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Trace element contamination in the nearshore sediments of the Tamiraparani estuary, Southeast coast of India

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ABSTRACT

The present study focused on the elemental distribution of nearshore environment and to understand the interrelationship between different parameters such as trace elements, organic matter, calcium carbonate and sediment texture. For this purpose, 24 surface samples were collected from the nearshore environment using a stainless steel Van Veen grab sampler. The above said parameters indicate that nearshore sediment transport, contaminants from estuarine source and anthropogenic activities deteriorates the sediment quality in the nearshore area. The enrichment factor reveals that the sediments are enriched with Pb, Co, Ni and Cr, whereas the geoaccumulation index highlights that the sediments are polluted with Pb, Ni and Co. The elevated concentration of Pb in the nearshore sediments are possibly from the port activities and thermal power plants situated in the north of the study area. Proper management of industrial effluents is needed to curb further metal pollution in the nearshore environment off Tamiraparani estuary.

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Marine sediments are important hosts for trace element pollution and play a major role in determining the fate and effects of a wide variety of contamination (Chester and Voutsinou, 1981). Accumulation of trace elements in sediment depends on various factors such as sediment texture, properties of the adsorbed compounds and prevailing physicochemical conditions. The measurement of trace element contents and distribution in the marine environment leads to a better understanding of their behaviour and is important for detecting sources of pollution (Förstner and Wittman, 1979). These elements occur in the sediments as adsorbed ions, hydroxides, oxides, phosphates, silicates, carbonates, sulfates, sulfides and organometallic compounds (Jenne, 1977). Moreover, trace elements generally participate in various biogeochemical mechanisms, have significant mobility, and could affect the ecosystems through bioaccumulation and bio-magnification processes (Salomons and Förstner, 1984; Bryan and Langston, 1992; GESAMP/UNESCO, 1994). However, trace elements need not necessarily be fixed to the sediment, as recycling can occur by biological, chemical, and physical processes (Adams et al., 1992; Das et al., 1995; Rees et al., 1996; Lee et al., 2003). The key step to understand the transport and deposition of trace elements in marine systems is well accomplished by comparing the concentrations with background levels (Chester and Voutsinou, 1981; Alexander et al., 1993; Delgado et al., 2010; Nobi et al., 2010, Magesh et al., 2011). Geospatial technology and multivariate statistics such as correlations, factor and cluster analysis helps to interpret the data and its association in the complex marine systems. Moreover, it allows the identification of possible factors that influence trace element geochemistry and offers a valuable tool for reliable management to pollution problems (Vega et al., 1998; Reghunath et al., 2002; Habes and Nugem, 2006).

The southern coast of Tamil Nadu is not only known for its natural resources like coral reefs, heavy minerals and pearl fishing but also for the flourishing fertilizer, chemical and mineral based industries. Recent proliferation of petrochemical industries and copper smelting industry in and around Tuticorin has set the alarm bell ringing in the minds of environmental scientist. It also calls for undertaking detailed multifaceted investigations. The discharge of industrial effluents into the sea, pesticides from agricultural lands and fly ash from coal fired power stations; result in a variety of inputs or disturbances in the sea. All these activities forewarn the consequences of environmental degradation in this coastal and nearshore marine environments. Hence, the present study is an attempt to assess the different elemental concentration available in the sediments and its impact on pollution aspect.

The study area is located in the district of Tuticorin. It is situated in the extreme southeastern corner of Tamil Nadu (8°35′12″ to 8°40′10″ N and 78°3′90″ to 78°10′26″ E). The coast is extensively covered by backwater system and Punnakayal is an extension of Tamiraparani river and is developed as a backwater system in the southern part of Tuticorin harbour. The depth of the Tamiraparani estuary ranges from 2 m to 3.5 m. The tidal level of the study area arises from 0.3 m to 1 m

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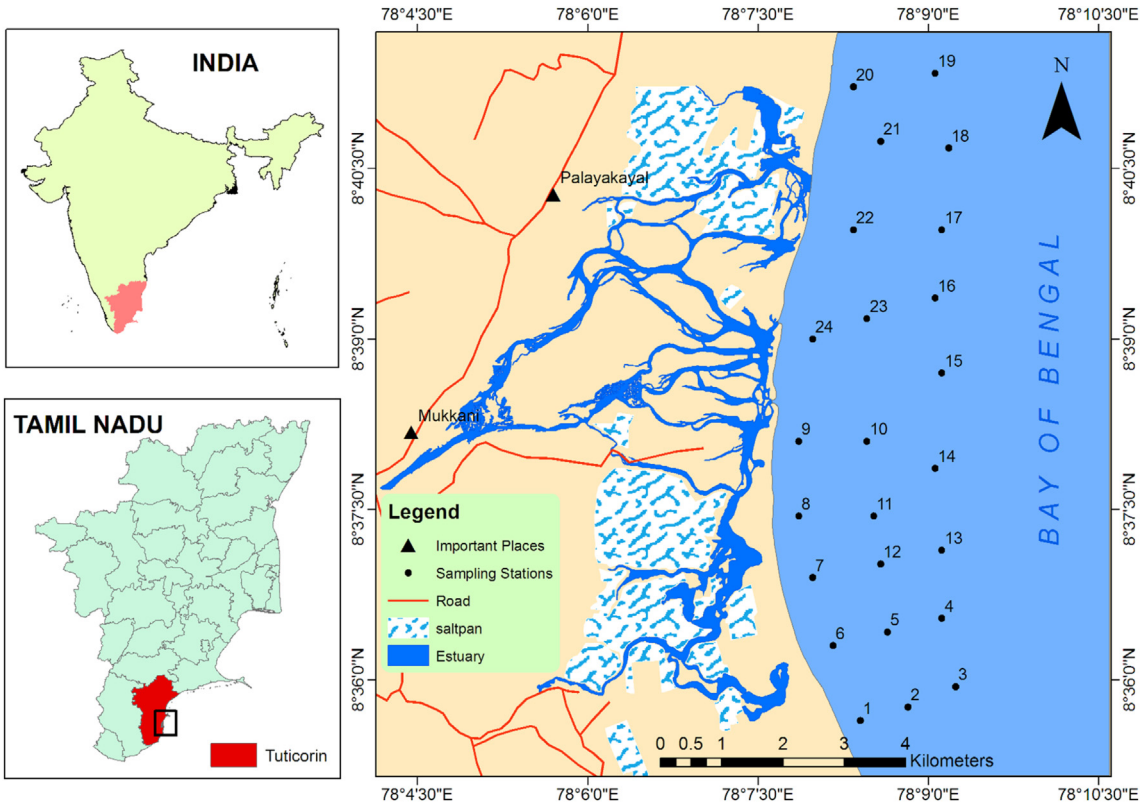

