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RESEARCH ARTICLE

HEAVY METAL CONCENTRATION IN WATER AND SEDIMENT SAMPLES OF HIGHLY POLLUTED CUDDALORE COAST, SOUTHEASTERN INDIA

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ABSTRACT

The present study aims to analyze the monthly variations of heavy metals like Cu, Cd, Zn and Pb in water and sediment samples collected from Cuddalore coast during January to December 2011. The result showed that the accumulation of heavy metals in sediments was higher than the water due to the metal sink in sediment as well as the fresh water runoff. The Cuddalore coast receives the waste from SIPCOT industries, municipal wastes, mining wastes, aquaculture and agricultural discharges are the sources to pollute the study area. The availability of metals in water samples increased in the order: Cu<Cd<Zn<Pb and in sediments: Cd<Cu<Zn<Pb. Two ANOVA analyses were performed to find out the significant or insignificant variations of heavy metals in water and sediment samples via month wise and station wise

INTRODUCTION

Heavy metals in aquatic environments are increasingly recognized as important intermediate sources for subsequent pollution in aquatic ecosystems or public health. Considerable efforts have been expended to assess their presence in harbors and estuaries. After being released from natural background or anthropogenic sources near the land surface, e.g., rivers carrying significant metal loadings, soluble heavy metal species are immobilized and deposited onto the sediment surfaces through various mechanisms (Lin *et al*., 2013). These immobilization mechanisms include adsorption onto soil/sediments by ion exchange, coagulation with dissolved or suspended species in water (organic matter), incorporation into the lattice structure of minerals, and precipitation by forming insoluble species of heavy metals (Du Laing *et al*., 2009). The determination of the total concentrations of metals in sediments is not sufficient to be able to predict the capacity for mobilization of these elements. The environmental behaviour of trace metals is critically dependent on their chemical form, that which influences mobility, bioavailability and toxicity to marine organisms (Passos *et al*., 2010). Activities such as mining, agriculture and industrial plants with large urban settlements systematically produce pollutants that are discharged in a dissolved form or suspended in material in rivers, thus significantly decreasing water quality and increasing the ecological risk to human health (Harguinteguy *et al*., 2014).

Heavy metals, such as Cd, Cu, Pb and Zn are elements that cannot be degraded by microbial or chemical process; therefore, they tend to accumulate in soils and aquatic sediment. The problem is not restricted to soils with high metal levels, such as those of mining areas, as well as includes those with moderate to low metal contamination (Eid *et al*., 2012). Metal contamination in aquatic environments has received much concern due to its toxicity, large quantity and persistence in the environment, and consequent accumulation in aquatic habitats. Heavy metal residues in contaminated habitats may accumulate in microorganisms like aquatic flora and fauna, which may enter into the human through food chain transfer and result in health problems (Varola and Şen, 2012). The change in environmental conditions such as pH, redox potential, naturally organic matters and sediment texture may affect their mobilization of metals from sediments (Choi *et al*., 2006). The trace metals associated with coarse particles may deposit on the upstream area of the estuary, while dissolved trace metal sand those associated with fine particles could be transported to downstream to the surrounding coastal area by physical transportation (Doong *et al*., 2008). Marine ecosystems are highly vulnerable to pollution due to their recipient position from continents, but their size and complexity often makes it difficult to evaluate the real impact of anthropogenic interference. For instance, heavy metal pollution is a serious worldwide problem for wildlife conservation due to the metals toxic effect on the biota (Belabed *et al*., 2013). In the present study water and sediment samples were collected from station

1 to 8 in Cuddalore coast for the estimation of heavy metals like Cd, Cu, Pb & Zn for the period from January to December 2011.

MATERIALS AND METHODS

Study area

The surface water and sediment samples were collected from 8 different stations along the Cuddalore coast, southeast coast of India. The sampling stations like station 1 and station 2 is a small fishing village in Cuddalore is located on the bank of Uppanar estuary. The Uppanar estuary runs behind the SIPCOT industrial complex. It originates from the north eastern part of the Shervarayan hills and opens into the Bay of Bengal near Cuddalore. This estuary receives untreated and partially treated industrial effluents containing toxic wastes from nearly 55 industries of SIPCOT industrial complex (Rajaram *et al*., 2005).

Station 3 is located at 1km away from the sea mouth where the discharged industrial effluents were mixed and diluted while at station 6 the source of pollution by many tourism related anthropogenic activities which is situated at sea shore of Cuddalore Old Town. The station 4 is one of the longest coastal line in Cuddalore. The small scale fishing activities is occurred in this area. Station 5 and station 7 are the polluted area in Cuddalore old town and these areas are located in the Gadilum river mouth. This station 4 and 5 are engaged with fishing related activities including processing and marketing of fish, repair of boats as well as other commerce and services. These stations are the major dumping places for fish waste, domestic discharge, boatyard activities etc. The station 8 receives illegal dumping of industrial toxic wastes through pipeline from SIPCOT industries. Monthly samplings were made during forenoon from January to December 2011 in all the stations (Fig. 1).

