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Study on Marine Sediment Quality Across the Coast of Kanyakumari, India: Status of Heavy Metals

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This article gives information about the trace metal contamination along the western coast of the Kanyakumari district, Tamil Nadu, India. The results obtained from the analysis of heavy metals such as zinc, cadmium, lead, copper and iron in marine sediment samples collected during July–November 2001 are presented here. The results of chemical analysis indicate that the concentration of zinc was found to be very high at stations S11 of Mondaikkadu and S16 of Thengapattanam. The deposition of cadmium and lead in the sediment was very high at stations S6 of Kadiapattanam zone. High concentration of iron was observed at stations S4 and S17 and copper content was found to be very high at stations S7 and S10.

Key Words: Marine sediment, Coast of Kanyakumari, Heavy metals.

INTRODUCTION

Recently, contaminated sediments have become one of the most important environmental issues. Both natural process and human activities influence trace metals deposition in coastal or marine sediments[1]. The heavy metals although naturally occurring in the environment, are not usually present in high concentrations in sediments, unless they are introduced *via* anthropogenic inputs. Sediments can act as a major pollutant reservoir for heavy metals that will often bio-accumulate through the food chain[2]. Heavy metals, in particular, have a high affinity for fine sediment particles. Aquatic sediments may be regarded as a mixture of inorganic and organic material that has been deposited as solid particulate matter[3]. Bottom sediments consist of particles of varying size, shape and chemical composition that have been transported by water, air or ice from the sites of their origin in a terrestrial environment and have been deposited on the river, lake or ocean floor[4]. Generally, coarse material, such as sand and pebbles, settles in the near shore zone and fine-grained particles such as silt and clay become deposited in deep waters with restricted currents. The particles accumulate on the bottom at different rates. Most of the hydrophobic organic

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contaminants, metals and nutrients entering the water bodies become associated with particulate matter, and accumulate in bottom sediments.

Most fine sediment particles are discharged by rivers and transported into the sea by means of small particulate matter and sediments are important indicators of anthropogenic activity[5, 6]. Metals are accumulated in sediments either through adsorption, flocculation, precipitation or coprecipitation[7]. Concentration and accumulation of heavy metals in the sediments is closely related to the frequency and duration of tidal flood. The difference in the seasonal flood and ebb tidal condition could also affect availability of heavy metals. The metal concentration in sediment is dependent on the nature, adsorption and retention capacity of the substratum[8]. The accumulation of metals from the overlying water to the sediment is dependent on a number of external environmental factors such as pH, electrical conductivity, anthropogenic input, ionic strength, the type and concentration of organic and inorganic ligands and the available surface area for adsorption caused by the variation in grain size distribution[9]. Estuarine input has a profound influence on the trace metal flux. Estuaries are complex dynamic systems that serve as transition zones between terrestrial and marine environments[10]. Estuarine processes control the distribution and transportation of suspended sediment. During monsoon months domestic and industrial wastes discharged into the estuarine system will be flushed out easily due to high river run off. The distribution of heavy metals in the coastal sediments provides a record of the spatial and temporal history of pollution in a particular region or ecosystem. Metallic pollution is the most serious global problem concerning the welfare of human beings in modern time[11].

The present study focuses on the trace metal distribution in the marine sediments along the coastal stretch of Kanyakumari district. The coastal belt of this district is 67 km in length. Several toxic heavy metals are being introduced into the system through various ways. Marine sediment samples were collected during July, August, October and November 2001 from six stations and analyzed. The Kanyakumari coast in south India is one of the potential areas receiving different kinds of pollutants through various sources. Hence the distribution, abundance and availability of five metals were carried out for a period of one year to identify the source, flux, nature and dynamics of metals with a view to delineate the extent of pollution.

EXPERIMENTAL

Eighteen marine sediment samples were collected from six stations, offshore of Manakkudy (S1, S2, S3), Kadiapattanam (S4, S5, S6), Manavalakkurichi (S7, S8, S9), Mondaikkadu (S10, S11, S12), Colachel (S13, S14, S15) and Thengapattanam (S16, S17, S18) and preserved separately as per the standard methods APHA[12]. The samples were brought to the laboratory and analyzed as per standard procedures[4]. Samples were transferred to prewashed glassware and kept in an oven at 80°C till they became dry. Dried samples were then ground into fine powder. These were then sieved through a 120 m-mesh size sieve. One gram of the sieved sample was weighed out and put into 100 mL of digestion flask. The samples were digested with 8 mL concentrated nitric acid and 2 mL perchloric acid over a sand bath. The samples were heated until the sediments became white and the digested samples were cooled and washed with distilled water and filtered through Whatman No. 1 filter paper and made up to 100 mL in a volumetric flask. The extracts were stored in a refrigerator for further analysis. Standard stock solution was prepared as per the method summarised in the working manual of voltammetric trace analyzer. Trace metals were analyzed using voltammetric trace analyzer (Metrohm VA 746, Switzerland) using hanging mercury drop electrode (HMDE) against Ag/AgCl as reference and platinum as auxiliary electrode.

