± 59.029	83.963 ± 9.478	63.817 ± 4.297	100 mg/kg

Pb	6.180 ± 0.198	5,627 ± 0.867	5.147 ± 0.613	3.620 ± 0.113	2 mg/kg
Cd	2.686 ± 1.632	4.273 ± 0.094	2.620 ± 1.584	1.340 ± 0.283	1 mg/kg
Cr	1.840 ± 0.085	3.673 ± 1.028	1.213 ± 0.405	1.793 ± 0.519	0.5 mg/kg
Mg	264.533 ± 65.714	515.200 ± 197.990	423.800 ± 83.721	342.133 ± 50.723	390 mg/kg
Table: 2 Comparing the highest concentration of metals in muscle tissue of Metapenaeus in each station with Maximum recommended limits for human consumption by FAO/WHO, 2002, September.					

3.5 Heavy metals in sediment samples.

Concentration of Zn varies between 0.005 ± 0.001 mg/kg (site 1) and 222.167 ± 2.946 mg/kg (site 1) (Fig. 10). The concentration of Fe varied between 0.371± 0.065 mg/kg (site 3) and 2104.633 ± 207.701 mg/kg (site 3) (Fig. 8). While that of Pb is between 0.015 ± 0.002 mg/kg (site 2) and 1.780 ± 0.223 mg/kg (site 3) (Fig. 12), Cd varied between 0.000 ± 0.000 mg/kg (site 1) and 4.615 ± 2.807 mg/kg (site 2) (Fig. 11), and Cr between 0.028 ± 0.005 mg/kg (site 1) and 1.481 ± 0.199 mg/kg (site 4)) (Fig. 13) . The study found highest concentration of Mg. Concentration of Mg ranged from 449.500 ± 96.167 mg/kg (site 3) to 1717.33 ± 116.908 mg/kg (site 1) (Fig. 9). Variations between sampling sites were less for Mg.