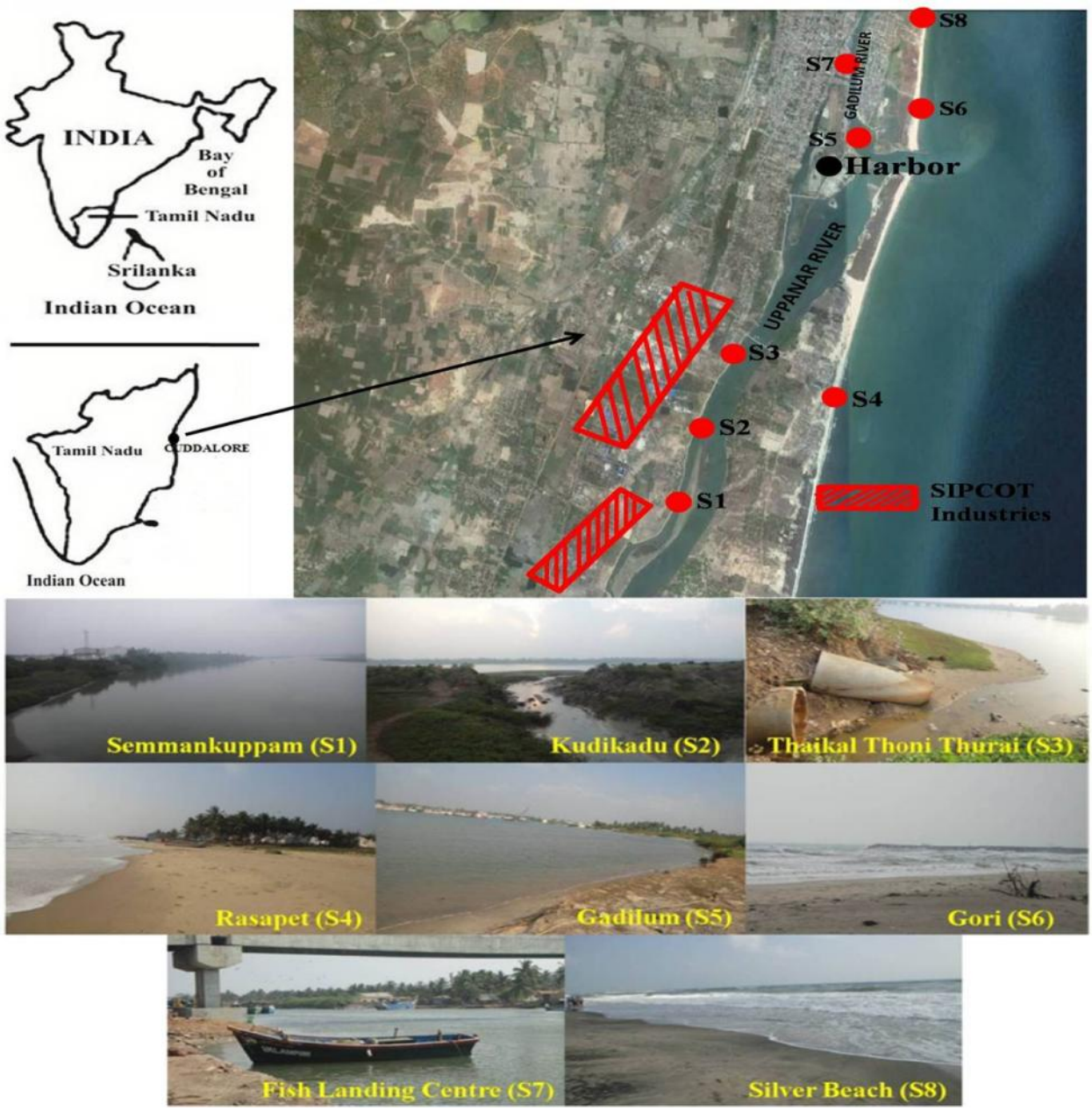

Fig. 1. Sampling Stations along the Cuddalore Coast

Surface water and sediment sample collection

The one litre polyethylene bottles were washed with sterilized water and acid to remove the minor elements and the water samples were collected in the bottles. The samples acidified with 1ml of concentrated HNO_3 and brought to laboratory for analysis of heavy metal. The sediments samples were collected from all the stations using sterilized PVC plastic pipe (1cm diameter and 3m length) at 1m depth and kept in zip-lock polythene bags. The collected sediment samples were transported to laboratory and dried at room temperature for 5 days.

