

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,400

Open access books available

174,000

International authors and editors

190M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Chapter

Investigations on Rare Earth Elements in Sediments from South Vellar Estuary along Bay of Bengal and Palk Strait, Tamil Nadu, India

Puliyakurichi Mookkan Velmurugan, Krishnan Vijayaprabhakaran, Periyathambi Thangappan Devika and Mohammad Suhail Meer

Abstract

The rare earth elements (REEs) in the sediments of the South Vellar estuary on the eastern coast of India were measured using thermal ionization mass spectrometry (TIMS). Lanthanides (La-Lu) and a number of other elements (Cr, Ni, Zn, Pb, Ag, Co, Cd, and V) were studied in bed sediment samples. The estuary's total REE content (REE) ranges from 73.30 to 360.50 g/g. Continental weathering has a substantial impact on the distribution of REEs. Using factor analysis on the elemental data, two important groups of elements were identified: (a) LREEs, HREEs, Pb, Ag, and Cd, revealing an association with river detritals; and (b) Co, Ni, Zn, Cr, and V, indicating complex estuary processes. Because of the silicate weathering of crustal materials and the resultant increase in LREEs in detritals, LREEs are more enriched than HREEs. We get to the conclusion that 30% of HREE flux and 70% of LREE flux to the Bay of Bengal are provided by the estuarine system.

Keywords: Bay of Bengal, rare earth element, sediment, South Vellar Estuary, TIMS

1. Introduction

Rare earth elements (REEs) are frequently employed as geochemical tracers for provenance studies due to their distinct and chemically coherent behavior [1]. Extensive studies have been reported on the distribution of REE in sediments, suspended particulate matter, and natural waters. Our understanding of REE distribution in the sediments has advanced significantly. For instance, earlier research had found that "REEs as a group are insoluble elements, exhibiting limited fractionation throughout the earth surface processes." The premise is that the REE are fractionated and mobilized during weathering in all climatic conditions in estuaries [2]. In addition, organic compounds, colloidal particles, and Fe-Mn oxyhydroxides may serve as hosts for REE and their presence in sediments may affect the total concentration of REE.

Rare earth elements and heavy metals have a well-established role in sediments as transporters and potential sources, and when these materials are distributed by geochemical processes in aquatic systems, they have an impact on surface ecosystems. At point inputs, the river mouths, sediments from the land, freshwater, and metals all enter the coastal zone. During transportation in river systems, fractionation of REEs and metals primarily takes place in the solid phase. The degree of REE fractionation in the silt and clay fractions of sediments is also controlled by the type of weathering, the lithology of the rocks, and their susceptibility to erosion [3]. Due to their extensive coverage of vast areas and contribution to a better understanding of the global REE cycle, a number of research investigations have concentrated on the distribution of REE in the sediments of big rivers. Large rivers drain through a variety of rock types under a range of climatic conditions and REEs from different sources are admixed during weathering, erosion, transportation, and deposition, resulting in homogenous REE patterns in large rivers around the world. As a result, it is challenging to identify the source rock characteristics from sediments of large rivers.

Several estuaries had high rates of REE removal to the sediments, but low rates of REE removal in low-salinity areas have also been reported [4]. In recent years, lanthanum to lutetium element groups, which are called rare earth elements, have received a lot of attention [5–8]. The distribution of rare earth elements by geochemical processes in aquatic systems has an impact on surface ecosystems, and sediments represent a well-established role as transports and potential sources of these materials. The coastal zone is impacted at points where metals, freshwater, sediments from the land, and river mouths enter [9, 10]. REE and metal fractionation primarily occur in the solid phase during transportation in river systems. As a result of the discharge of household and agricultural wastes, the intrusion of waste from the metal plating industry, the entry of organic and inorganic chemicals, the leaching of metals from solid waste, and the use of metal and metal components, concentrations of chromium (Cr), cobalt (Co), nickel (Ni), Zinc (Zn), lead (Pb), cadmium (Cd), silver (Ag), and vanadium (V) are significantly increasing in coastal environment [11, 12].

The coastal zone eventually receives all of the elements derived from river systems. Additionally, estuaries have a history of regulating the quantity of REEs that enter the coastal ecosystem and eventually the deep ocean [13]. Understanding low-temperature geochemical processes consequently requires an understanding of the distribution and concentration of REEs in estuaries [14]. Estuaries are significant from an ecological and economic perspective since they are the places where the land meets the sea. The marine and freshwater inflows contribute a significant amount of nutrients to the estuary's water column and sediment [15, 16]. The elemental cycles play a significant role in estuarine environments. Estuaries are important to the world's biogeochemical cycles, including the carbon cycle, nitrogen cycle, and nutrient cycles, although taking up less than 10% of the ocean's surface [17, 18]. Insight into the marine cycling of REEs is provided by the quantity of these elements in estuarine sediments, precisely as it is by their abundance in the continental crust [19]. Additionally, it gives more knowledge on the interactions between sediment and water and redox processes that occur in surface environments. The quantity and distribution of REEs in South Vellar estuarine sediments are presented in **Table 1**, the two classes of REE are light rare earth elements (LREEs) from lanthanum to gadolinium as well as from yttrium to lutetium are the heavy rare earth elements (HREEs).

