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Bioaccumulation of Trace Metals in Planktonic *Lucifer* (Crustacea: Decapoda) from Cochin Backwaters

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***Abstract*:** The study explores the bioaccumulation of trace metals like Fe, Ni, Zn, Cu, Cr, Mn, Cd and Pb in water and planktonic *Lucifer* samples that were collected from the Cochin backwaters during the period of March 2017 to January 2019. Significant spatial and seasonal variability for most of the trace metals was detected in water and *Lucifer*. The average concentration of trace metals in *Lucifer* samples analysed follows an order: Fe > Zn > Mn > Cu > Ni > Cr > Pb > Cd whereas the average bioaccumulation factors follow another order: Fe > Cu > Mn > Zn > Cr > Ni > Cd > Pb. *Lucifer* showed a great ability to accumulate metals by several hundred to thousand times, when compared to their concentrations detected in water, in particular for the essential elements Fe, Zn, Mn, Cu, Ni and Cr and for the non-essential metals Pb and Cd. High values of Bioaccumulation factors noted for trace metals in *Lucifer* reveal an enhanced bioavailability of the studied trace metals in the Cochin backwaters.

Keywords: Plankton, *Lucifer*, Trace metals, Bioaccumulation factor, Cochin backwaters

Trace metals are considered as major pollutants due to their bioaccumulation, high toxicity and persistence in aquatic environments (Chen et al 2011, Lee et al 2023). Some of the trace metals, such as iron (Fe), Copper (Cu), chromium (Cr), zinc (Zn), and manganese (Mn), are essential for the metabolism of organisms including plankton (Morel and Price 2003) while others like mercury (Hg), lead (Pb) and cadmium (Cd) are nonessential. All metals are toxic above a threshold bioavailability (Pandey and Madhuri 2014). The toxic effects of trace metals have been detected in a variety of aquatic organisms including plankton (Jakimska et al 2011, Jyothirmaye et al 2022). Plankton plays a major role in the accumulation, transfer and biogeochemical cycling of trace metals in aquatic environments (Baltar et al 2018). Plankton is considered one of the most sensitive indicators of environmental changes and most abundant organisms in the estuary and can accumulate trace metals at relatively high levels. Zooplankton plays a key link in the transfer of trace metals through aquatic food webs (Rejomon et al 2008a, Biju et al 2023). They accumulate trace metals from both dissolved phases and from ingested food (Rejomon et al 2008b). Genus *Lucifer* is a holoplanktonic group of organisms come under the family Luciferidae, and is one of the major constituents in zooplankton communities of the Cochin estuary (Geetha and Antony 2001). The abundance of these epiplanktonic decapodan shrimps serves as indicators of fishing and nursery grounds of prawns and fishes (Arokiasundaram et al 2014). Aquatic edible organisms like fishes are at the top of the aquatic food chain have accumulated trace metals in their tissues may be transferred to humans through fish intake, which could result in chronic or acute illnesses (Sharma and Singh 2022). Trace metal studies in zooplankton communities from the shallow coastal waters of India are very scarce and no previous studies have analysed the concentration of trace metals in the zooplankton group, *Lucifer*, from the Cochin coastal environments. The present study attempts to evaluate the concentration of trace metals like iron, zinc, manganese, copper, nickel, chromium, cadmium and lead in *Lucifer* samples collected from the Cochin estuary.

MATERIAL AND METHODS

Study area: Cochin backwaters, located on the southwest coast of India extend from Cochin to Alappuzha (9° 40.12' N and 10° 10.48'N and 76° 09.52' E and 76° 23.57'E). This backwater system is separated from the Arabian Sea by barrier spits with two permanent tidal inlets one at Cochin and the other at Azhikode. Specific geographic features, anthropogenic activities and the inflow of pollutants from different sources were the major criteria for the selection of sampling stations. Five sampling stations were fixed along the Cochin backwaters (Fig. 1). They are Fort Kochi (S1), the freshwater from the perennial rivers of the Western Ghats meets the Arabian Sea at the Fort Kochi area. High saline water forms a major environmental characteristic of this region. The Cochin Shipyard and Cochin Port Trust as well as various industrial plants and their functioning are in the vicinity of this site; Bolghatty (S2), effluents from chemical factories in the northern zone of the estuaries are discharged into the Periyar River and are mixed into the Bolghatty region of the estuary by tides and freshwater flows; Arookutty (S3), is a receptor of urban sewage as well as effluents from chemical industries discharged into the Chithrapuzha River; Vaikom (S4) is an important fish landing centre in the Kottayam district. Muvattupuzha River drains into the Cochin backwater near Vaikom and carries industrial effluents from the Hindustan newsprint factory; Thanneermukkom north station (S5) located on the northern side of the Thannermukkom bund. This station is located 40 km away from the Fort Kochi. The bund regulates the free flow of water into the Arabian Sea and the intrusion of saline water into the southern sector from post-monsoon till the onset of monsoon.