Heavy metal extraction from water

The preserved 1liter of water samples were filtered through Whatman filter paper and taken into an acid-cleaned separating funnel (2 litres), 10ml of 1% ammonium pyrolidine dithio carbomate (APDC) that binds with metal ions and the extracted with isobutyl methyl ketone (MIBK) after shaking with 10minutes (Jonathan *et al*., 2009). The organic phase (upper layer) was collected and aqueous phase (lower layer) was removed. 50% of HNO_3 was added to organic phase and makeup to 25ml with distilled water.

Heavy metal extraction from sediment

The concentration of heavy metal in sediment samples was analyzed using acid-digestion method by following Kumar *et al*. (2008) with slight modifications. The dried sediments were grained using mortar and pestle, sieved through 2mm sieve for metal analysis. 1gm of grained sediment was digested with 5ml of acid mixture HNO_3, $H2SO_4$ and $HCLO_4$ (1:5:2 ratio) and the mixture was dried using hotplate. The complete digestion was achieved by adding the few drops of HCl were added with dried mixture and the makeup to 25ml with milli Q water for metal analysis.

Metal analysis

The different heavy metals such as Copper, Cadmium, Zinc and Lead present in the water and sediment extracts were analyzed using Flame Atomic Absorption Spectrometer (FAAS) (GBC HG 3000; Sens AA, Australia).

Statistical analysis

The collected data were subjected to statistical analysis. Two-way analysis of variance was used to test differences. All the data were analyzed statistically applying for all the studied parameters (Graph Pad Prism, Ver. 5.0).

RESULTS

The water and sediment samples were collected from 8 stations at in and around the Cuddalore coastal area, Southeast Coast of India. Heavy metal such as cadmium, copper, zinc and lead were analyzed in water and sediment samples at ppm concentration.

Heavy metals in water

Copper

The concentration of Copper in water samples at eight stations were analyzed and differed between 0.059 to 0.831ppm in the study area (Fig. 2a).

In station 1, the Cu concentration was varied from 0.126 (September 2011) to 0.831 (December 2011) ppm. In station 2, the high concentration was recorded at December 2011 (0.369ppm) and the low concentration was recorded at September 2011 (0.063ppm). The mean concentration of Cu at station 3 varied from 0.123 to 0.391ppm in September 2011 and October 2011. In station 4, the Cu concentration was varied from 0.059 (July 2011) to 0.666 (May 2011).In station 5, has a range of 0.076 to 0.359 ppm in December 2011 and August 2011. In station 6, the low concentration was recorded at 0.071 ppm in September 2011 and high concentration was recorded at 0.753 ppm in November 2011. In station 7, the Cu was varied from 0.076 ppm (September 2011) to 0.474 ppm (October 2011). In station 8, the high concentration was recorded at August 2011 (0.61 ppm) and low concentration was recorded at June 2011 (0.097 ppm).

Cadmium

The concentration of Cadmium in water samples at eight stations were analyzed and differed between 0.001 to 1.507ppm in the study area (Fig. 2b). In station 1, the Cd concentration was varied from 0.02 (April 2011) to 0.91 (October 2011) ppm. In station 2, the high concentration was recorded at December 2011 (0.004ppm) and the low concentration was recorded at May 2011 (0.425ppm). The mean concentration of Cd at station 3 varied from 0.007 to 1.507ppm in May 2011 and September 2011. In station 4, the Cd concentration was varied from 0.023 (December 2011) to 0.089 (June 2011). In station 5, has a range of 0.003 to 0.398 ppm in November 2011 and August 2011. In station 6, the low concentration was recorded at 0.012 ppm in October 2011 and high concentration was recorded at 0.102 ppm in November 2011. In station 7, the Cd was varied from 0.004 ppm (June 2011) to 0.325 ppm (August 2011). In station 8, the high concentration was recorded at September 2011 (0.671 ppm) and low concentration was recorded at August 2011 (0.001 ppm).

Zinc

The concentration of Zinc in water samples at eight stations were analyzed and were differed between 0.254 to 0.817ppm in the study area (Fig. 2c). In station 1, the Zn concentration was varied from 0.254 (December 2011) to 0.671 (May 2011) ppm. In station 2, the high concentration was recorded at June 2011 (0.817ppm) and the low concentration was recorded at September 2011 (0.255ppm). The mean concentration of Zn at station 3 varied from 0.259 to 0.393ppm in August 2011 and June 2011. In station 4, the Zn concentration was varied from 0.284 (November 2011) to 0.414 ppm (December 2011). In station 5, has a range of 0.271 to 0.404 ppm in October 2011 and December 2011. In station 6, the low concentration was recorded at 0.282 ppm in September 2011 and high

concentration was recorded at 0.465 ppm in May 2011. In station 7, the Zn was varied from 0.294 ppm (September 2011) to 0.661 ppm (June 2011). In station 8, the high concentration was recorded at November 2011 (0.256 ppm) and low concentration was recorded at May 2011 (0.459 ppm).

ppm (November 2011) to 1.022 ppm (January and August 2011). In station 8, the high concentration was recorded at November 2011 (0.001 ppm) and low concentration was recorded at September 2011 (0.98 ppm).