As compared to HREEs, LREEs are generally richer in all estuarine sediments [20]. The deltaic and estuarine regions of India are not widely recognized. An earlier study [21] looked briefly at the distribution of heavy metals in the Gangetic delta.

Sampling location	Latitude	Longitude
SS1	10° 4' 26.004"N	79° 14' 17.844"E
SS2	10° 4' 25.968"N	79° 14' 30.732"E
SS3	10° 4' 19.488"N	79° 14' 44.592"E
SS4	10° 4' 11.028"N	79° 14' 53.196"E
SS5	10° 4' 7.644"N	79° 14' 57.804"E
SS6	10° 3' 51.624"N	79° 15' 11.916"E
SS7	10° 3' 42.516"N	79° 15' 14.364"E
SS8	10° 3' 25.668"N	79° 15' 10.620"E
SS9	10° 3' 6.552"N	79° 15' 9.901"E
SS10	10° 3' 55.296"N	79° 14' 29.652"E
SS11	10° 3' 38.916"N	79° 14' 32.932"E
SS12	10° 3' 23.256"N	79° 14' 38.832"E

Table 1.
 Field sampling locations of South Vellar estuary.

The chemical characteristics of suspended sediments in the estuaries of the Narmada, Tapi, Mahanadi, and Godavari rivers were originally studied by Borole et al. in 1982 [22]. Seralathan and Seetharamaswamy (1987) reported on the clay mineralogy and

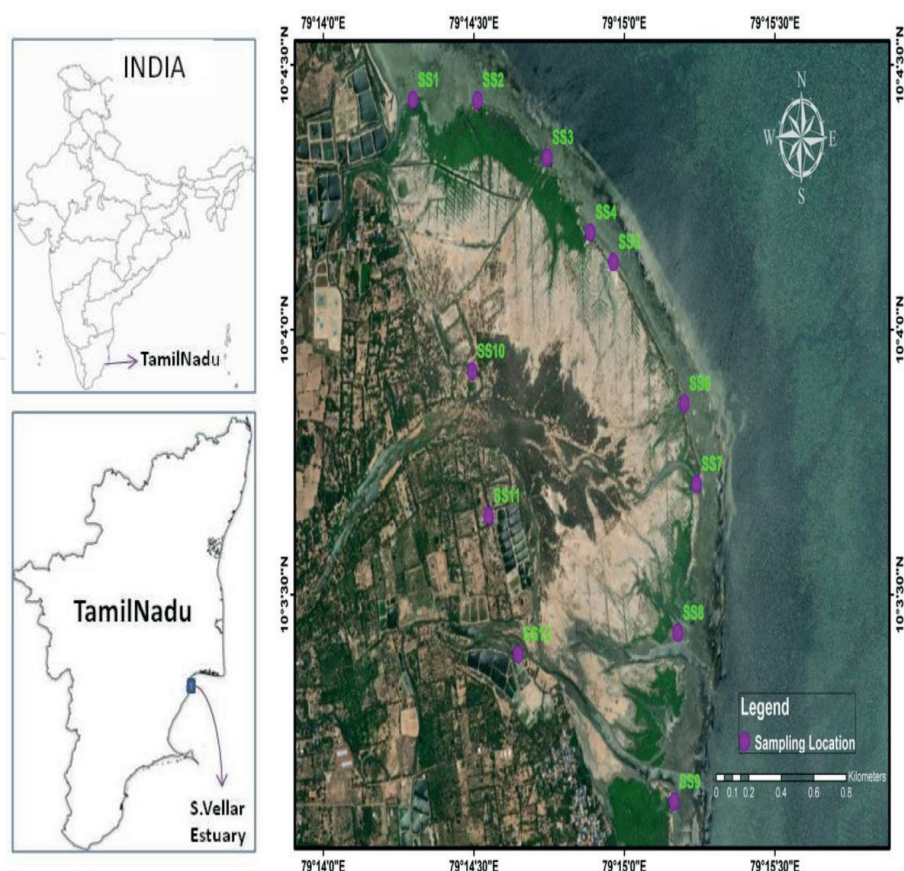


Figure 1.
 Study area map: South Vellar estuary.

trace element chemistry of the Cauvery delta based on a single-time sampling (monsoon season) [23]. Later, Ramanathan et al. (1993) investigated the Cauvery delta's geochemical properties [24]. The majority of these writers' publications focus on the elemental distribution in these estuaries, while earlier reports did not mention trace metals like V, Ag, Cd, and Co. On the subject of REE distribution in Indian estuaries and deltaic regions, hardly any research has been published. The South Vellar estuary baseline study is comprised of this study (**Figure 1**). We are providing the distribution of REE in South Vellar estuarine sediments along India's east coast for the first time, along with its association with heavy metal enrichment.