Fig. 1. Location map of the study area.

height. In the nearshore area, the sea floor topography is not horizontal, but of highly uneven in nature. The coastal geomorphology of the study area is represented by the depositional features like deltaic plain, saltpans, beaches, spits and islands, beach ridges, swales/backwater zones, partially stabilized sand dunes with different types of configurations (Loveson and Rajamanickam, 1987; Loveson, 1994). Major part of the coastal tracts derives rain mainly from NE monsoon during the month of October to December. An appreciable contribution of rainfall from SW monsoon during June to September is also recorded in the Tuticorin and Kanyakumari district. The mean annual rainfall ranges from 805.2 mm. Normally, high temperature is recorded during the months of May and June while December and January records the lowest temperature. The normal recorded maximum temperature is 43 °C and minimum of 20 °C. The nearshore sediment transport is influenced by the monsoonal variation in the study area.

The precise locations of the sampling stations were fixed using a hand-held GPS (Garmin eTrex) (Fig. 1). 24 sediment samples were collected from the near-shore environment using a stainless steel Van Veen grab. The samples were packed in thick polyethylene bags and tagged systematically before performing geochemical analysis. The samples were dried in a hot-air oven at 40 °C and powdered using an agate mortar (Shetye et al., 2009). Organic matter in the sediments was determined by the method proposed by Gaudette et al. (1974). The sediments were digested by following the procedure of Loring and Rantala (1992) i.e., 1 g of powdered sediment sample (>63 μm) was mixed with 1 ml of aqua regia (HNO3: HCl; 1:3 v/v) with 6 ml of HF in a Teflon bomb. After addition of the acid mixture, the bomb was placed in a hot water bath (95 °C) for 2.5 h. In order to re-dissolve the precipitated fluorides from complex unreacted HF, boric acid crystals were added to the solution. Finally, the digested samples were made-up to 100 ml. The residues were avoided by centrifuging the final solution at 200 rpm and the extracted solution is analysed for trace element contents using an Inductively Coupled Plasma Atomic Emission Spectrophotometer (Model No. Iris Intrepid II XSP of the Thermo Electron Corporation). The detection limits of analysed trace elements were 0.01 ppm for Fe, Mn, Cu, Cr, Ni, Co, and 0.05 ppm for Pb. Suitable chemical standards for trace elements (AccuTrace, USA) were used to calibrate the instrument and other reagents used in this study were of high purity analytical grade (Rankem, India). The certified reference material (MESS-3) obtained from the National Research Council of Canada was used to ensure the accuracy of the analyses. The recovery percentage of the elements was within 94.65 to 98.34%. The sediment texture was analysed with standard procedures of desalination, dehydration, homogenization and quartering (Ramesh and Anbu, 1996). The shells and other debris were removed from the dried sediment samples through mechanical sieving before subjected to size fraction analysis by following the procedures of Wentworth (1922). 100 g of sample was sieved through a 63-μm mesh in a mechanical sieve shaker for 10 min, the samples that remained on sieve were treated as sand, and the rest was treated as mud (silt plus clay). The silt and clay fractions were separated by using the pipette method described by Lindholm (1987). The results were statistically analysed using SPSS

Table 1
Descriptive statistics of trace elements in the study area.

Elements	Min	Max	Mean	SD	Bgv
Ni	130.27	769.68	413.46	187.95	68
Pb	43.85	919.45	461.38	269.55	20
Cr	30.33	805.25	184.54	174.56	90
Co	119.04	749.95	344.71	132.91	25
Cu	5.46	68.94	29.63	18.86	45
Mn	110.34	1081	528.3	257.8	850
Fe	5245.3	61,236.7	44,708.3	14,423.6	47,000.0
Sand%	81.34	96.01	89.87	4.39	N/A
Silt%	0.5	16.65	6.35	4.48	N/A
Clay%	0.14	10.29	3.75	3.14	N/A
OM%	0.24	2.1	1.27	0.48	N/A
$CaCO_3$%	1	52	21.2	16.56	N/A

All elements are reported in ppm, SD-Standard deviation, Bgv - Background value.

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