Sampling: Bimonthly field sampling was carried out from five selected stations during three seasons from March 2017 to January 2019. Standard Protocols were followed for water sample collection and preservation (Strickland and Parsons 1972, APHA 2012). Zooplankton samples were collected using a W.P net (mesh size 200 µm, mouth area 0.6m²).

Trace metal analysis: In the laboratory, sorted *Lucifer* samples were rinsed with Milli-Q water to remove salts. Water adhering to the samples was removed by using good-quality laboratory filter paper. Samples were completely dried

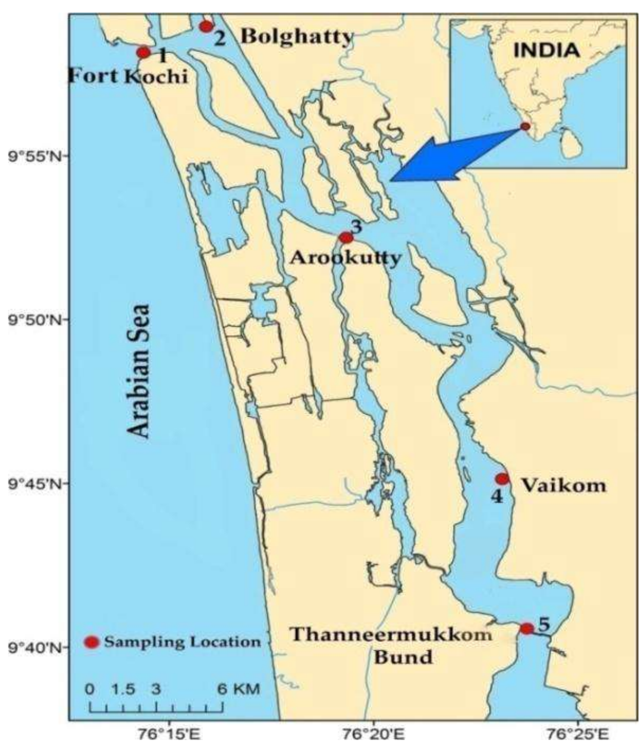

Fig. 1. Sampling stations in the Cochin backwaters

overnight in an oven at 65°C. The dried *Lucifer* samples were first powdered and a portion of about 300 mg was digested for 3 hours at 80°Cwith 3 ml of HNO_3 and 1 ml of $HClO_4$. The digests were made up to 25 mL with Milli-Q water. The concentration of trace metals (Fe, Ni, Zn, Cu, Cr, Mn, Cd and Pb) in *Lucifer* and water samples was determined with an Atomic Absorption Spectrophotometer (Perkin Elmer India Pvt. Ltd; model: PinAAcle 900 H). The water samples were pre-concentrated before spectrophotometer analysis following a standard protocol (Grasshoff et al 1983).

Concentration of trace metal in the sample

$$= \frac{\text{AAS reading} \times \text{Volume of the sample (ml)} \times \text{dilution factor (if any)}}{\text{Dry weight of the sample taken}}$$

Bioaccumulation factor and metal pollution index: The bioaccumulation factor (BAF) is calculated as the ratio of metal present in the organism to the metal present in the surrounding medium (Karlsson et al 2002).

$$\text{BAF} = \frac{\text{The mental concentration in organism}}{\text{Metal concentration in the surrounding medium (Water)}}$$

Metal pollution indices (MPI) were calculated following the equation (Usero et al 2005). Here; Cf_1= Concentration of I^{st} metal, Cf_2= Concentration of II^{nd} metal, Cf_n= Concentration of n^{th} metal.

$$\text{MPI} = (Cf_1 \times Cf_2 \ldots \ldots Cf_n)^{1/n}$$

Statistical analysis: Data on trace metal concentrations in *Lucifer* and water were analysed statistically by using the XL-STAT Pro software package. Two-factor without replication analysis of variance (ANOVA) was used to determine seasonal and temporal variations of trace metals in *Lucifer* during the present study.