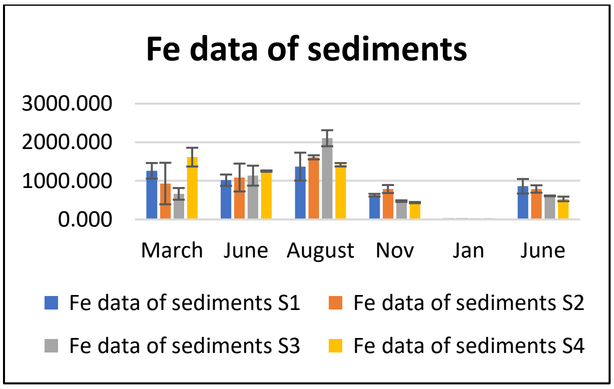

Fig. 8. Heavy metal concentration in Fe

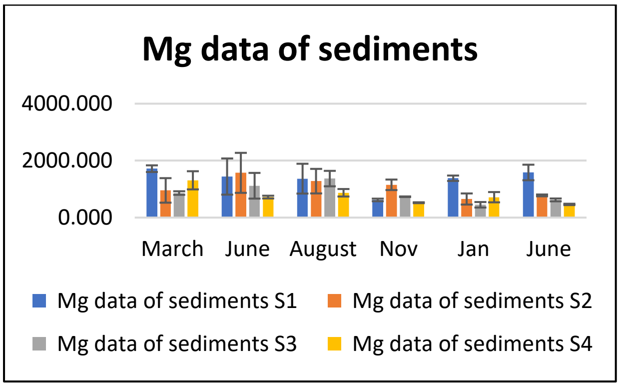

Fig. 9. Heavy metal concentration in Mg

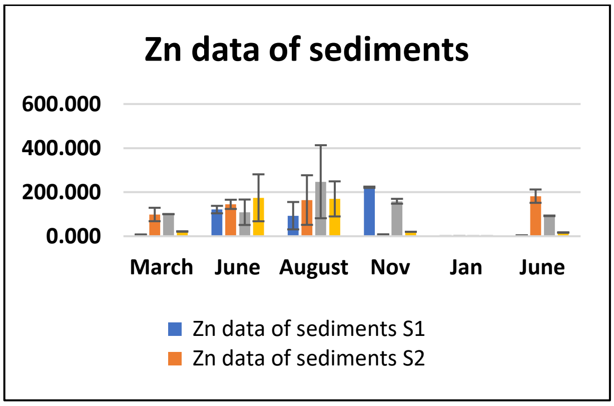

Fig. 10. Heavy metal concentration in Zn

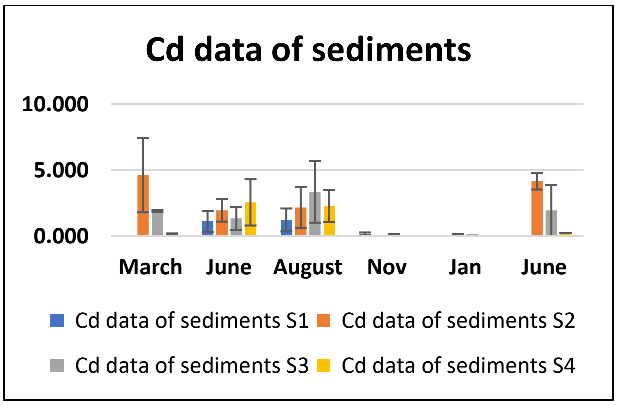

Fig. 11. Heavy metal concentration in Cd

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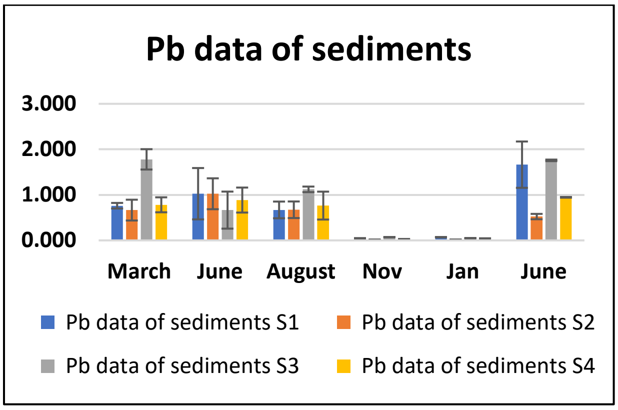

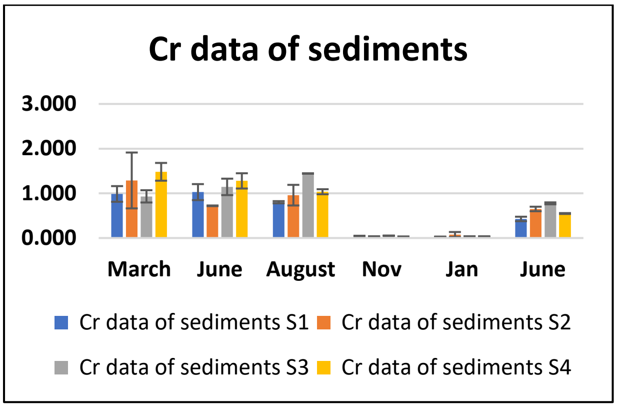

Fig. 12. Heavy metal concentration in Pb

Fig. 13. Heavy metal concentration in Cr

3.6 Levels of heavy metals in sediment samples and permissible limits by EPA.

Concentration of Fe in all sampling sites were above the recommended limit by EPA with highest level in Station III. However a far lower concentration of Cd, Pb and Cr were observed in all four sampling sites than the recommended limit. While level of Zn in station I and station III crossed the maximum recommended limit by EPA and level of Zn in station II and station IV are near to maximum recommended limit (Table 3).

