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Seasonal variations in physico-chemical parameters and heavy metals in water and sediments of Uppanar estuary, Nagapattinam, India

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Abstract: *The present study was carried out to determine the physico-chemical characteristics and heavy metals in water and sediments in Uppanar Estuary, Nagapattinam, Southeast coast of India during January to December 2007. The minimum and maximum values of atmospheric and surface water temperatures (°C), salinity (‰), pH and dissolved oxygen (ml l^{-1}) were: 26.0-35.0; 25.0-33.5; 8.0-35.0; 7.2-8.2 and 2.8-5.5 respectively. The ranges of nitrate, nitrite, phosphate and silicate were: 7.05-24.23; 0.82-3.15; 0.31-2.18 and 40.0-198.0 (µM) respectively. The ranges of heavy metals in water (µg 1^{-1}) and sediment (µg g^{-1}) copper, zinc, cadmium and mercury were: 2.45-18.25; 26.43-101.24; 1.23-24.35 and 0.01-0.22 and 5.02-81.27; 22.47-75.42; 2.25-10.06 and 0.01-0.16 respectively.*

Key words: *Physico-chemical parameters, Heavy metals, Uppanar estuary, Nagapattinam*
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Introduction

Many reports are available on the physico-chemical features of Indian estuaries (Govindasamy *et al*., 2000; Rajasegar, 2003; Balasubramanian and Kannan, 2005; Paramasivam and Kannan, 2005; Rajaram *et al*., 2005; Ajithkumar *et al*., 2006; Asha and Diwakar, 2007; Ashok Prabu *et al*., 2008; Saravanakumar *et al.,* 2008; Gowda *et al.,* 2009; Vengadesh *et al*., 2009).

Heavy metals in the sediment are essential to assess the extent of metal pollution. The distribution of heavy metals in solution has widely been recognized as a major factor in the geochemical behavior, transport and biological effects of these elements in natural waters (Ananthan *et al*., 1992, 2005, 2006; Karthikeyan *et al*., 2004, 2007). Moreover, sediment has aptly been called as 'Trace element trap' (Eugenia *et al*., 2004) because they eventually receive almost all the heavy metals, which enter the aquatic environment (Karthikeyan *et al*., 2007). The scavenging by suspending particles results in large concentration of pollutants being retained in estuarine sediments (Jurascic and Prohic, 1986). Sediment samples have also been widely used to monitor heavy metal pollution in coastal areas (Aksu *et al*., 1998; Karthikeyan *et al*., 2007). Heavy metal contamination could frequently be identified through analysis.

Some studies were carried out on the distribution of heavy metals in water and sediments from Indian regions are limited (Pragatheeswaran *et al.,* 1986; Subrahmanyam and Ananthalakshmi Kumari, 1990; Ramachandran, 1990; Satyanarayana *et al*., 1990; Subramanian and Mohanachandran, 1990; Senthilnathan and Balasubramanian, 1997; Ananthan *et al*., 1992, 2005, 2006; Karthikeyan *et al*., 2004, 2007).

Many investigations have been carried out on adsorption of dissolved metals in estuaries in relation with the role of physical and chemical parameters (Zhou and Kot, 1995; Saeedi *et al.,* 2004; Jayaprakash *et al.,* 2005; Adefemi *et al*., 2007). Heavy metal levels in sediment samples were investigated in various water, Turkish Black Sea, Aegean Sea coasts and Marmara Sea (Algan *et al.,* 1999; Kut *et al.,* 2000; Balkys and Cagatay, 2001; Topcuoglu *et al.,* 2002; 2004 a,b; Balkys *et al.,* 2007). No paper has been published on the heavy metal concentrations in Uppanar Estuary, Nagapattinam. Hence, the present study deals with the spatio-temporal variations of physico-chemical parameters and heavy metals distribution (Cu, Zn, Cd and Hg) in water and sediments of Uppanar estuary, southeast coast of India.

Materials and Methods

Uppanar estuary is located in Tranquebar (Lat. 10°25'N; Long. 79°39'E) of the Bay of Bengal, southeast coast of India. On the seashore are found rocks and broken stones of an ancient temple and a fort. About 1 km from the study area at Tranquebar, Uppanar river alone meets the Bay of Bengal.