RESULTS AND DISCUSSION

Trace metals in water : Spatial variation of dissolved Fe, Ni, Zn, Cu, Cr, Mn, Cd and Pb showed distinctive enrichment patterns from stations 1 to 5 (Table 1). The spatial variation of most metals in water showed a higher enrichment in the north estuary (stations 1 and 2) when compared to the south estuary (station 5). The dissolved metals like Fe, Zn, Cu, Mn, and Cd showed higher values (0.85, 0.25, 0.029, 0.044 and 0.011 ppm) at station 2 of the north estuary when compared to other stations (Table 1). Similarly, dissolved metals like Ni and Pb showed higher values (0.061 ppm) at station 1 of the north estuary when compared to other stations. However, dissolved Cr showed a higher value (0.037 ppm) at station 4 of the south estuary when compared to other stations. The increased levels of dissolved metals like Fe, Zn, Cu, Mn and Cd at station 2 (Bolghatty) are probably due to industrial effluent discharges from industries located at Eloor which reaching at this region by tidal currents and freshwater flows through the Periyar River (Rejomon et al 2016, 2021).

Likewise, the pulsed levels of dissolved metals like Ni and Pb at station 1 of the Bar mouth region might be due to the extensive dredging operations, shipyard and port activities at the nearby region (Robin et al 2012, Anas et al 2015). The elevated levels of dissolved Cr at station 4 of the south estuary are possibly due to industrial effluent discharges reaching this region from the Hindustan newsprint factory located at Piravam by tidal currents and freshwater flows through the Muvattupuzha River (Rejomon et al 2012). Elamin et al (2021), observed increased concentration of trace metals in the water and might be due to the large quantities of solid wastes mixed with the wastes of factories, market and industrial wastes that discharge directly or indirectly into the water bodies. The increased levels of dissolved metals noted during non-monsoon seasons (Table 2) can be attributed to their enrichment caused by enhanced evaporation and increased dissolution from bottom-contaminated sediments due to the prevailing higher water column temperature (Rejomon et al 2016). In most of the dissolved trace metal showed significant spatial and seasonal variation ($p \leq 0.05$) at Cochin backwaters (Table 1 and 2).

Trace metals in *Lucifer:* The average concentration of trace metals in studied *Lucifer* samples followed the sequence: Fe > Zn > Mn > Cu > Ni > Cr > Pb > Cd. The high enrichment of trace metals like Fe, Ni, Zn, Cu and Cd in *Lucifer* at station 2 is might be due to the effluent discharges from the nearby chemical industries and domestic sewage inputs in this area from Cochin City through the Periyar River (Rejomon et al 2012, Biju and Rejomon 2020) (Table 3). The high enrichment of trace metals like Fe, Zn and Cr in *Lucifer* at station 1 is due to the influence of effluent discharges associated with port and shipyard activities at this locality (Balachandran et al 2005). A similar high enrichment of trace metal like Mn in *Lucifer* at station 5 is due to the influence of agricultural effluent discharges at this locality from the Kuttanad agricultural fields (Rejomon et al 2013). During the present study, except Cu and Cd all the studied trace metals in *Lucifer* showed significant spatial variations ($p \leq 0.05$) (Table 3). The spatial variability of metals observed in *Lucifer* during the present study laid out emphasis on the hot spot of each metal contamination site that exists in Cochin backwaters.