Comparing the elemental analysis in the sediment samples with international standards of EPA							
Metals Analysed	**Concentration of metals in each station (Lowest and highest mean values are recorded)**				**EPA heavy metal guidelines (mg/kg)**		
	Mean ± SD						
	I	**II**	**III**	**IV**	**Non Polluted**	**Moderatly Polluted**	**Heavily Polluted**
Fe	Between 1.010 ± 0.171 and 1369.637 ± 361.138	Between 1.466 ± 0.315 and 1609.453 ± 52.929	Between 0.371 ± 0.065 and 2104.633 ± 207.701	Between 0.660 ± 0.090 and 1614.333 ± 243.127	<4	NO	>480
Zn	Between 0.005 ± 0.001 and 222.167 ± 2.946	Between 0.180 ± 0.014 and 181.867 ± 30.311	Between 0.054 ± 0.008 and 247.397 ± 165.652	Between 0.026 ± 0.006 and 169.480 ± 79.620	<90	90-200	>200
Cd	Between 0.003 ± 0.001 and 1.229 ± 0.869	Between 0.006 ± 0.001 and 4.615 ± 2.807	Between 0.044 ± 0.007 and 3.367 ± 2.342	Between 0.018 ± 0.001 and 2.559 ± 1.752	NM	<6	>6
Pb	Between 0.036 ± 0.014 and 1.663 ± 0.509	Between 0.015 ± 0.002 and 1.024 ± 0.339	Between 0.072 ± 0.000 and 1.780 ± 0.223	Between 0.026 ± 0.006 and 0.946 ± 0.008	<40	40-60	>60

Cr	Between 0.029 ± 0.005 and 1.027 ± 0.179	Between 0.034 ± 0.001 and 1.288 ± 0.625	Between 0.037 ± 0.001 and 1.444 ± 0.002	Between 0.031 ± 0.004 and 1.481 ± 0.199	<25	25-75	>75
Mg	Between 619.917 ± 45.373 and 1717.333 ± 116.908	Between 652.167 ± 195.279 and 1570.750 ± 702.511	Between 449.500 ± 96.167 and 1369.333 ± 271.058	Between 462.250 ± 23.688 and 1308.833 ± 318.434	NM	NM	NM

Table: 3 Comparing the elemental analysis in the sediment samples with international standards of EPA. 2014.

3.7 Heavy metals in water samples.

Level of heavy metals in water serene from four sampling sites revealed the following order Pb > Fe > Cr > Cd > Zn. Level of Pb during the month of March and August were higher in station IV with maximum concentration of 0.550 ± 0.013 mg/l in March and 0.306 v 0.024 mg/l in August respectively (Fig. 14). Concentration of Fe observed to be highest in November in 2nd sampling site, recorded as 0.630 ± 0.317 mg/l (Fig. 18). Maximum level of Cr was observed in march in 1st and 4th sampling as 0.109 ± 0.000 mg/l and 0.090 ± 0.002 mg/l respectively (Fig. 15). Cd also showed a higher level of concentration in March with maximum level of 0.055 ± 0.002 mg/l in 4th sampling site (Fig. 16). Concentration of Zn was highest in November as station IV with 16.837 ± 0.118 mg/l. Zn in water samples collected from all other stations during all other months were below the detectable level (Fig. 17). Level of Mg observed to be maximum in station IV as 34.447 ± 14.288 in August (Fig. 19).