2. Methodology

2.1 Study area and geologic context

The Palk Strait, a Bay of Bengal strait, is between southern India and northern Sri Lanka. Its boundary is bounded by the Gulf of Mannar, Pamban Island, Adam's (Rama's) Bridge, and Mannar Island. The southwest part of the strait is also known as Palk Bay [25]. The strait is less than 100 m deep, 64 to 135 km wide, and 137 km long. The South Vellar River, a non-perennial river, flows into the Bay of Bengal along with Palk Strait. The river originates as a cluster of small streams in the Kumirakatti forest reserve, which is located about 9 km west of the village of Karumalai after passing through Tovarankurichchi and Karumalai, flowing to the southeast after receiving the additional flow from the Vembar retention basin, which is located south of Kodumbalur. After passing through Avudaiyarkoil, it turns to the east and flows until Mumpalai village in the Manamelkudi taluk, where it creates an estuary and discharges into the sea northeast of Manamelkudi.

There are three main lithostratigraphic units in Tamil Nadu's southern region, which contains the coastal areas to be visited. Charnockites, granulitic retrograded products, and basic intrusive and Tertiary calcareous sandstone are layered above Precambrian granitic rocks, as are recent coastal deposits. During the Proterozoic, the granulitic terrain was divided into multiple massive shear zones, which caused the granulitic facies assemblages to retrograde. Based on changes in landforms and the presence of lineaments, seven major blocks have been discovered between Kanyakumari and Kodiyakarai on Tamil Nadu's southeast coast [26]. According to a theory, the seven blocks from the glaring weaknesses in the lineaments are what keep striking slip faults from continuing. In the shallow marine shelf areas along the Tamil Nadu coast, the mean annual rate of sediment deposition in the Gulf of Mannar, Palk Bay, and Sand Heads are 0.01 m, 0.006 m, and 0.003 m, respectively, according to a research by Chandramohan et al. [27]. There are numerous examples of erosional and depositional landforms along Tamil Nadu's southeast coast. Beach ridges, spits, swales, and estuaries are important features of depositional landforms. In and around Kodiyakarai, Thondi, Manamelkudi, Rameshwaram, Mandapam, and other surrounding areas, extensive erosional features such as marine terraces, sea caves, cliffs, and wave-cut platforms can be observed [28].

2.2 Sampling technique

Runoff from the land, bank erosion and internal channel reworking are all possible sources of fluvial sediments. In the estuary ecosystem, sediment performs a lot