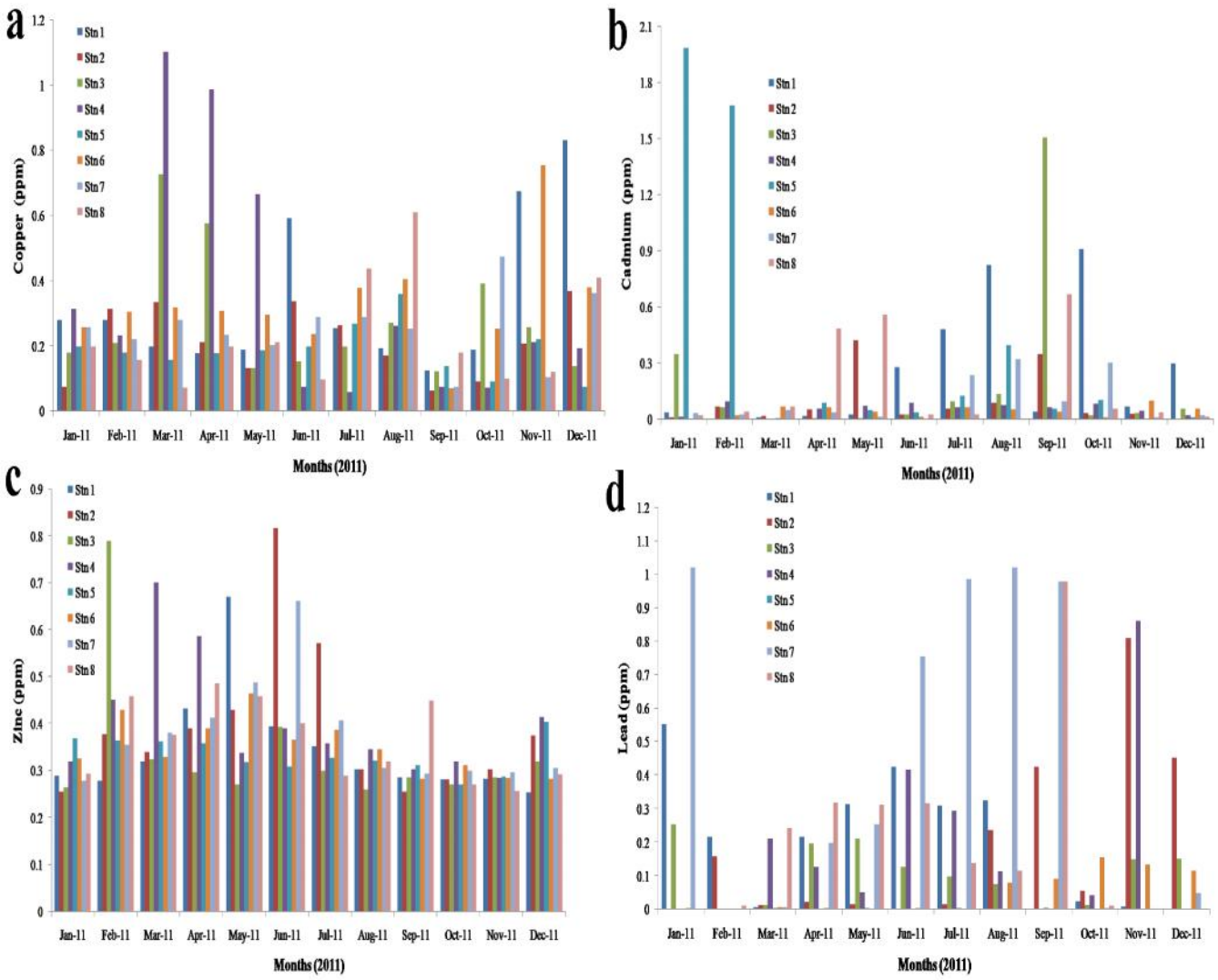

Fig. 2 a-d Concentration of Heavy Metals (Cu, Cd, Zn & Pb) in water samples collected from station 1 to station 8 during January to December 2011

Lead

The concentration of Lead in water samples at eight stations were analyzed and were differed between 0.001 to 1.124ppm in the study area (Fig. 2d). In station 1, the Pb concentration was varied from 0.001 (December 2011) to 0.425 (June 2011) ppm. In station 2, the high concentration was recorded at November 2011 (0.811ppm) and the low concentration was recorded at June 2011 (0.001ppm). The mean concentration of Pb at station 3 varied from 0.002 to 0.212ppm in September 2011 and May 2011. In station 4, the Pb concentration was varied from 0.001 (December 2011) to 0.861(November 2011).In station 5, has a range of 0.001 to 0.003 ppm in December 2011 and July 2011. In station 6, the low concentration was recorded at 0.001 ppm in July 2011 and high concentration was recorded at 0.154 ppm in October 2011. In station 7, the Pb was varied from 0.002