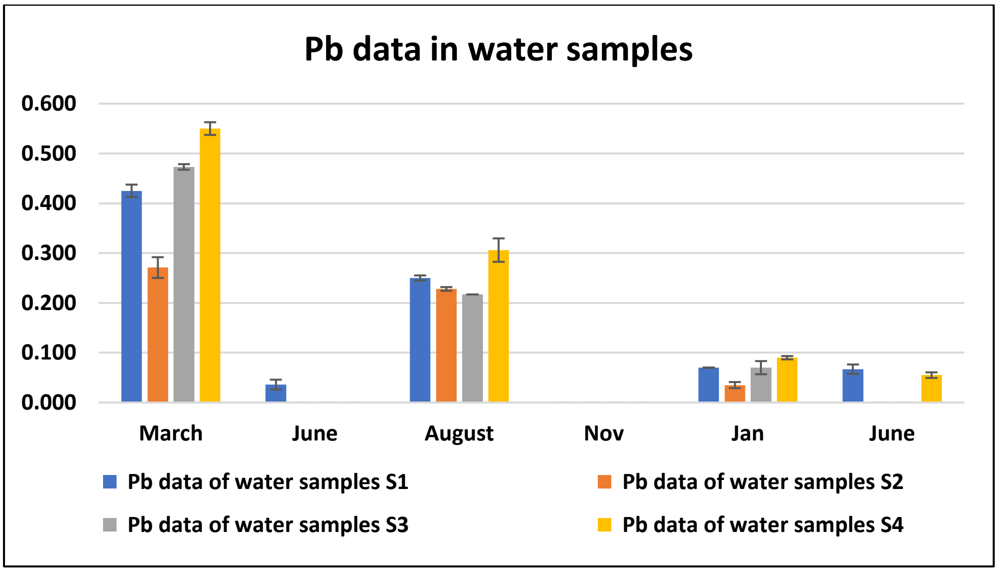

Fig. 14 Concentration of Pb in water samples

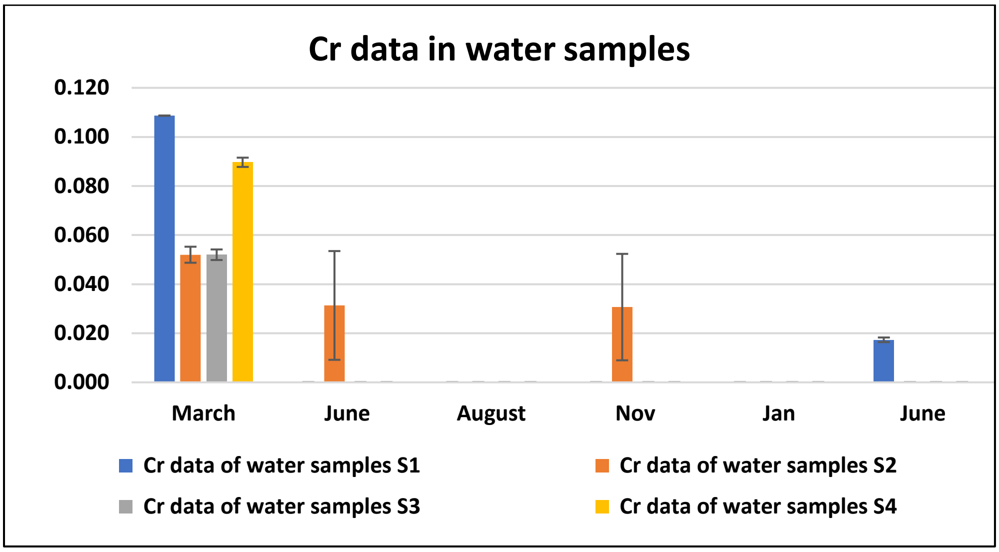

Fig. 15 Concentration of Cr in water samples

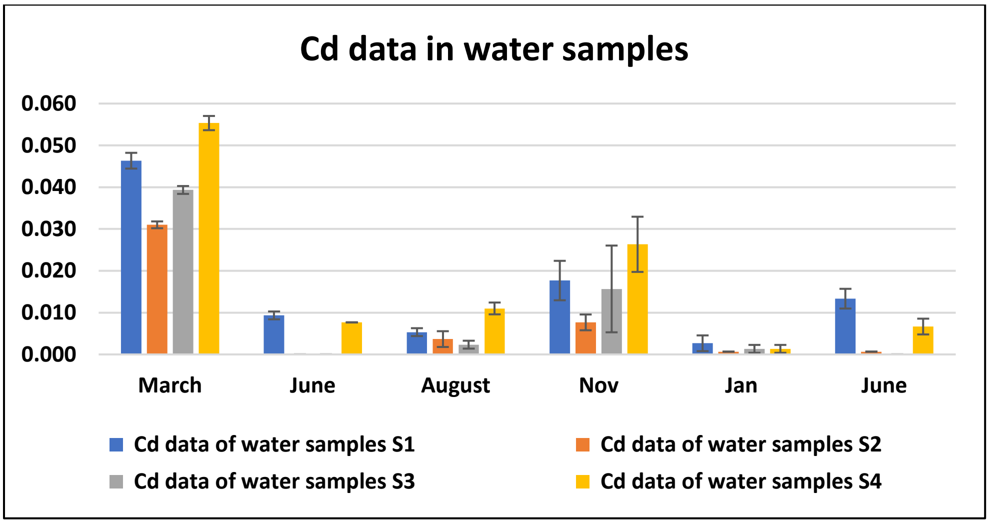

Fig. 16 Concentration of Cd in water samples

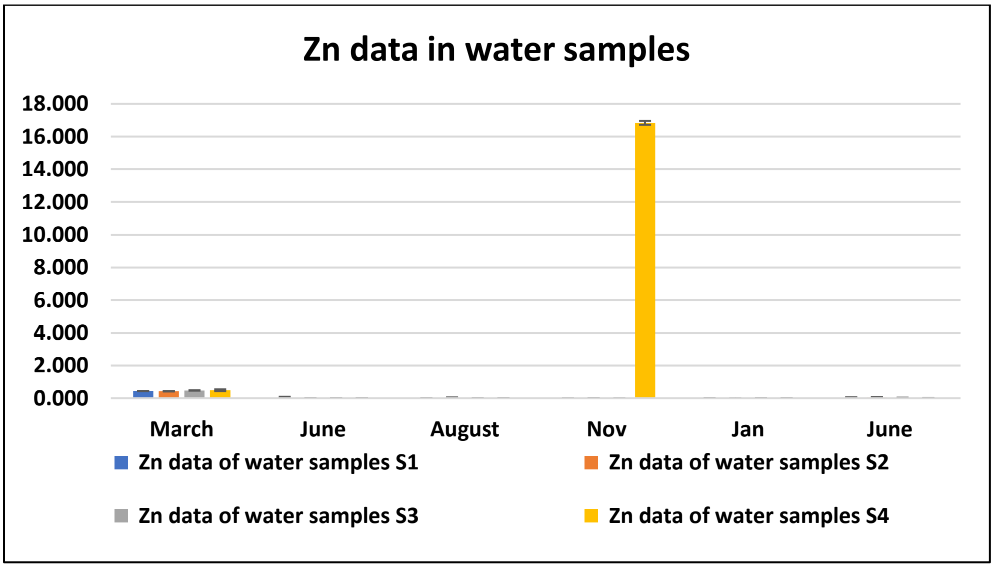

Fig. 17 Concentration of Zn in water samples

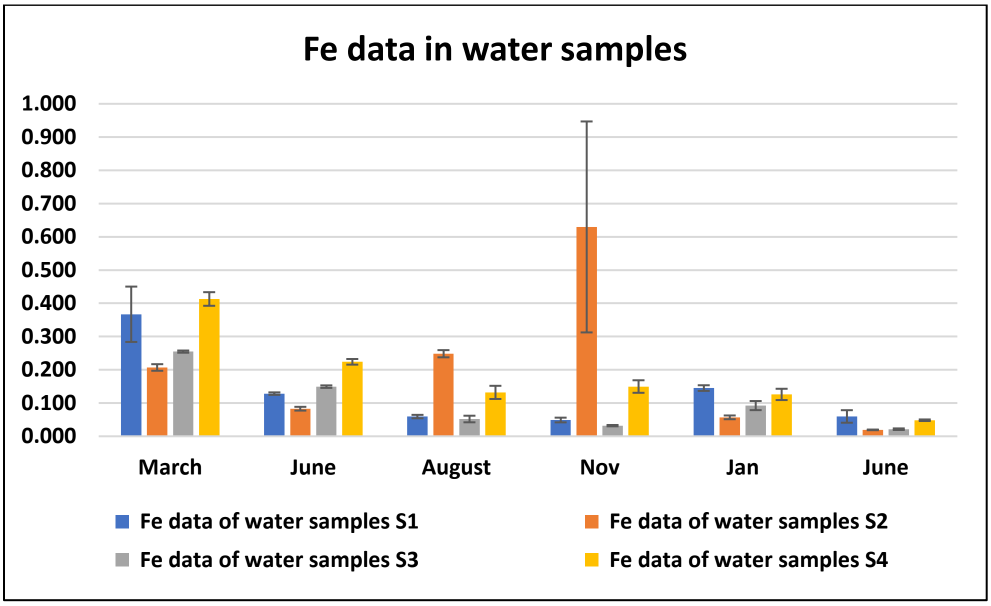

Fig. 18 Concentration of Fe in water samples

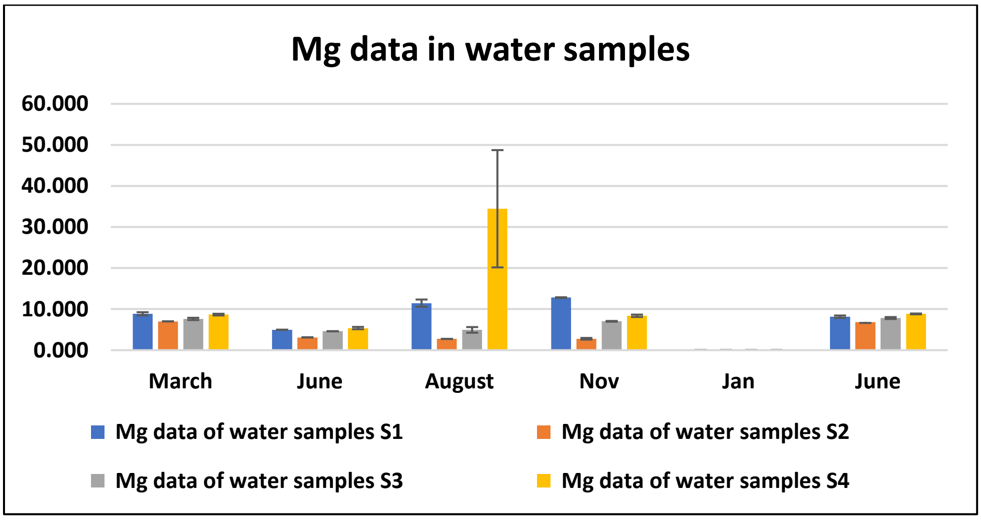

Fig. 19 Concentration of Mg in water samples

3.8 Level of heavy metals in water samples and permissible limits by Pollution Control Board of India