For the present study, two sampling sites were chosen. Station 1 is 1 km away from the mouth of the Uppanar estuary and the mouth of the estuary sets station 2. Monthly samplings were made during forenoon from January to December 2007 for four seasons *viz.* monsoon (October-December), post-monsoon (January-March), summer (April-June) and pre-monsoon (July-September).

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Field data like temperature, salinity, dissolved oxygen and pH were measured in forenoon. Atmospheric and surface water temperatures were measured using thermometer. Salinity was estimated with a hand refractometer (Atago, Japan) and pH was measured using Elico pH meter (Model LC-120). Dissolved oxygen was estimated by the modified Winkler's method (Strickland and Parsons, 1972). For the analysis of nutrients, surface water samples were collected in clean polyethylene bottles and kept in an ice box and transported immediately to the laboratory. The water samples were filtered using a Millipore filtering system (MFS) and analyzed for dissolved inorganic phosphate, nitrate, nitrite and reactive silicate by adopting the standard methods described by Strickland and Parsons (1972).

The filtered water samples were pre-concentrated with APDC-MIBK extraction procedure as described by Brooks *et al.* (1967) and aspirated to a Flame Atomic Absorption Spectrophotometer (Philips Pye Unicam 9000). Filtered water (1 l) was divided into two 500 ml aliquots and the pH was adjusted to pH 4±0.1 by careful drop-wise addition of 50% HNO_3. The heavy metals were pre-concentrated and separated from the bulk matrix by complexation with APDC and extraction into MIBK. The organic layer containing the metal chelates was collected and was back extracted with 50% HNO_3, and diluted with metal free double distilled water to a minimum quantity (25 ml).

Sediment samples were collected using a pre-cleaned and acid washed PVC corer and samples were transferred to clean polyethylene bags. The samples were stored frozen until analysis. The preserved sediment sub-samples were dried at 150°C for 5-6 hr, ground to powder in a glass mortar, and stored in pre-cleaned polythene bags. Analysis for trace metals was continued by redigesting the sample from which 250 mg was taken and digested with a mixture of 1 ml conc. H_2SO_4, 5 ml conc. HNO_3 and 2 ml of conc. $HClO_4$. A few drops of HF (Hydrofluoric acid) were added in order to achieve complete dissolution of the materials. The mixture was boiled, evaporated to near dryness and the resuspended in 10 ml 2 N HCl. This was passed through a filter paper and made up to 25 ml with metal free double distilled water. The resulting solution was then stored in acid washed Borosil glass vials for Hg and polypropylene containers for other metals. Concentrations of Cu, Zn and Cd in the solution were determined by aspirating the solution to a standard Flame Atomic Absorption Spectrophotometer (Perkin-Elmer model 373) and Hg was determined using a standard mercury analyzer (ECIL) by cold vapors Atomic Absorption Spectrophotometer (Chester and Hughes, 1967). Blank digestions were also carried out.

Simple correlation coefficient (*r*) was made for describing physico-chemical characteristics and two-way analysis (ANOVA) was employed for hydrographic parameters.

Results and Discussion

Atmospheric and surface water temperature varied from 26.0 to 35.0°C and 25.0 to 33.5°C, respectively at the two stations, with minimum and maximum mean values of 31.21±2.64 (Stn. 1) and 31.58±2.63 (Stn. 2), and 29.67±2.62 (Stn. 1) and 30.04±2.36 (Stn. 2). Salinity values varied from 8.0 to 35.0‰, with minimum and maximum mean values of 23.0±8.80‰ (Stn. 1) and 31.75±2.34‰ (Stn. 2). pH in water ranged between 7.2 and 8.2, with minimum and maximum mean values of 7.76±0.38 (Stn. 1) and 7.99±0.22 (Stn. 2). Variation in dissolved oxygen content was from 2.8 to 5.5 ml l^{-1}, with minimum and maximum mean values of 3.55±0.81 ml l^{-1} (Stn. 2) and 3.67±0.95 ml l^{-1} (Stn. 1). Nitrate values varied from 7.05 to 24.23 µM, with minimum and maximum mean values of 12.79±5.09 µM (Stn. 2) and 13.95±5.25 µM (Stn. 1). Nitrite values ranged between 0.82 and 3.15 µM, with minimum and maximum mean values of 1.74±0.71 µM (Stn. 2) and 1.89±0.79 µM (Stn. 1). Phosphate concentration varied from 0.31 to 2.18 µM, with minimum and maximum mean values of 1.04±0.57 µM (Stn. 2) and 1.14±0.66 µM (Stn. 1). Silicate values ranged between 40.0 to 198.0 µM, with minimum and maximum mean values of 81.92±41.44 µM (Stn. 2) and 92.08±51.33 µM (Stn. 1) (Table 1).