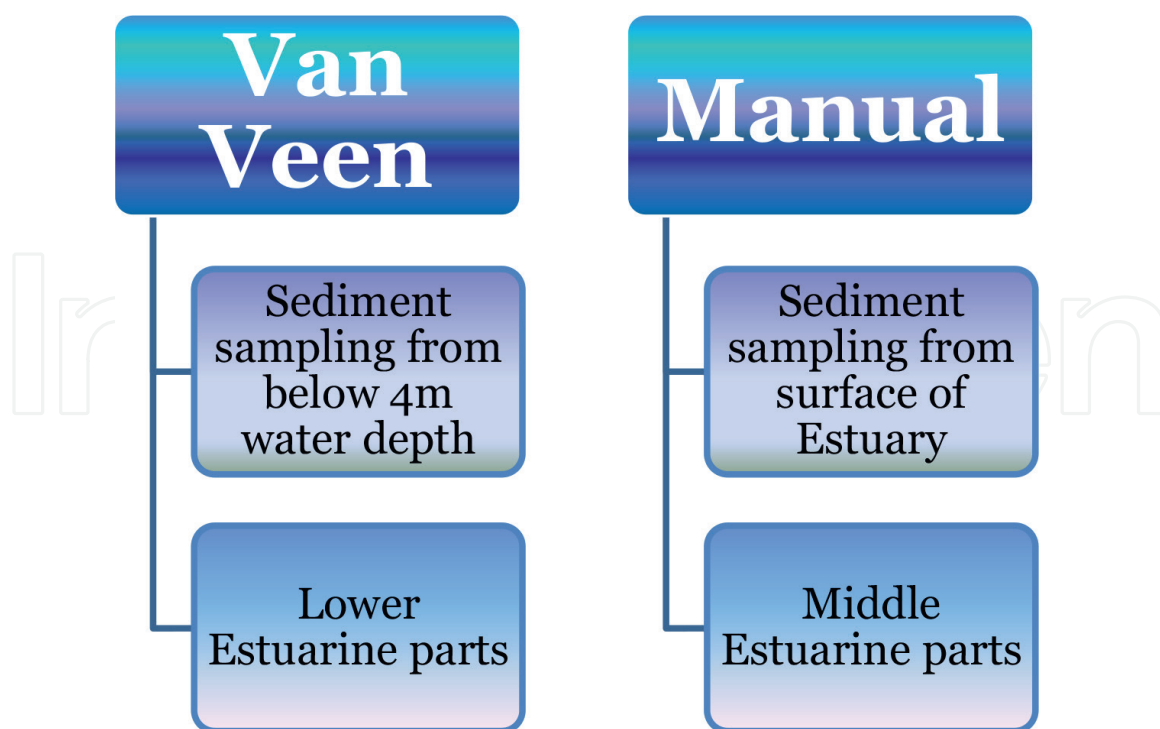


Figure 2.
Sampling processes in South Vellar estuary.

of significant roles and serves as the substrate for a huge assortment of organisms. Field sampling is carried out using some scientific procedures (**Figure 2**). During the monsoon period of July 2022, 12 sediment samples were collected from various parts of the South Vellar estuary (**Figure 3**). Twelve sediment samples (SS) were obtained in the South Vellar Estuary (**Figure 1**). Nine samples (SS1-SS9) were collected from the lower estuarine parts using Van Veen grabs on small boat (**Figure 4.a**). The basic concept of all grab samplers is the same: A specialized bucket or scoop is lowered through the water column used with rope until it meets the bed, at which point, a release mechanism enables sample collection and withdrawal. To minimize disturbance at the sediment surface on contact and to reduce the loss of fine-grained material as the grab is raised through the water column, the grab was lowered and raised gradually and vertically while avoiding free fall. The grab sampler was properly cleansed after collecting to remove any additional material that had become adhered to the equipment. The samples were transferred to plastic bags with labels. Three samples (SS10-12) were collected manually from surface of middle estuary (**Figure 4.b**). Surface sediments are relatively simple to collect because there is no need to know the exact depth from which the sediment was collected or to preserve sediment structure. Where sampling locations are easily and safely accessible by foot or small boat, samples can be collected by hand using a scoop, allowing for very accurate sampling site location with GPS. All sediment samples were collected by labeled and sealed plastic bags and transported to the laboratory, where they were stored at 4°C until analysis [29–31].

2.3 Analytical method

The samples are kept in an air-dried environment for further REE extraction. Using a mortar and pestle, the dehydrated samples were crushed to a homogeneous powder. All samples were prepared in a flux mixture containing 100 mg of each



Figure 3.
Sediment sampling locations of South Vellar estuary.

sample. The samples were then heated in an inert, heat-resistant graphite crucible at 1050°C, past the melting point of the flux. The crucible was regularly agitated and heated until the sample was completely dissolved in the molten flux. The melt was then poured into a 50 ml aqueous solution of 5% HNO₃. This solution required progressive agitation *via* shaking and magnetic stirring to dissolve the flux with the sample in the acidic solution. Each sample was prepared for plasma quad analysis by taking 1.5 ml of this dilution, adding 0.1 ml of 9.997 mg lIndium internal standard, and 8.4 ml de ionized water. This procedure produced an aqueous solution with a ~ 3300 whole sediment sample dilution and a concentration of 99.97 µg/l. VG thermal ionization mass spectrometer was used to analyze the extracted samples for rare



Figure 4.
Types of sampling methods. a. Van Veen grab sampling; b. manual sampling.

earth elements [29]. The technology known as Thermal Ionization Mass Spectrometry (TIMS) was primarily created for the analysis of samples of geological sediment. By using isotope dilution analysis, the technique is frequently used to determine rare-earth elements and other specific elements [32]. Nine Faraday cup collectors were installed on a VG Sector 54–30 thermal TIMS (VG Isotopes Ltd., UK) for the isotope dilution analytical procedures to measure rare earth elements.

An important analytical instrument for determining the elemental composition of environmental samples, especially soil and sediments, is energy-dispersive X-ray fluorescence Spectrometer (EDXRF). The instrument used for this experiment is an EDXRF spectrometer, model EX-6600SDD. This technique has a high sample throughput, which is multi-elementary and nondestructive. EDXRF is utilized in the current study for large area screening as it is quick and only requires a little sample amount [33].