Heavy metals in Sediment

Copper

The concentration of Copper in sediment samples at eight stations were analyzed and differed between 0.45 to 30.85 ppm in the study area (Fig. 3a). In station 1, the Cu concentration was varied from 0.45 (April 2011) to 30.27 (June 2011) ppm. In station 2, the high concentration was recorded at January 2011 (18.7ppm) and the low concentration was recorded at April 2011 (0.45ppm). The mean concentration of Cu at station 3 varied from 0.525 to 24.325ppm in March 2011 and May 2011. In station 4, the Cu concentration was varied from 0.55 (March 2011) to 6.77 (February 2011).In station 5, has a range of 0.625 to 18.375 ppm in March 2011 and January 2011. In station 6, the low concentration was recorded at 0.45 ppm in March 2011 and high concentration was recorded at 23.1 ppm

in April 2011. In station 7, the Cu was varied from 0.475 ppm (March 2011) to 30.85 ppm (January 2011). In station 8, the high concentration was recorded at July 2011 (7.125 ppm) and low concentration was recorded at March 2011 (0.65 ppm).

Cadmium

The concentration of Cadmium in sediment samples at eight stations were analyzed and differed between 0.025 to 4.95ppm in the study area (Fig. 3b). In station 1, the Cd concentration was varied from 0.05 (October 2011) to 2.375 (December 2011) ppm. In station 2, the high concentration was recorded at December 2011 (4.95 ppm) and the low concentration was recorded at February 2011 (0.15ppm). The mean concentration of Cd at station 3 varied from 0.05 to 1.475ppm in June 2011 and November 2011. In station 4, the Cd concentration was varied from 0.25 (August 2011) to 1.3 (October 2011).In station 5, has a range of 0.375 to 3.65ppm in May 2011 and September 2011. In station 6, the low concentration was recorded at 0.025 ppm in July 2011 and high concentration was recorded at 1.225 ppm in October 2011. In station 7, the Cd was varied from 0.175 ppm (June 2011) to 2.525 ppm (March 2011). In station 8, the high concentration was recorded at December 2011 (1.375 ppm) and low concentration was recorded at May 2011 (0.1 ppm).

Zinc

The concentration of Zinc in sediment samples at eight stations were analyzed and differed between 0.1 to 35.85 ppm in the study area (Fig. 3c). In station 1, the Zn concentration was varied from 0.325 (August 2011) to 19.775 (November 2011) ppm. In station 2, the high concentration was recorded at September 2011 (12.95ppm) and the low concentration was recorded at April 2011 (0.1ppm). The mean concentration of Zn at station 3 varied from 0.225 to 35.85 ppm in January 2011 and May 2011. In station 4, the Zn concentration was varied from 0.875 (September 2011) to 19.3(November 2011). In station 5, has a range of 1.15 to 4.075 ppm in October 2011 and July 2011. In station 6, the low concentration was recorded at 0.254 ppm in March 2011 and high concentration was recorded at 16.55 ppm in April 2011. In station 7, the Zn was varied from 0.125 ppm (January2011) to 20.1 ppm (April 2011). In station 8, the high concentration was recorded at August 2011 (18.125 ppm) and low concentration was recorded at March 2011 (0.125 ppm).

Lead

The concentration of Lead in sediment samples at eight stations were analyzed and differed between 0.75 to 112.25ppm in the study area (Fig. 3d). In station 1, the Pb concentration was