Copper in water values varied from 2.45 to 18.25 µg 1^{-1} at the two stations, with minimum and maximum mean values of 10.20±4.24 µg 1^{-1} (Stn. 1) and 10.56±4.66 µg 1^{-1} (Stn. 2). Zinc in water values ranged between 26.43 and 101.24 µg 1^{-1}, with minimum and maximum mean values of 53.19±21.12 µg 1^{-1} (Stn. 2) and 58.74±24.34 µg 1^{-1} (Stn. 1). Cadmium in water concentration varied from 1.23 to 24.35 µg 1^{-1}, with minimum and maximum mean values of 7.38±5.79 µg 1^{-1} (Stn. 1) and 7.43±6.90 µg 1^{-1} (Stn. 2). Mercury in water values ranged between 0.01 to 0.22 µg 1^{-1}, with minimum and maximum mean values of 0.06±0.05 µg 1^{-1} (Stn. 2) and 0.08±0.07 µg 1^{-1} (Stn. 1) (Table 2).

Copper in sediment values varied from 5.02 to 81.27 µg g^{-1} at the two stations, with minimum and maximum mean values of 21.92±16.65 µg g^{-1} (Stn. 1) and 27.09±21.04 µg g^{-1} (Stn. 2). Zinc in sediment values ranged between 22.47 and 75.42 µg g^{-1}, with minimum and maximum mean values of 49.13±15.54 µg g^{-1} (Stn. 1) and 50.26±15.36 µg g^{-1} (Stn. 2). Cadmium in sediment concentration varied from 2.25 to 10.06 µg g^{-1}, with minimum and maximum mean values of 6.63 ±1.82 µg g^{-1} (Stn. 1) and 6.95±2.25 µg g^{-1} (Stn. 2). Mercury in sediment values ranged between 0.01 to 0.16 µg g^{-1}, with minimum and maximum mean values of 0.05±0.03 µg g^{-1} (Stn. 1) and 0.07±0.05 µg g^{-1} (Stn. 2) (Table 2).

Total rainfall (mm) recorded during January to December, 2007 was 1110.4 which ranged between 2 and 537 and there was no rainfall in February, March, May, and June, 2007. In the present study, the peak values of rainfall were recorded during the monsoon month of October. Perumal (1993) has reported the bulk of rainfall during the northeast monsoon season along the southeast coast of India.

The surface water temperature showed an increasing trend from November through June and was influenced by the intensity of solar radiation, evaporation, freshwater influx and cooling and mix

up with ebb and flow from adjoining neritic waters (Ajithkumar *et al*., 2006; Saravanakumar *et al*., 2008). The observed low value of October was due to strong land sea breeze and precipitation and the recorded high value during summer could be attributed to high solar radiation (Ajithkumar *et al*., 2006; Ashok Prabu *et al*., 2008; Rajkumar *et al*., 2009).

The salinity was found to be high during summer season and low during the monsoon season at both the stations. The recorded higher values could be attributed to the low amount of rainfall, higher rate of evaporation and also due to neritic water dominance (Balasubramanian and Kannan, 2005; Sridhar *et al*., 2006; Asha and Diwakar, 2007). During the monsoon season, the rainfall and the freshwater inflow from the land moderately reduced the salinity. Statistical analysis revealed highly significant negative correlation of salinity with rainfall.

Hydrogen ion concentration (pH) in surface waters remained alkaline throughout the study period at both stations with maximum value during the post-monsoon and summer seasons and the minimum during monsoon. Generally, its seasonal variation is attributed to factors like removal of CO_2 by photosynthesis through bicarbonate degradation, dilution of seawater by freshwater influx, low primary productivity, reduction of salinity and temperature, and decomposition of organic matter (Paramasivam and Kannan, 2005; Bragadeeswaran *et al*., 2007). The recorded high summer pH might be due to the influence of seawater penetration and high biological activity (Govindasamy *et al*., 2000) and due to the occurrence of high photosynthetic activity (Sridhar *et al*., 2006; Saravanakumar *et al*., 2008).