2.4 Result and discussion

As with their abundance in the continental crust, REEs are prevalent in estuary sediments, which can shed light on their marine cycling. Additionally, it gives more knowledge on the interactions between sand and water and redox reactions that take place in surface environments [34]. There are two primary categories of rare earth elements: Currently conducted research compares low and high rare earth elements (**Table 2**). The distribution and quantity of REEs in the estuary sediments in South Vellar Estuary are displayed in **Tables 3–5**. In comparison with HREEs, LREEs are typically more enriched in all sampling locations of estuary (**Figure 5**). Based on mean concentration from LREE group, La (37.75 $\mu\text{g/g}$) is the dominant element, followed by Ce (36.65 $\mu\text{g/g}$), Pr (21.38 $\mu\text{g/g}$), Nd (17.17 $\mu\text{g/g}$), Sm (7.64 $\mu\text{g/g}$), Gd (5.35 $\mu\text{g/g}$), and Eu (4.09 $\mu\text{g/g}$) (**Table 3**). In addition, Y (34.53 $\mu\text{g/g}$) is also abundant in HREE followed by Tb (5.68 $\mu\text{g/g}$), Dy (3.93 $\mu\text{g/g}$), Er (3.07 $\mu\text{g/g}$), Ho (2.67 $\mu\text{g/g}$), Tm (2.11 $\mu\text{g/g}$), Yb (1.84 $\mu\text{g/g}$), and Lu (1.45 $\mu\text{g/g}$) (**Table 4**). Based on the individual

Rare earth element (REE)			
Low rare earth element (LREE)		High rare earth element (HREE)	
La	Lanthanum	Y	Yttrium
Ce	Cerium	Tb	Terbium
Pr	Praseodymium.	Dy	Dysprosium.
Nd	Neodymium.	Ho	Holmium
Pm	Promethium	Er	Erbium
Sm	Samarium	Tm	Thulium
Eu	Europium	Yb	Ytterbium
Gd	Gadolinium	Lu	Lutetium

Table 2.
Type of rare earth element.

Sampling location	Concentration of LREE ($\mu\text{g/g}$)								
	(La)	(Ce)	(Pr)	(Nd)	Pm	(Sm)	(Eu)	(Gd)	Σ LREE
SS1	34.4	48.3	12.3	11.64	—	7.02	2.87	6.58	123.11
SS2	32.42	34.92	19.54	12.14	—	8.68	4.57	7.45	119.72
SS3	28.5	32.1	26.4	13.54	—	6.35	3.68	4.62	115.19
SS4	37.5	41.52	23.34	18.65	—	7.37	4.72	5.08	138.18
SS5	37.64	39.42	29.25	14.52	—	8.13	4.45	4.86	138.27
SS6	36.61	41.67	26.21	13.65	—	6.94	5.42	4.08	134.58
SS7	39.12	38.42	29.08	17.52	—	9.04	6.05	5.17	144.4
SS8	53.64	39.52	27.62	24.74	—	10.54	4.57	6.66	167.29
SS9	91.52	63.62	44.47	36.01	—	9.34	5.84	7.73	258.53
SS10	22.56	17.52	8.05	15.61	—	6.58	3.15	3.86	77.33
SS11	19.65	16.24	5.84	14.25	—	6.02	2.54	4.24	68.78
SS12	19.43	14.58	4.45	13.73	—	5.7	1.25	3.88	63.02
Total	452.99	427.83	256.55	206	—	91.71	49.11	64.21	1548.4
Average	37.75	35.65	21.38	17.17	—	7.64	4.09	5.35	129.03

Table 3.
Concentration of low rare earth elements.

rare earth element, the average concentration of La (37.75 $\mu\text{g/g}$) and Ce (35.65 $\mu\text{g/g}$) described in this research was higher than Pichavaram Mangrove (La: 1.43 $\mu\text{g/g}$; Ce: 1.26 $\mu\text{g/g}$) [7] and Cauvery estuary (La: 19.92 $\mu\text{g/g}$; Ce: 34.98 $\mu\text{g/g}$) [35], five times lesser than Yamuna river (156.0 $\mu\text{g/g}$) [36].

Mean concentration of Dy (3.93 $\mu\text{g/g}$), Ho (2.67 $\mu\text{g/g}$), and Er (3.07 $\mu\text{g/g}$) described in this research was higher than Pichavaram Mangrove (Dy: 130 $\mu\text{g/g}$; Ho: 1.75 $\mu\text{g/g}$; Er: 1.06 $\mu\text{g/g}$) [7], and Cauvery estuary (Dy: 3.43 $\mu\text{g/g}$; Ho: 0.70 $\mu\text{g/g}$; Er: 2.19 $\mu\text{g/g}$) [35]. Distribution of yttrium is 3.22–63.48 $\mu\text{g/g}$ in this research is higher than Tagus estuary (2.4–32.0 mg/kg), which is located in Portugal [37]. The