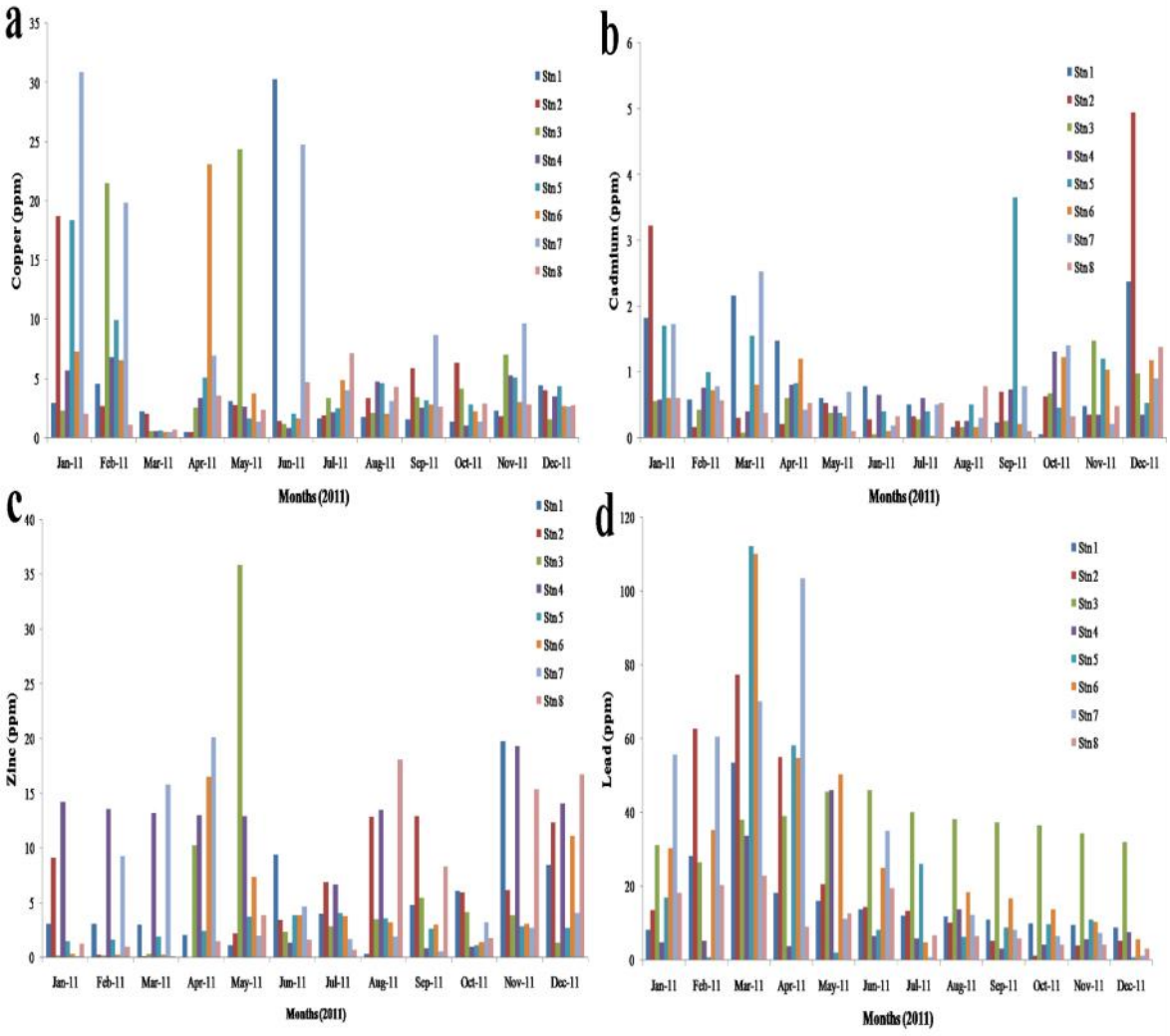

Fig. 3a-d Concentration of Heavy Metals (Cu, Cd, Zn and Pb) in sediment samples collected from station 1 to station 8 during January to December 2011

varied from 8.225 (January 2011) to 53.6 (March 2011) ppm. In station 2, the high concentration was recorded at March 2011 (77.375ppm) and the low concentration was recorded at October 2011 (1.225ppm). The mean concentration of Pb at station 3 varied from 26.525 to 46.154ppm in February 2011 and June 2011. In station 4, the Pb concentration was varied from 3.15 (September 2011) to 46.275 (May 2011). In station 5, has a range of 0.75 to 112.25 ppm in February 2011 and March 2011. In station 6, the low concentration was recorded at 4.975ppm in July 2011 and high concentration was recorded at 110.3 ppm in March 2011. In station 7, the Pb was varied from 0.825 ppm (July 2011) to 103.7 ppm (April 2011). In station 8, the high concentration was recorded at December 2011 (3.1 ppm) and low concentration was recorded at March 2011 (22.875ppm).

Statistical analysis

Two ANOVA results showed that the heavy metal concentration in water was insignificantly varies over the month wise rather than the station wise although the concentration of Cu in sediment samples was not significant at station wise and month wise (p>0.005%). Two way ANOVA showed that the significant variations at station wise (p<0.005%) were obtained in zinc and cadmium and insignificant at month wise (p>0.005%) in water samples while in sediment samples the concentration of Cd and Zn was not significant (p>0.005%) over the station wise and also month wise. The significant variation of lead concentration at month wise (p>0.005%) and insignificant at station wise in water samples was obtained from Two way ANOVA analysis. While the concentration of lead in sediment samples was significantly varies over the station wise and month wise (Table 1 & 2).