RESULTS AND DISCUSSION

Copper, zinc, cadmium, lead and iron concentrations obtained from the analysis of sediment samples collected during July–November 2001 are presented here (Table-1). The concentration of metals varied with seasons and locations. The results obtained in the Kanyakumari sedimentary environments are discussed.

Zinc: The organic matter status of sediments had profound influence on the distribution of zinc. The source of zinc in the sediment was the sewage containing domestic effluents, domestic wastes, detergents and discharges from agricultural area containing rodenticide residues[14], pesticides etc. Zinc has greater mobility than lead. Concentrations of zinc and lead were higher in sediment compared to cadmium and copper levels. The main pollutant sources of zinc are metalliferous mining activities, ore dressing and processing and the use of agrochemicals[15]. Zinc salts are relatively non-toxic but heavy doses cause disorders[16].

Cadmium: The concentration of cadmium was low as the source for this metal was found lacking in the vicinity of the study area. The presence of non-essential heavy metals (lead and cadmium) and that too in high concentrations is indicative of heavy metal pollution. It has been estimated that fertilizers contain cadmium[17]. The application of municipal sewage sludge to agricultural soil as a manure can also be a significant source of cadmium. Peak level of cadmium was found in October 2001. Highest recorded value was 6.937 mg/kg in October at S6 and 6.55 mg/kg at S6 in November 2001. Cadmium could not be detected at Thengapattanam and Colachel in November, *i.e.*, cadmium was not traceable there. Farmers are using fertilizers, which are a major source of cadmium. The agricultural applications of phosphate fertilizers represent a direct input of cadmium to arable soils.

Lead: The concentration of lead in sediment ranged from 18.14 to 177.64 mg/kg. The concentration of lead was found highest 177.64 mg/kg in August at S6. The concentration of lead in sediment varied due to its addition through certain pesticides, paints, mining industries, fertilizers and automobiles. Some lead is deposited in the engine and when washed it goes to the drainage water. All these ultimately increase the lead status of soil, which is harmful to men as well as animals. The lead concentration across the coast showed an alarming value.

TABLE-1
MEASUREMENTS OF HEAVY METALS IN SEDIMENT SAMPLES

Samples	July 2001					August 2001					October 2001					November 2001				
	Zn	Cd	Pb	Cu	Fe	Zn	Cd	Pb	Cu	Fe	Zn	Cd	Pb	Cu	Fe	Zn	Cd	Pb	Cu	Fe
S1	116.21	ND	82.30	83.50	1850	111.24	0.4293	74.49	75.78	2950	85.13	5.050	60.260	35.73	2100	83.20	4.780	51.76	11.06	1450
S2	192.50	ND	96.14	97.82	3100	187.18	0.3476	91.93	76.07	2250	70.11	5.199	64.513	30.25	2700	62.40	4.980	53.98	12.54	3500
S3	98.88	ND	89.73	81.17	2000	88.13	0.3750	75.53	64.95	3000	84.57	5.500	69.350	71.68	2100	88.10	4.390	44.00	12.87	3200
S4	170.00	0.25	68.82	67.78	2150	133.45	0.2642	134.17	77.25	6000	50.33	3.856	77.420	27.65	4000	83.30	5.875	79.27	17.48	2000
S5	170.05	ND	ND	92.00	1300	161.69	0.6080	109.40	86.98	2300	69.05	5.278	65.380	26.23	2700	58.30	5.580	61.45	16.02	1950
S6	132.80	ND	ND	71.50	3100	126.97	0.2897	177.64	67.31	3300	67.05	6.937	76.730	36.50	2200	113.00	6.548	80.00	19.34	2350
S7	194.02	ND	ND	120.00	1800	179.08	0.7950	118.20	112.20	2000	42.74	3.770	54.740	27.08	2700	63.90	6.090	68.75	23.02	1850
S8	137.00	0.56	91.32	73.12	4250	107.50	0.4030	81.25	74.98	4000	64.76	4.500	67.070	36.68	2850	27.70	2.262	18.14	11.73	3000
S9	115.20	ND	ND	74.25	1800	113.70	0.6628	89.12	61.09	2700	63.55	5.790	59.800	28.75	3100	57.90	5.050	53.52	10.31	1850
S10	145.00	ND	ND	119.00	2600	133.60	0.4220	104.35	112.32	2700	63.05	5.173	63.500	36.40	2250	73.40	5.350	60.05	12.77	2050
S11	174.85	0.70	110.20	87.36	1850	160.03	0.3280	116.44	75.40	2650	134.22	ND	ND	59.26	2250	46.50	4.060	42.71	11.18	2050
S12	130.06	ND	ND	85.00	2500	120.70	0.4605	86.88	77.69	3400	66.88	4.610	61.000	36.38	2500	56.21	ND	ND	32.86	2800
S13	96.40	ND	ND	42.02	2250	92.85	0.2707	83.84	30.57	3400	75.48	6.350	90.460	41.69	2500	58.60	ND	43.65	45.21	2700
S14	112.50	ND	ND	32.50	1250	102.23	0.2621	88.65	26.81	4375	52.37	4.560	57.820	39.84	1900	52.45	ND	ND	27.05	2250
S15	98.03	ND	ND	ND	1900	91.03	0.2440	66.84	57.89	2450	60.74	3.920	53.440	29.13	3200	47.50	ND	ND	18.15	2800
S16	146.45	0.33	111.94	82.57	2600	80.64	0.2560	69.97	23.01	4350	231.78	4.340	54.470	41.46	4500	135.00	ND	ND	35.00	4750
S17	105.20	ND	ND	ND	3250	84.62	0.1146	74.00	24.45	2700	84.48	4.690	63.520	29.65	3500	53.70	ND	ND	22.50	6000
S18	183.12	ND	ND	ND	3300	157.44	0.3046	85.63	21.80	3750	77.29	5.180	68.400	32.25	2700	59.50	ND	ND	28.14	2900