Metals like Fe, Ni, Zn and Cd in *Lucifer* showed higher values (4029.28 , 38.75, 310.16 and 2.63 ppm respectively) at station 2 and lowest was at station 5 (571.75 , 10.65 and 145.75 ppm) except Cd where the lowest value was at station 4 (1.17 ppm). The highest mean value of Fe and Zi was during monsoon and Ni and Cd was during post- monsoon (Fig. 2). The highest and lowest seasonal Cu concentration in *Lucifer* were at station 1 (61.8 ppm) and station 5 (12.7 ppm) respectively (Fig. 2). Metals like Cr and Mn in *Lucifer*, showed a higher value (38.93 and 88.62 ppm) at station 4 of the central estuary during monsoon and premonsoon periods respectively, and the lowest Cr (12.7 ppm) and Mn (24.1 ppm) at station 5 (Fig. 2). In contrast, Pb concentration in *Lucifer* were peak at station 3 (19.9 ppm) during post-monsoon and the lowest was at station 4 (4.37 ppm) during the pre-monsoon season (Fig. 2). The seasonal variations of Fe, Ni, Zn, Cu, Cr, Mn, Cd and Pb contents in *Lucifer* were statistically significant.

Lucifer has accumulated Fe and Zn in higher concentrations than other metals irrespective of seasons. High Fe concentrations noted in *Lucifer* are due to its function in mitochondria which catalyses redox reactions during respiration (Chen 2011). Zooplankton have accumulated a high amount of zinc as a result of co-precipitating zinc with calcium carbonate (Paimpillil et al 2010). For aquatic animals, diet is the primary source of zinc, and it plays a

Table 1. Average concentration of dissolved trace metals (ppm) in the Cochin backwaters

Trace metals (ppm)	Stations					ANOVA *p*-value
	S1	S2	S3	S4	S5	
Fe	0.680 ± 0.18	0.850 ± 0.26	0.620 ± 0.29	0.570 ± 0.32	0.430 ± 0.18	0.05*
Ni	0.061 ± 0.03	0.056 ± 0.03	0.044 ± 0.02	0.027 ± 0.02	0.015 ± 0.01	0.002**
Zn	0.210 ± 0.06	0.250 ± 0.07	0.200 ± 0.05	0.150 ± 0.07	0.080 ± 0.05	0.000**
Cu	0.025 ± 0.01	0.029 ± 0.01	0.028 ± 0.01	0.024 ± 0.01	0.016 ± 0.01	0.03*
Cr	0.031 ± 0.02	0.029 ± 0.01	0.028 ± 0.01	0.037 ± 0.02	0.029 ± 0.01	0.57
Mn	0.032 ± 0.01	0.044 ± 0.02	0.032 ± 0.01	0.043 ± 0.02	0.036 ± 0.01	0.35
Cd	0.010 ± 0.01	0.011 ± 0.01	0.008 ± 0.01	0.003 ± 0.01	0.003 ± 0.01	0.026*
Pb	0.061 ± 0.01	0.059 ± 0.02	0.035 ± 0.02	0.027 ± 0.01	0.034 ± 0.03	0.007**

* Significant at 0.05 level; ** significant at 0.01 level

significant role in zinc concentration than zinc absorption from seawater (Battuello et al 2016). Wide fluctuation in the bio concentration of metals in the present study is attributed to the trace metals availability in the respective stations. High Cu concentrations noted in *Lucifer* are due to the Cu requirement for respiratory pigment hemocyanin. Mn, Cu, Ni, and Cd concentrations noted during the present quite agree with the Mn, Cu, Ni, and Cd concentrations reported for other groups of zooplankton including *Lucifer* which were based on bioassay studies in laboratory conditions (Subrahmanyam

Table 2. Seasonal variation of dissolved trace metals (ppm) in the Cochin backwaters