Concentration of HREE ($\mu\text{g/g}$)									
Sampling location	(Y)	(Tb)	(Dy)	(Ho)	(Er)	(Tm)	(Yb)	(Lu)	Σ HREE
SS1	39.58	5.02	4.85	2.83	3.58	2.45	1.11	1.23	60.65
SS2	35.86	5.05	5.42	2.98	3.88	2.12	2.74	1.83	59.88
SS3	33.46	7.87	3.54	2.98	2.94	1.57	1.65	1.65	55.66
SS4	36.33	5.12	4.14	3.04	3.08	2.03	1.08	1.08	55.9
SS5	42.97	5.95	3.54	2.17	4.41	2.84	1.15	1.64	64.67
SS6	42.4	3.48	4.08	2.96	3.04	2.64	1.82	1.18	61.6
SS7	33.25	9.45	4.11	2.71	3.05	2.43	2.01	1.86	58.87
SS8	52.75	8.08	5.04	3.04	3.37	3.09	2.19	1.74	79.3
SS9	63.48	13.65	6.76	3.86	4.65	3.66	3.26	2.65	101.97
SS10	15.81	2.51	2.06	2.27	1.94	1.15	2.08	1.14	28.96
SS11	15.31	1.09	1.96	2.08	1.65	0.98	1.85	0.94	25.86
SS12	3.22	0.87	1.68	1.14	1.32	0.42	1.18	0.45	10.28
Total	414.42	68.14	47.18	32.06	36.91	25.38	22.12	17.39	663.6
Average	34.53	5.68	3.93	2.67	3.07	2.11	1.84	1.45	55.3

Table 4.
Concentration of high rare earth elements.

Concentration of REE ($\mu\text{g/g}$)			
Sampling location	Σ LREE	Σ HREE	Σ REE
SS1	123.11	60.65	183.76
SS2	119.72	59.88	179.60
SS3	115.19	55.66	170.85
SS4	138.18	55.90	194.08
SS5	138.27	64.67	202.94
SS6	134.58	61.6	196.18
SS7	144.40	58.87	203.27
SS8	167.29	79.3	246.59
SS9	258.53	101.97	360.50
SS10	77.33	28.96	106.29
SS11	68.78	25.86	94.64
SS12	63.02	10.28	73.30
Total	1548.4	663.6	2212
Average	129.03	55.3	184.33

Table 5.
Concentration of rare earth elements.

determined heavy metal concentration for 12 coastal locations in the South Vellar estuary by EDXRF, as well as the distribution of heavy metals (other elements than REE) in the sediments, is examined (**Table 6**). When compared to all other heavy metals, Cr is frequently higher concentrated in all estuarine sampling locations

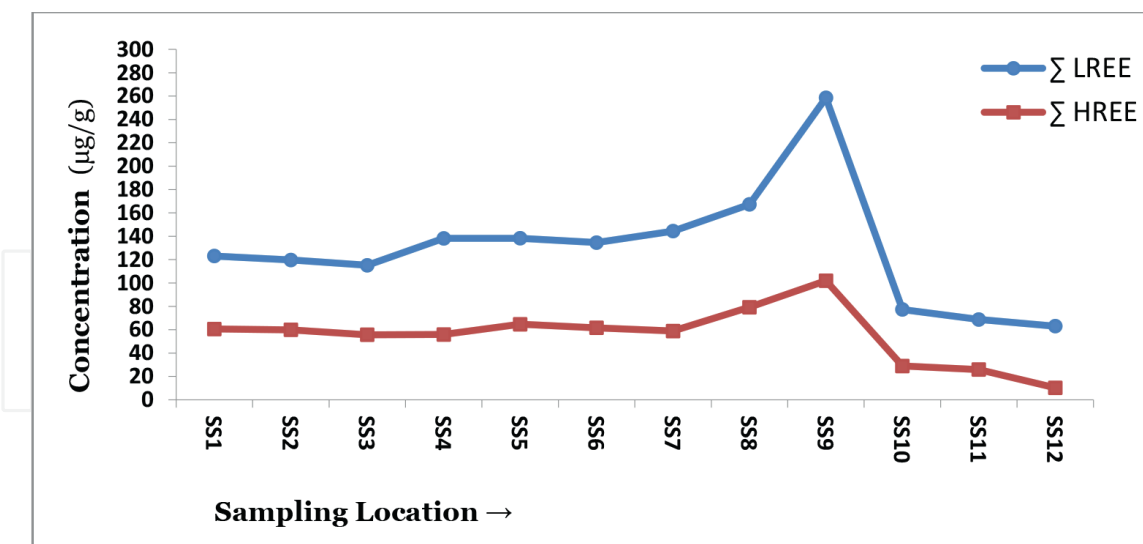


Figure 5.
Concentration of LREE and HREE from all sampling locations.