Maximum concentration of Fe of sampling site I, II and III were above the recommended limit of Pollution Control Board of India. While the level of Zn was above the recommended limit only is station IV. Concentration of Pb and Cd were above the permissible limit in all 4 sites. Level of Cr also crossed permissible limit in station I and IV. Whole Mg concentration level was below the recommended limit in all 3 sampling sites except sampling site IV (Table 4).

Comparing elemental analysis of water samples with recommended limits by PCB of India					
Metals Analysed	Highest concentration of metals in water samples of each stations				Indian Standards mg/L
	I	II	III	IV	
Fe	0.367 ± 0.083	0.630 ± 0.317	0.255 ± 0.003	0.413 ± 0.021	0.30
Zn	0.442 ± 0.005	0.429 ± 0.018	0.475 ± 0.012	16.837 ± 0.118	5.00
Cd	0.046 ± 0.002	0.031 ± 0.001	0.039 ± 0.001	0.055 ± 0.002	0.01

Pb	0.425 ± 0.012	0.271 ± 0.021	0.473 ± 0.006	0.550 ± 0.013	0.10
Cr	0.109 ± 0.000	0.052 ± 0.003	0.052 ± 0.002	0.090 ± 0.002	0.05
Mg	12.800 ± 0.085	7.017 ± 0.022	7.829 ± 0.239	34.447 ± 14.288	30 Mg/L

Indian Standard Specification for Water (10500-1983)