It is well known that the temperature and salinity affect the dissolution of oxygen (Saravanakumar *et al*., 2008). In the present investigation, higher values of dissolved oxygen were recorded during monsoon season which might be due to the cumulative effect of higher wind velocity coupled with heavy rainfall and the resultant freshwater mixing (Govindasamy *et al*., 2000; Rajasegar, 2003; Saravanakumar *et al*., 2008). Paramasivam and Kannan (2005) attributed that seasonal variation of dissolved oxygen is mainly due to freshwater flow and terrigenous impact of sediments.

The recorded highest monsoonal nitrate value could be mainly due to the organic materials received from the catchment area during ebb tide (Ashok Prabu *et al*., 2008). Another possible way of nitrate input could be through oxidation of ammonia form of nitrogen to nitrite formation (Rajasegar, 2003). The recorded low values during non-monsoon period may be due to its utilization by phytoplankton as evidenced by high photosynthetic activity and the dominance of neritic seawater having a negligible amount of nitrate (Rajaram *et al*., 2005; Bragadeeswaran *et al*., 2007).

The recorded higher nitrite values during monsoon season could be due to the increased phytoplankton excretion, oxidation of ammonia, reduction of nitrate, and the recycling of nitrogen and bacterial decomposition of planktonic detritus (Govindasamy *et al*., 2000; Asha and Diwakar, 2007), and also due to denitrification and air-sea interaction exchange of chemicals (Rajasegar, 2003; Ashok Prabu *et al*., 2008). The recorded low nitrite value during summer season may be due to high salinity (Saravanakumar *et al*., 2008).

The observed high monsoonal phosphate value might be due to the regeneration and release of total phosphorus from bottom mud into the water column by turbulence and mixing (Saravanakumar *et al*., 2008). Moreover, the bulk of weatherings of rocks soluble alkali metal phosphates (in the upstream area) are carried into the estuaries (Govindasamy *et al*., 2000). The addition of super phosphates applied in the agricultural fields as fertilizers and alkyl phosphates used in households, as detergents can be other sources of inorganic phosphates during the season (Bragadeeswaran *et al*., 2007). The post-monsoonal low value could be attributed to the limited flow of freshwater, high salinity and utilization of phosphate by phytoplankton (Rajasegar, 2003). The variation may also be due to the processes like adsorption and desorption of phosphates and buffering action of sediment under varying environmental conditions (Rajasegar, 2003).

The silicate content was higher than that of the other nutrients and the recorded high monsoon values could be due to large influx of freshwater derived from land drainage carrying silicate leached out from rocks and also from the bottom sediment (Govindasamy *et al*., 2000; Rajasegar, 2003). The removal of silicates by adsorption and co-precipitation of soluble silicate silicon with humic compounds and iron (Rajasegar, 2003). The observed low summer and post-monsoonal values could be attributed to uptake of silicates by phytoplankton for their biological activity (Ashok Prabu *et al*., 2008; Saravanakumar *et al*., 2008).

Concentrations of heavy metals in water at the two stations varied seasonally. Variability in the distribution of metals appeared to be more related to hydrobiological conditions. Concentrations of dissolved metals especially of Cu and Zn were high during the summer season. Cd and Hg concentrations were high during the summer and post-monsoon season. Generally, the natural sources of heavy metals in coastal waters are through land and river runoff, and the mechanical and chemical weathering of rocks. The components also were washed from the atmosphere through rainfall, wind blown dust, forest fire, and volcanic particles, adding to the distribution of heavy metals in water (Bryan, 1984). Low levels of Cu in the surface water during the monsoon could be due to the adsorption of Cu on to the particulate matter and consequent settlement to the bottom.