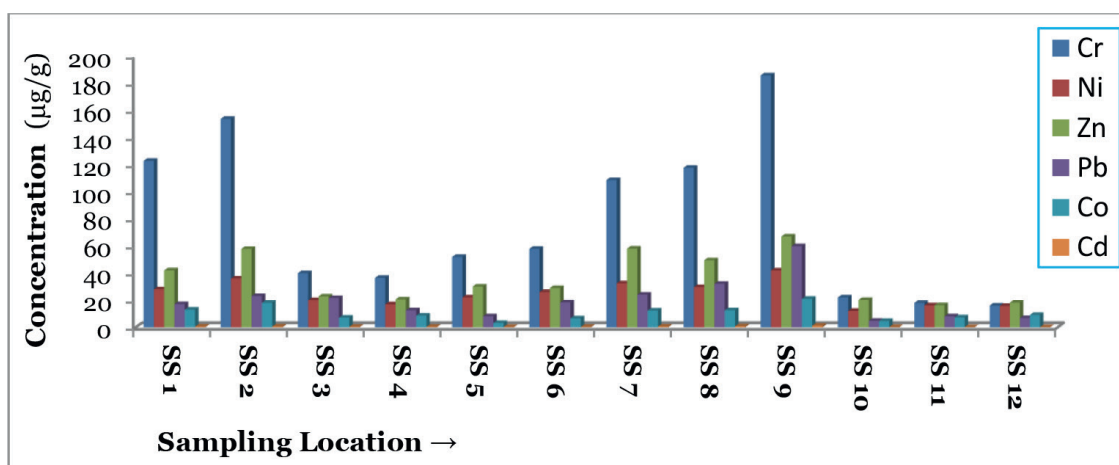


Figure 6.
Concentration of heavy metal from all sampling locations.

(**Figure 6**). For Cr, the heavy metal concentration ranges from 16.02 to 186.1 µg/g; for Zn, it ranges from 16.36 to 67.26 µg/g; for Ni, it ranges from 12.13 to 42.16 µg/g; for Pb, it ranges from 4.76 to 60.08 µg/g; for Co, it ranges from 4.64 to 21.08 µg/g; and for Cd, it ranges from 0.10 to 1.12 µg/g. Based on the individual heavy metal, the average concentration of Cr (77.75 µg/g) described in this research was lower than Pichavaram Mangrove (141.2 µg/g) [38], East Coast estuaries 318.0 µg/g [39], and Tamirabharani estuary 97.162 µg/g [40]. Distribution of Ni reported (12.13 to 42.16 µg/g) and mean concentration (24.86 µg/g) in this research is lesser than Pichavaram Mangrove (62.0 µg/g) [38], East Coast estuaries (582.0 µg/g) [39], and Pondicherry estuary (33.51 µg/g) [41], higher than Tamirabharani estuary (11.852 µg/g) [40].

Distribution of Zn reported (16.36 to 67.26 µg/g) and mean concentration (36.07 µg/g) in this research is higher than Cauvery estuary (26.0 µg/g) [42]; and lesser than Pichavaram Mangrove (89.0 µg/g) [38] and East Coast estuaries (125.0 µg/g) [39]. Mean concentration of Pb (19.76 µg/g) in this research is higher than Cauvery estuary (10.0 µg/g) [42], Pichavaram Mangrove (11.2 µg/g), and East Coast estuaries

Concentration of heavy metal in sediment ($\mu\text{g/g}$)								
Sampling location	Cr	Ni	Zn	Pb	Ag	Co	Cd	V
SS1	123.16	28.12	42.17	17.14	—	13.06	0.47	—
SS2	154.08	36.14	58.06	23.13	—	18.12	0.57	—
SS3	40.12	20.06	22.82	21.62	—	07.14	0.32	—
SS4	36.62	17.02	20.64	12.60	—	08.62	0.35	—
SS5	52.14	22.17	30.17	08.17	—	03.17	0.24	—
SS6	58.13	26.14	29.06	18.38	—	06.64	0.26	—
SS7	109.04	32.62	58.32	24.16	—	12.42	0.56	—
SS8	118.11	29.73	49.62	32.17	—	12.63	0.74	—
SS9	186.08	42.16	67.26	60.08	—	21.08	1.12	—
SS10	22.14	12.13	20.18	04.76	—	04.64	0.18	—
SS11	18.07	16.24	16.36	08.13	—	07.34	0.10	—
SS12	16.02	15.85	18.24	06.80	—	09.18	0.13	—
Average	77.75	24.86	36.07	19.76	—	10.34	0.42	—

Table 6.

Heavy metal concentration from all sampling locations.

(11.0 $\mu\text{g/g}$); and lesser than Mahanadi estuary (23.88 $\mu\text{g/g}$) [43]. Mean concentration of Co (10.34 $\mu\text{g/g}$) in this research is lesser than Cauvery estuary (64.0 $\mu\text{g/g}$) and East Coast estuaries (12.0 $\mu\text{g/g}$). Distribution of Cd reported (0.10 to 1.12 $\mu\text{g/g}$) and mean concentration (0.42 $\mu\text{g/g}$) in this research is lesser than Pichavaram Mangrove (6.96 $\mu\text{g/g}$) and both sites of Uppanur estuary (site 1; 4.99 $\mu\text{g/g}$ & site 2; 4.375 $\mu\text{g/g}$) [44]. The mean heavy metal concentrations are in the following order: Cr > Zn > Ni > Pb > Co > Cd (**Table 6**). According to results from other countries around the world, this study's heavy metal concentration is comparable. **Figure 6** shows the distribution of heavy metals in sediment from South Vellar estuarine for all sampling locations.