Trace metals (ppm)	Stations						ANOVA *p*-value
		S1	S2	S3	S4	S5	
Fe	Pre-monsoon	0.60 ± 0.18	0.97 ± 0.37	0.78 ± 0.34	0.93 ± 0.24	0.54 ± 0.16	0.07
	Monsoon	0.63 ± 0.15	0.66 ± 0.16	0.44 ± 0.14	0.36 ± 0.15	0.37 ± 0.13	
	Post-monsoon	0.82 ± 0.18	0.92 ± 0.16	0.62 ± 0.31	0.41 ± 0.17	0.38 ± 0.23	
Ni	Pre-monsoon	0.04 ± 0.26	0.05 ± 0.23	0.04 ± 0.24	0.02 ± 0.009	0.06 ± 0.01	0.001**
	Monsoon	0.05 ± 0.03	0.03 ± 0.021	0.03 ± 0.02	0.02 ± 0.011	0.01 ± 0.01	
	Post-monsoon	0.09 ± 0.01	0.08 ± 0.01	0.06 ± 0.01	0.04 ± 0.02	0.02 ± 0.01	
Zn	Pre-monsoon	0.25 ± 0.07	0.30 ± 0.08	0.23 ± 0.07	0.18 ± 0.10	0.06 ± 0.04	0.04*
	Monsoon	0.17 ± 0.03	0.20 ± 0.03	0.17 ± 0.02	0.12 ± 0.06	0.12 ± 0.06	
	Post-monsoon	0.21 ± 0.08	0.24 ± 0.05	0.19 ± 0.04	0.14 ± 0.05	0.08 ± 0.06	
Cu	Pre-monsoon	0.02 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.01 ± 0.01	0.004**
	Monsoon	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.02	
	Post-monsoon	0.04 ± 0.01	0.04 ± 0.02	0.04 ± 0.01	0.03 ± 0.01	0.02 ± 0.02	
Cr	Pre-monsoon	0.03 ± 0.02	0.04 ± 0.02	0.03 ± 0.02	0.05 ± 0.02	0.04 ± 0.02	0.002**
	Monsoon	0.01 ± 0.01	0.01 ± 0.01	0.02 ± 0.01	0.02 ± 0.11	0.01 ± 0.01	
	Post-monsoon	0.05 ± 0.03	0.02 ± 0.01	0.03 ± 0.02	0.04 ±.016	0.03 ± 0.01	
Mn	Pre-monsoon	0.03± 0.01	0.05 ± 0.03	0.04 ± 0.02	0.06 ± 0.02	0.05 ± 0.01	0.02*
	Monsoon	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.01 ± 0.01	0.03 ± 0.02	
	Post-monsoon	0.06 ± 0.01	0.05 ± 0.01	0.03 ± 0.02	0.04 ± 0.01	0.03 ± 0.01	
Cd	Pre-monsoon	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.01	0.014*
	Monsoon	0.01 ± 0.00	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	
	Post-monsoon	0.01 ± 0.03	0.02 ± 0.02	0.01 ± 0.02	0.01 ± 0.00	0.01 ± 0.00	
Pb	Pre-monsoon	0.07 ± 0.00	0.05 ± 0.01	0.02 ± 0.02	0.03 ± 0.02	0.02 ± 0.01	0.04*
	Monsoon	0.04 ± 0.02	0.05 ± 0.03	0.04 ± 0.03	0.03 ± 0.02	0.03 ± 0.03	
	Post-monsoon	0.07 ± 0.01	0.07 ± 0.01	0.04 ± 0.01	0.03 ± 0.01	0.05 ± 0.04	

* Significant at 0.05 level; **Significant at 0.01 level

Table 3. Average concentration of trace metals (ppm) in *Lucifer* at Cochin backwaters

Trace metals (ppm)	Stations					ANOVA *p*-value
	S1	S2	S3	S4	S5	
Fe	1908.83 ± 1303.60	2531.63 ± 1711.06	1862.84 ± 1042.14	1779.42 ± 864.78	926.07 ± 528.56	0.04*
Ni	25.28 ± 12.96	31.98 ± 10.27	28.02 ± 09.12	22.09 ± 5.25	18.05 ± 8.09	0.04*
Zn	256.81 ± 95.08	263.45 ± 67.02	229.11 ± 69.77	173.33 ± 58.84	173.58 ± 81.60	0.003**
Cu	43.11 ± 18.07	45.07 ± 13.62	36.20 ± 19.87	31.80 ±15.22	28.03 ± 12.05	0.36
Cr	26.03 ± 08.11	23.61 ± 08.37	24.47 ± 10.57	30.64 ± 14.02	18.49 ± 07.44	0.02*
Mn	35.99 ± 09.66	35.96 ± 19.34	38.38 ± 12.25	79.55 ± 41.74	43.03 ± 24.75	0.003**
Cd	1.98 ± 00.51	2.19 ± 00.76	2.10 ± 00.59	1.66 ± 00.57	1.77 ± 00.50	0.04*
Pb	10.50 ± 06.31	11.52 ± 07.31	12.88 ± 06.26	10.86 ± 06.90	11.74 ± 08.08	0.88