DISCUSSION

In the modern world, the source for the heavy metal wastes to coastal environment from various activities such as anthropogenic, industrial discharge, agriculture and aquaculture wastes, river run off etc., that cannot be averted by naturally or mechanically. The effect of heavy metals on aquatic organisms depends upon the concentration that leads to affect the total marine environment. In the present study, the concentration of heavy metals was differed owing to the existence and seasonal divergence in both the water and sediment samples. Due to the effortless settling ability of metals, sediments have high concentration than water in all the stations. There are 8 stations selected along the Cuddalore coastal area were based on the discharge of industrial wastes, anthropogenic activities etc., to analyse the heavy metal concentration in water and sediment samples. The heavy metals like cadmium, copper, zinc and lead were analysed in the collected samples.

Agricultural and industrial activities are mainly responsible for elevated levels of the measured elements in river water. The mean values of the elements at different stations showed that, Pb was the most abundant element in all stations followed by Zn, Cd and Cu. Generally, all the metals had a higher concentration at station 2 and 3. This may be due to the large quantities of sewage, industrial wastes and also agricultural discharges received by this station. It was found that these stations are rich in organic carbon (Mathivanan *et al*., 2014), and many authors found a correlation between the concentration of heavy metals in the water and the abundance of organic matter (Sankar *et al*., 2010). The highest levels in the water were found during summer, while the lowest values

Table 1. Two way ANOVA and seasonal variations of heavy metals in water samples of study area (mean± standard deviation)

Metals	Stations	Minimum	Maximum	Average	STDV	Factor	*df*	F- Value	P-Value	MS
	1	0.126	0.83	0.35	0.23					
	2	0.063	0.37	0.21	0.11					
	3	0.123	0.73	0.30	0.19					
Copper	4	0.059	1.10	0.39	0.35	Stations	11	1.397	0.195	0.050
	5	0.076	0.36	0.19	0.07	Months	7	1.240	0.291	0.044
	6	0.071	0.75	0.34	0.16					
	7	0.076	0.47	0.26	0.10					
	8	0.074	0.61	0.25	0.16					
	1	0.004	0.91	0.28	0.32					
	2	0.004	0.43	0.11	0.14					
	3	0.002	1.51	0.27	0.42					
Cadmium	4	0.004	0.10	0.06	0.03	Stations	11	3.59	0.0004	0.034
	5	0.003	1.99	0.47	0.68	Months	7	0.77	0.6112	0.007
	6	0.004	0.10	0.05	0.03					
	7	0.004	0.33	0.11	0.12					
	8	0.001	0.67	0.19	0.24					
	1	0.254	0.67	0.36	0.11					
	2	0.255	0.82	0.41	0.16					
	3	0.259	0.79	0.36	0.14					
Zinc	4	0.284	0.70	0.41	0.12	Stations	11	3.590	0.0004	0.034
	5	0.271	0.40	0.33	0.04	Months	7	0.773	0.6112	0.007
	6	0.282	0.47	0.35	0.06					
	7	0.278	0.66	0.39	0.11					
	8	0.256	0.49	0.36	0.08					
	1	0.001	0.55	0.21	0.19					
	2	0.001	0.81	0.22	0.25					
	3	0.002	0.25	0.11	0.09					
	4	0.000	0.86	0.21	0.25	Stations	11	1.243	0.274	0.074
Lead	5	0.001	0.00	0.00	0.00	Months	7	3.521	0.002	0.210
	6	0.001	0.15	0.05	0.06					
	7	0.002	1.02	0.45	0.45					
	8	0.001	1.12	0.26	0.31					

Table 2. Two way ANOVA and seasonal variations of heavy metals in sediment samples of study area (mean± standard deviation)

Metals	Stations	Minimum	Maximum	Average	STDV	Factor	*df*	F- Value	P-Value	MS
	1	0.45	30.28	6.22	7.97					
	2	0.45	18.70	5.01	4.76					
	3	0.53	24.33	7.04	7.86					
Copper	4	0.55	6.78	3.30	1.98	Stations	11	1.930	0.048	70.23
	5	0.63	18.38	5.63	4.74	Months	7	1.350	0.238	49.12
	6	0.45	23.10	5.99	5.90					
	7	0.48	30.85	10.34	9.94					
	8	0.65	7.13	3.17	1.69					
	1	0.05	2.38	0.97	0.79					
	2	0.15	4.95	1.21	1.47					
	3	0.05	1.48	0.53	0.40					
Cadmium	4	0.25	1.30	0.63	0.28	Stations	11	2.434	0.011	1.255
	5	0.38	3.65	1.19	0.92	Months	7	1.186	0.320	0.611
	6	0.03	1.23	0.63	0.45					
	7	0.18	2.53	0.94	0.68					
	8	0.10	1.38	0.54	0.33					
	1	0.33	19.78	6.10	5.16					
	2	0.10	12.95	6.12	4.83					
	3	0.23	35.85	7.62	9.63					
Zinc	4	0.88	19.30	10.29	6.06	Stations	11	1.264	0.261	45.98
	5	1.15	4.08	2.68	0.96	Months	7	1.507	0.177	54.81
	6	0.25	16.55	5.08	4.81					
	7	0.13	20.10	6.18	6.19					
	8	0.13	18.13	6.34	6.76					
	1	8.23	53.60	18.86	12.55					
	2	1.23	77.38	25.83	25.45					
	3	26.53	46.15	37.05	5.53					
Lead	4	3.15	46.28	13.62	13.45	Stations	11	7.524	0.0001	2173
	5	0.75	112.25	26.79	31.86	Months	7	3.817	0.0013	1102
	6	4.98	110.30	35.14	29.00					
	7	0.83	103.70	34.14	33.00					
	8	3.10	22.88	11.42	7.10					