Low level of Hg in the surface waters might have been caused by the higher ingestion rate of organisms, resuspension of sediments and absorption onto the particulates during the monsoon season at this station. In both stations, the same trend of abundance of different metals was observed in the present study: the essential metal (Zn) recording the maximum concentration and the non-essential metal (Hg) recording the minimum concentration, as

Table – 1: Seasonal variations in physico-chemical parameters of Uppanar estuary during January to December 2007

Parameter		Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
Atmospheric temperature (°C)	St.1	29	32	34	32	34	35	33	30	31	26	28.5	30
	St.2	29.5	32	35	33	34.5	35	33	30	31.5	27	28.5	30
Surface water temperature (°C)	St.1	28	29	33	30	33	33.5	31.5	28.5	28.5	25	27	29
	St.2	28	30	33	31	33	33	32	29	29	26	27.5	29
Salinity (‰)	St.1	26	28	31	30	31	33	28	20	16	8	15	10
	St.2	30	31	34	33	34	35	34	33	30	28	29	30
pH	St.1	7.3	8	8.1	8.1	8.2	8.2	8	7.4	7.7	7.2	7.5	7.4
	St.2	8.1	8.1	8.2	8.1	8.2	8	8.1	7.9	8	7.4	7.8	8
Dissolved oxygen (ml l^{-1})	St.1	3.1	3.1	2.9	3	2.8	2.9	3.2	4.2	3.5	5.5	4.8	5
	St.2	3.1	3	3.1	2.9	2.9	2.8	3.1	4	3.4	5.2	4.5	4.6
Nitrate (µM)	St.1	16.35	10.52	9.35	11.25	9.26	8.15	11.04	14.26	12.23	24.23	19.65	21.15
	St.2	15.22	9.25	8.95	10.52	8.26	7.05	10.65	12.68	10.58	23.85	17.25	19.26
Nitrite (µM)	St.1	1.96	1.24	1.02	1.16	1.02	0.98	2.05	2.74	2.15	3.15	2.85	2.34
	St.2	1.82	1.16	1.01	1.09	1	0.82	1.98	2.58	1.91	2.97	2.35	2.14
Phosphate (µM)	St.1	0.61	0.52	0.35	0.81	0.57	0.78	0.98	1.98	1.24	2.18	1.75	1.96
	St.2	0.58	0.5	0.31	0.79	0.61	0.75	0.85	1.57	1.04	2.01	1.66	1.82
Silicate (µM)	St.1	60	52	50	68	48	52	67	124	95	198	115	176
	St.2	52	40	47	63	45	51	65	117	90	160	108	145

Table – 2: Seasonal variations in heavy metals in water (µg l^{-1}) and sediments (µg g^{-1}) of Uppanar estuary during January to December 2007

Parameter		Jan.	Feb.	Mar.	Apr.l	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
							Water						
Copper	St.1	2.45	6.87	8.76	10.59	15.98	17.25	5.89	9.86	14.58	8.79	9.86	11.48
	St.2	4.05	9.87	17.95	9.87	13.97	18.25	5.89	9.76	12.25	3.96	9.71	11.21
Zinc	St.1	34.51	65.48	78.54	26.43	79.85	101.24	26.45	48.3	68.84	36.12	59.75	79.42
	St.2	29.45	43.75	52.34	32.15	72.45	92.15	29.51	49.68	63.41	30.14	67.48	75.72
Cadmium	St.1	1.75	9.63	18.45	7.98	5.67	8.15	2.35	10.82	16.84	1.37	2.45	3.04
	St.2	1.84	7.58	24.35	4.34	4.87	5.36	1.23	9.62	17.21	1.24	4.59	6.87
Mercury	St.1	0.041	0.057	0.095	0.103	0.215	0.221	0.028	0.039	0.057	0.031	0.039	0.054
	St.2	0.021	0.189	0.154	0.032	0.083	0.0143	0.042	0.047	0.053	0.012	0.049	0.067
							Sediments						
Copper	St.1	6.97	42.1	65.72	14.5	18.4	24.87	13.2	16.89	20.69	5.78	19.41	14.53
	St.2	5.02	53.68	81.27	15.89	18.65	24.53	24.78	27.86	25.04	6.35	17.83	24.12
Zinc	St.1	48.53	51.23	67.46	26.47	48.65	63.1	22.47	48.52	75.42	36.41	46.21	55.09
	St.2	43.41	55.47	62.14	28.79	58.78	71.26	27.6	63.15	69.39	48.57	40.38	34.19
Cadmium	St.1	6.14	7.88	10.06	7.15	2.98	4.89	5.78	5.89	6.02	6.76	7.38	8.63
	St.2	6.47	7.12	8.69	2.25	3.75	6.43	5.43	7.76	9.68	7.68	8.88	9.21
Mercury	St.1	0.026	0.069	0.089	0.022	0.098	0.054	0.045	0.016	0.023	0.039	0.025	0.043
	St.2	0.021	0.163	0.148	0.029	0.079	0.115	0.038	0.049	0.057	0.012	0.054	0.072

observed by Ramachandran (1990) in the Bay of Bengal along the Tamil Nadu coast.