* Significant at 0.05 level; **Significant at 0.01 level

1990). Bioaccumulation of metals in zooplankton is reported to be dependent on bioavailability, the amount of dissolved metal absorption, the physiological efficiency of the organism to excrete metals, as well as the feeding rate and prey availability (Chouvelon et al 2019).

Table 4. Average BAF of trace metals in *Lucifer*

Trace metals	Trace metal concentration in *Lucifer* (ppm)	Trace metal concentration in surface water (ppm)	Bioaccumulation factor (BAF)
Fe	1801.76	0.63	2859.93
Ni	25.10	0.04	612.19
Zn	219.25	0.18	1224.86
Cu	36.84	0.03	1473.60
Cr	24.65	0.03	795.00
Mn	46.60	0.04	1259.00
Cd	1.94	0.01	276.00
Pb	11.50	0.04	262.00

Average BAFs and MPI for trace metals in *Lucifer* of Cochin backwaters: The average BAF value of different trace metals in *Lucifer* of Cochin backwater are maximum in Fe: 2859.93, followed by Ni, Zn, Cu, Cr, Mn, Cd and Pb (Table 4). Seasonal variations of BAF for trace metals in *Lucifer* observed at different sites are given in Table 5.

MPI values for *Lucifer* ranged from 23.10 to 34.46, 41.38 to 56.06 and 40.85 to 51.46, respectively, for pre-monsoon, monsoon and post-monsoon periods (Table 6). MPI values of *Lucifer* exhibited higher values during the monsoon period when compared to post-monsoon or pre-monsoon periods. MPI values of *Lucifer* during the pre-monsoon, monsoon and post-monsoon periods showed higher values at station 2 (Bolghatty) when compared to station 5 (Thanneermukkom).

Bioaccumulation factor is a model which considers a ratio of contaminant concentration in biota to its medium of exposure (water) (Battuello et al 2018, Mc Geer et al 2003). This factor gives information about how enriched an organism in a certain trace element with its relation to the

Table 5. Seasonal variations of BAF for trace metals in *Lucifer* observed at different stations at Cochin backwaters

Trace metals (ppm)		Stations				
		S1	S2	S3	S4	S5
Fe	Pre-monsoon	3005.27	1620.61	1354.12	1832.45	1052.95
	Monsoon	3274.32	6063.63	6148.95	5839.99	3531.75
	Post-monsoon	2280.98	2169.35	2910.86	3627.58	2290.37
Ni	Pre-monsoon	449.89	503.06	578.01	1020.93	710.00
	Monsoon	418.99	964.44	1033.85	913.51	2188.94
	Post-monsoon	396.98	457.50	526.44	668.42	976.54
Zn	Pre-monsoon	786.74	737.77	725.46	826.83	2322.71
	Monsoon	1794.99	1513.01	1374.04	1665.60	1690.66
	Post-monsoon	1274.97	1064.11	1387.27	1212.35	2484.62
Cu	Pre-monsoon	1016.18	1700.59	584.49	912.58	1667.51
	Monsoon	3572.25	2403.64	1971.68	2557.91	1978.94
	Post-monsoon	1247.71	909.31	1496.43	929.82	1636.36
Cr	Pre-monsoon	71.00	485.64	432.69	386.53	282.22
	Monsoon	2641.67	1848.28	1961.08	2017.49	1322.54
	Post-monsoon	497.03	824.02	764.30	756.61	616.07
Mn	Pre-monsoon	1294.12	604.46	763.21	1423.70	769.12
	Monsoon	1509.9	1681.83	2171.55	3314.85	2630.00
	Post-monsoon	847.68	471.64	1069.97	1613.75	759.06
Cd	Pre-monsoon	115.86	139.67	267.86	392.50	498.67
	Monsoon	758.33	531.25	531.25	812.50	812.50
	Post-monsoon	156.73	164.06	164.11	543.75	549.38
Pb	Pre-monsoon	145.71	89.18	266.81	159.85	378.27
	Monsoon	177.65	268.72	331.148	488.51	445.60
	Post-monsoon	193.49	222.26	443.50	509.92	258.12