All values are expressed in mg/kg. ND: Not detected.

Concentrations in the range 15–50 mg/kg are reported for coastal/estuarine sediments. Lead occurs mainly as Pb^{2+} although its oxidation state, Pb^{4+}, is also known and it forms natural waters. Although the geochemical characteristics of Pb^{2+} somewhat resemble the divalent alkaline earth group of metals, lead has the ability to replace potassium, bromine, strontium and even calcium both in minerals and in sorption sites.

Copper: Copper content in sediment samples showed wide variation. The presence of copper may be due to the spraying of fungicide on the rubber plantations and agricultural fields. The entire rubber plantation in the state is in this district. Copper in aqueous systems received attention mostly because of its toxic effects on biota. Excess of copper in human body (> 470 mg) is toxic and causes hypertension, sporadic fever, coma and even death. Copper also produces pathological changes in brain tissues[16]. Maximum concentration of copper was 112.20 mg/kg in August at S7 of Manavalakkurichi and at S10 of Mondaikkadu (112.32 mg/kg). Copper was not detected at S1, S2, S5, S6, S7, S9, S10, S12-15, S17, S18 during July. This indicated that copper in the sewage effluents and land run-off was either low or insignificant. The high amount of metals in sediments may be due to high alkalinity of the water when most of the metals in water precipitated. Some authors have also reported that most of the metals in water precipitated down into the sediments, if pH is increased. Increasing sediment pH increases the number of sorption sites available in clay materials.

Iron: Iron was the most dominant metal throughout the study period at all the stations, *i.e.*, the iron level was found to be the highest among all the metals studied. The source of iron content in the sediments may be ferruginous laterite and the transportation of weathering products[18]. The influence of organic matter buried into the sediments might account for the higher iron content. The concentration of iron fluctuated between 1250 mg/kg and 6000 mg/kg during the study period. The highest value of 6000 mg/kg recorded at sites S4 and S17 could be due to the effluents from the mining sites. The concentration of iron was very low at S14 (1250 mg/kg) of Colachel station. Iron causes rapid increase in respiration, pulse rate, congestion of blood vessels, hypertension and drowsiness.

Conclusion

Sediments are indicators of the quality of overlying water and its study is a useful tool in the assessment of the status of environmental pollution. The survey on pollution level in sediment samples collected during the study period brings out the presence of high concentration of certain heavy metals. This is caused due to the net effects of urban discharge and industrial effluents. The order of abundance of elements in marine sediment is Fe > Zn > Pb > Cu > Cd. The metal pollution may increase due to the urbanisation, anthropogenic activities and the fast changing land use pattern. Considerable fluctuations observed in trace metal concentration could be due to the varied level of mixing and to the textural non-homogeneity of sediments in this area.

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