occurred during winter. The seasonal variations may be due to the fluctuation of the amount of agricultural drainage water, sewage effluents, and industrial wastes discharged into the estuary.

Copper occurs high at station 1 and 7 in water and sediments samples at December and January 2011 respectively. Station 1 receives the industrial and agricultural discharges while station 7 covers fish landing centre where the anthropogenic activities are relatively high. High concentration of Cu in post-monsoon season can be attributed to industrial effluents derived from the SIPCOT industrial complex during the monsoonal and their subsequent settlement during post-monsoon season (Rajaram *et al*., 2013; Mathivanan *et al*., 2014). Low concentration was obtained in water at July (Station 4) and in sediment at March and April (Station 1, 2 and 6). Palanques *et al*. (1995) reported that the sediment mobilization, biodegradation and recycling of heavy metals in sediments may contribute to decrease the concentration of heavy metals. According to Sankar *et al*. (2010) lower levels of copper in the surface water could be the result of Cu adsorption by particulate matter and their accumulation in sediments. Extensive use of antifouling paints are source of Cu content during post monsoon was reported (Ananthan *et al*., 2005). Eventually, it would be settled from the water column by flocculation and sedimentation (Karthikeyan *et al*., 2007, Sankar *et al*., 2010).

The concentration of Cd and Zn in water was high at station 3 and in sediment at station 2 during September and December 2011 respectively. The low amount of Cd was recorded at station 8 and station 6 in August and July 2011 respectively.

Cd is one of the most dangerous pollutants due to its high-potential toxic effects. The high concentration of Cadmium may be due to input of sewage and industrial discharges, metal and plastic pipes constitute a possible source of Cd in water. The overall data showed that variation in Cd concentrations was dramatically influenced by coastal tidal action and regular discharges of Cd containing effluents from SIPCOT industrial complex (Mathivanan and Rajaram, 2014). The main source of zinc in coastal areas arises from smelting, industrial and domestic waste discharges and agricultural use of pesticides and fungicides containing $ZnSO_4$ adds up zinc accumulation. The amount of Zn was low at station 1 and 2 in water and sediment due to the high river run off during the study period. Jain *et al*., (2008) stated that the many factors such as rain fall, river run off and recycling of metals might be occupied for the inhibition of sedimentation.

High amount of lead was at station 7 in water during January and August due to the more anthropogenic activities and the low amount was obtained in station 8 during September. Lead in water mainly comes from lead processing industries, or due to the use of lead pipes. The low concentration of Pb observed during the post-monsoon season could be attributed to the scavenging of this metal from the water due to adsorption by the increasing suspended or re-suspended bottom sediments (Ananthan *et al*., 2005). The high concentration of Pb in water and sediment samples of station 5 and station 8 is due to Pb consuming industries like pigment, electroplating industries etc. A number of mechanized fishing boats also cause for Pb contamination in this study site. The differentiation of lead content in water and sediment at station 8 owing to the metal

content in water varies very short periods (minutes to hours) whereas the sediments tend to be much more stable (months to years). Cameron (1992) reported that the high concentration of lead due to the decomposition of rocks, industrial and household wastes (paints and batteries).

Overall, the probable enlightenment for the accumulation of heavy metal at this study area that located near the discharging point sources of heavy industrial flow, domestic wastes, municipal wastes, agricultural wastes and anthropogenic activities. Kannel *et al*., (2007) reported that the due to flow of organic waste that changes the pH of water leads to modify the biochemical process and increase the level of pollution in watershed while Nazeer *et al*., (2014) reporting that the contribution of organic waste via drainage and river runoff plays a major role in rise the concentration of heavy metals in sediments. From the above study, it is clear that surface sediments show high degree of heavy metals contamination than water samples. Station 2 and station 3 showed the highest degree of contamination among the stations as it received domestic and sewage effluents and also indicates high anthropogenic pressure on upstream Uppanar riverine ecosystem. However, the highest metal concentrations were generally detected at station 5 and station 8 along with highest values of Pb. These results showed that the industrial effluent discharge is responsible for the deposition of heavy metals in sediments and water of Cuddalore coastal area.

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