4. DISCUSSION

Macro invertebrates like Metapenaeus sp. are commonly recommended as fauna-indicators for evaluating the fluctuations of aquatic disorders in the region of probable pollution (Xiaoyu Li et al.,2013). Being a vagile benthic fauna, Metapenaeus sp. are particularly exposed to heavy metals by accidental injection (Monisha Jaishankar et al.,2014). Contaminants in aquatic environment not only generate direct toxicity on aquatic organisms, but also bring potential threats to human health through domestic water and food chain (Swaroop S Sonone et al.,2021). A systematic study of the distribution of heavy metals in surface water, sediments and organisms is necessary for contamination control and environmental management (Xi Liu et al.,2022Distribution of the heavy metals concentration in the tissue of Metapenaeus monoceros was Mg > Zn > Fe > Pb > Cd > Cr. Concentration of Mg is higher than other heavy metals as it act as a catalyst for a wide array of enzymes vital for metabolism of carbohydrates, lipids, nuclear acids and proteins. Mg is also required in osmoregulation, cell membrane integrity and modulating neuro muscular transmission (Ha H. Truong et al.,2022). Levels of essential metals Fe and Zn have been found to be higher than Pb and Cd because Fe and Zn play an important role in the enzymatic and respiratory processes of shrimp. Non-essential metals Pb and Cd do not have any function for fish's metabolism and are not regulated by the organism (Tuzun Aytekin et al.,2019; Gurel Turkmen, 2012). Further Zn being an essential element for normal growth and metabolism of minerals, exhibited highest accumulation in shrimp muscle (Gurel Turkmen,2012). Levels of Zn and Pb observed to be relatively higher during summer compared with rainy season. Elevated heavy metals in tissues in summer could be due to the increase in physiological activity of shrimps in summer. The growth rate of fish would be higher in summer, resulting in higher metal accumulation (Zubcov E et al., 2012; Kargin F et al., 2001; Cogun H.Y et al.,2005). South west monsoon and north east monsoon also influence metal concentration in biota of shrimp. In the study, highest concentration of Fe is found post monsoon seasons. Concentration of Fe was lowest during pre-monsoon periods ie., in January, March and in the beginning of June. This variation is due to high pollution occurring in post-monsoon season because of the excessive sediment deposit from upstream after monsoon rain fall (Justus and Sudalaimuthu, 2023). Levels of Cr and Cd were highest during November. As Metapenaeus monoceros is a benthic species, it has a greater exposure to sediments and have accumulated higher metal concentration. In benthic forms, metal concentration is largely controlled by the habitat feeding habits, metal accumulation capacity and organism type (Tuzun Aytekin et al.,2019; Agah H et al., 2009). Factors affecting variations in the level of heavy metals in tissue with different stations are feeding habits, food contamination of aquatic environment, etc. Sediments forms a major source of heavy metals and also food source for many benthic organisms (Shanmugaasokan et al.,2013). Contamination of sediments with heavy metals is an important factor affecting the bioaccumulation of heavy metals is tissues of bottom dwellers (Nandakumar G., and Damodaran R., 1998). Sediment contamination with heavy metals is different for different sampling sites. The distribution of heavy metals concentration in sediment samples collected from 4 sampling sites followed the decreasing order Fe > Zn > Cd > Pb > Cr. Level of Fe was observed to be higher. In all 4 sampling sites followed by Zn, Fe is the richest element of the earth's crust (Aisen et al.,2001). Ferric iron (Fe3+) is virtually insoluble in aqueous solution. As it cannot be degraded, they are deposited in sediment and accumulate in the tissues of benthic fauna and detritus feeders (Nandakumar G., and Damodaran R., 1998). Further, the higher the grain size, the higher the particulate organic carbon which might contribute to the higher Zn and Fe concentrations (Widyastuti et al., 2022). Concentration of Zn, Fe, Cr and Pb was greater during the months of June and August. Stirring of sediments during monsoon is a factor for difference in metal concentration between seasons (Tengku et al.,2021). Levels of Zn, Cd and Pb was very low during November and January. Variations between sampling sites were less for Mg. Level of heavy metals in water serene from four sampling sites revealed the following order Mg > Zn > Fe >Pb > Cr > Cd . Industrial effluents, municipal waste, agricultural activities, land run off all contribute to the higher concentration of Mg, Zn, and Pb to aquatic bodies. They are regarded as serious pollutant metals in aquatic ecosystem due to their environmental perseverance, toxicity and ability to incorporate into food chains. (Ramkumar Mu et.al., 2024).

5.CONCLUSION

The study reveals that the aquatic bodies of central division are polluted with heavy metals due to the nature of anthropogenic activities like Industrial discharge, dredging, trawling, unscientific application of chemical fertilizers etc. The Kochi coastal zone is under increased industrial activity with over 250 large and medium industries causing heavy metal contamination leading to ecological decay in the region. The volume of industrial effluents discharged from the Eloor- Kalamassery industrial belt is about 260 million litres per day, much of which is directly discharged into the Periyar River from where it enters the backwaters. Though the study reveals that many of the heavy metals are within the permissible limit, continuous discharge of these non-degradable heavy metals can cause serious threats in aquatic ecosystem due to assimilation, deposition and bioaccumulation.

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