Table 6. Seasonal variation of metal pollution index (MPI) in *Lucifer* at Cochin backwaters

Seasons	Stations				
	S1	S2	S3	S4	S5
Pre-monsoon	34.17	34.46	27.70	32.08	23.10
Monsoon	44.37	56.06	47.25	46.54	41.38
Post-monsoon	42.66	51.46	46.26	45.47	40.85

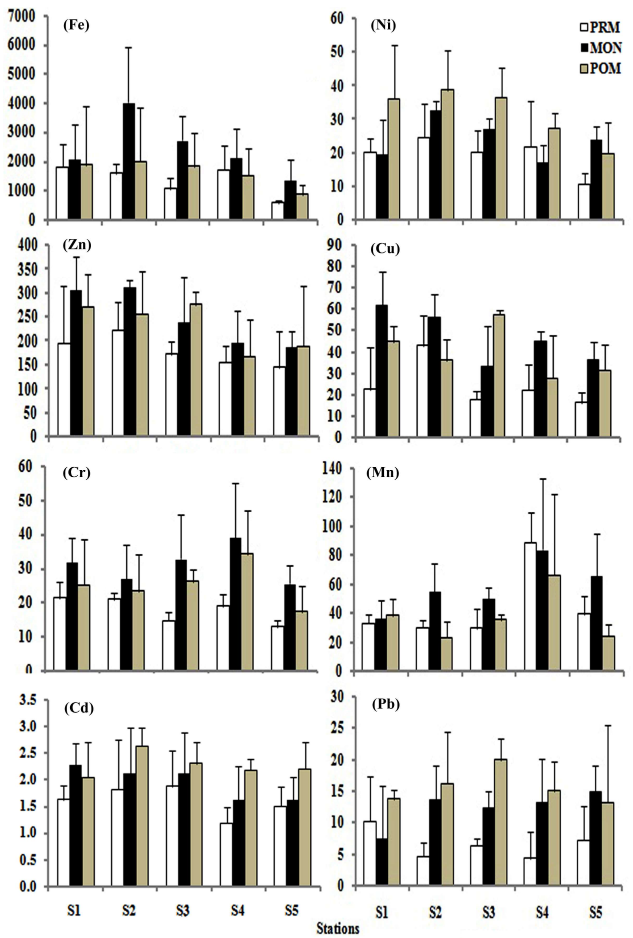

Fig. 2. Seasonal variations of trace metal (ppm) concentrations in *Lucifer* at Cochin backwaters

surrounding medium. The average BAFs in *Lucifer* were in the following order: Fe > Cu > Mn > Zn > Cr > Ni > Cd > Pb. The observed BAFs of each metal remained >100 which indicates that the *Lucifer* has a strong ability to bioconcentrate metals effectively. The high concentrations of metals and high bioaccumulation values indicate that the studied zooplankton group, *Lucifer* has an enormous capacity for the accumulation of trace metals and are thus potentially excellent bioindicator for the evaluation of the contamination of estuarine ecosystems by metals (Rejomon et al 2008a, 2010, Achary et al 2020). The high enrichment of MPI values at station 2, when compared to station 5 of the estuary, could be due to the effluent discharges in this area from the industries that are located at the downstream regions of the river Periyar.

CONCLUSION

Bioaccumulation of trace metals in *Lucifer* collected from the Cochin backwaters showed marked spatial and seasonal variations. *Lucifer* showed a great ability to accumulate metals when compared to their concentrations detected in water. High values of Bioaccumulation factors for trace metals in *Lucifer* reveal an enhanced bioavailability of the studied trace metals in the Cochin backwaters. The high concentrations of metals and high bioaccumulation values indicate that *Lucifer* has an enormous capacity for the accumulation of trace metals and are thus potentially excellent bioindicator for the evaluation of the contamination of estuarine ecosystems by metals.

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