Levels of the metals observed in the present study are significantly higher or similar to the levels reported from the coastal and nearshore waters in and around India especially from the Bay of Bengal. It is therefore concluded that the Tranquebar coastal area is getting polluted with these metals, thus substantiating the view of Ramachandran (1990) who reported that the coastal waters of Tamil Nadu state are likely polluted with heavy metals.

When compared to water, sediments contained very high concentration of metals. Concentration of heavy metals in the sediments showed spatial and temporal variations at Uppanar estuary during the study period. Cd and Zn concentrations were high at station 1 whereas Cu and Hg concentrations were high at station 2. At both stations, Cu and Cd concentrations were high during the post-monsoon season. Zn and Hg concentrations were high during the pre-monsoon, summer and post-monsoon. The higher concentration of metals observed during monsoon could be attributed to the heavy rainfall and subsequent river runoff, bringing much industrial and land derived materials along with domestic, municipal, and agricultural wastes, which include residues of heavy metal containing pesticides (Pragatheeswaran *et al*., 1986; Senthilnathan and Balasubramanian, 1997; Ananthan *et al*., 1992, 2005, 2006; Karthikeyan *et al*., 2004, 2007).

Zn and Cu always have a tendency to couple with organic carbon. Decomposition of the organic matter remain are found to release heavy metals back to sediments and accumulated; and this process might be responsible for the strong association of Zn and Cu with organic carbon (Bardarudeen *et al*., 1996). Higher organic carbon values recorded in the post-monsoon coincided with the elevated level of Zn and Cu in sediments. Besides, the release of organically bound heavy metals through influx from land runoff might have also contributed elevated level of Zn and Cu, despite they are meager in amount. Zn and Cu are generally good indicators of anthropogenic inputs (Forstuer and Wittman, 1979). The extensive use of antifouling paints during the peak fishing season in post-monsoon would have released cuprous oxide which in turn enriches the Cu content in the water (Ananthan *et al*., 1992, 2005, 2006). Eventually, it would be settled from the water column by flocculation and sedimentation (Karthikeyan *et al*., 2007).

In summer, these metals might slightly elevated in content because the low salinity and high pH water might have caused the adsorption of these metals, leading to their removal from the water column. The low concentration of Zn and Cu in monsoon might be due to the prevailing lower pH which renders dissolved metal carbonate complexes to release free metal ions into the water column. In addition, phytoplankton activity can also cause seasonal variation in Cu as this metal is an essential one for phytoplankton (Govidasamy and Azariah, 1999). Ananthan *et al*. (2005) found that phytoplankton could consume more Cu and Zn. Evidently high density of phytoplankton population during monsoon consumed more Cu and Zn, leading to their low concentration in the monsoon season. Colloidal and particular fractions of metals are highly correlated with finer fraction of sediments.

The relative enrichment of Cd (at station 1) and Cu (at station 2) in the near shore sediments during the post-monsoon could be attributed to the particulate fractions derived from the river runoff caused by monsoonal flow and occurrence of relatively higher percentage of particulate matter (Satyanarayana *et al*., 1990; Ananthan *et al*., 1992, 2005, 2006).

Sediments are the principal sites of Hg accumulation in the estuarine environment. During the pre-monsoon season, less land drainage and rainfall and less turbulence resulted in stagnant condition rather than mixing thus facilitating higher accumulation of Zn and Hg in the sediments. In addition, excretion and elimination of exoskeletons by abundantly occurring plankton and by settlement of particulate matter probably have played a significant role in enhancing the concentration of Hg and Zn in the sediments. High metal concentrations in sediment at station 1 could have been resulted from the fresh water inputs through Uppanar river along with land drainages. Fishing activities and anthropogenic activities might have increased the Cd and Hg levels in nearshore sediments. Metals in sediments at the two stations showed a similar trend of distribution. Among the essential metals, only Cu and Zn recorded the maximum concentrations whereas the non-essential metals Cd and Hg showed the minimum concentrations.

The present baseline information of the physico-chemical parameters, heavy metals in water and sediments would form a useful tool for further ecological assessment and monitoring of these coastal ecosystems of Uppanar estuary.

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