3. Conclusion

Due to the widespread use of REE in daily life, it is imperative that we have a thorough understanding of how these elements behave in estuarine and coastal mixing zones in order to improve our comprehension of REE geochemistry at the continent-ocean interface. The major causes of the minor heavy metal contribution to the estuary sediment may be several anthropogenic sources. Weathering influences REE and metal distribution in the South Vellar estuary along the Bay of Bengal and the Palk Strait in Tamil Nadu, India. The main source of REEs and heavy metals in Estuary sediments is continental weathering, but anthropogenic activities and the marine environment also contribute significantly. Because of complex physicochemical processes, the elements are significantly altered in the intertidal ecotonal region of different salinities. The sediments have a REE range of 73.30–360.50 ($\mu\text{g/g}$) and a mean value of 184.33 ($\mu\text{g/g}$). The average LREE and HREE values are 129.03 and 55.3 ($\mu\text{g/g}$), respectively. The South

Vellar river-estuarine systems contribute roughly equal amounts of LREEs (70%) and HREEs (30%) to the Bay of Bengal along with Palk Strait. Therefore, we suggest that it is possible to estimate the processes of continental weathering on the Indian subcontinent using the distribution of REE in these estuaries.

Acknowledgements

The authors express their gratitude to Sathyabama Institute of Science and Technology (SIST) for providing support and facilities during this research.

Author details

Puliyakurichi Mookkan Velmurugan^{1*}, Krishnan Vijayprabhakaran¹,
Periyathambi Thangappan Devika² and Mohammad Suhail Meer³


1 Centre for Earth and Atmospheric Sciences, Sathyabama Institute of Science and Technology, Chennai, India

2 Centre for Remote sensing and Geoinformatics Sathyabama institute of science and Technology, Chennai, India

3 Department of Biochemistry, Mohamed Sathak College of Arts and Science, Chennai, India

*Address all correspondence to: velapmv@gmail.com

IntechOpen

© 2023 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] McLennan SM. Rare earth elements in sedimentary rocks: Influence of provenance and sedimentary processes. *Geochemistry and Mineralogy of Rare Earth Elements. Reviews in Mineralogy*. 1989;**21**:169-200. DOI: 10.1515/9781501509032
- [2] Shiller AM. Seasonality of dissolved rare earth elements in the lower Mississippi River. *Geochemistry, Geophysics, Geosystems*. 2002;**3**:1068-1078
- [3] Sharma A, Rajamani V. Weathering of gneissic rocks in the upper reaches of Cauvery River, South India: Implications to neotectonics of the region. *Chemical Geology*. 2000;**166**:203-223
- [4] Adebayo SB, Cui M, Hong T, White CD, Martin EE, Johannesson KH. Rare earth element geochemistry and Nd isotopes in the Mississippi River and Gulf of Mexico mixing zone. *Frontiers in Marine Science*. 2018;**5**:166
- [5] Babu SS, Venkata Ramana R, Purnachandra Rao V, Ram Mohan M, Sawant S, Satyasree N, et al. Rare earth elements of sediments in rivers and estuaries of the east coast of India. *Current Science*. 2021;**120**(3):00113891
- [6] Balaram V. Rare earth elements: A review of applications, occurrence, exploration, analysis, recycling, and environmental impact. *Geoscience Frontiers*. 2019;**10**:1285-1303
- [7] Krishna Prasad BM, Ramanathan A. Distribution of rare earth elements in the Pichavaram Mangrove sediments of the Southeast Coast of India. *Journal of Coastal Research*. 2008;**24**:126-134
- [8] Henderson PAUL. General geochemical properties and abundances of the rare earth elements. In: *Developments in geochemistry*. Oxford: Elsevier; 1984;**2**:1-32
- [9] Ramkumar T, Venkatramanan S, Anithamary I, Ibrahim SMS. Evaluation of hydro geochemical parameters and quality assessment of the groundwater in Kottur blocks, Tiruvarur district, Tamilnadu, India. *Arabian Journal of Geosciences*. 2013;**6**:101-108
- [10] Niu L, Cai H, Jia L, Luo X, Tao W, Dong Y, et al. Metal pollution in the Pearl River Estuary and implications for estuary management: The influence of hydrological connectivity associated with estuarine mixing. *Ecotoxicology and Environmental Safety*. 2021;**225**:112747
- [11] Karthikeyan P, Marigoudar SR, Mohan D, Nagarjuna A, Sharma KV. Ecological risk from heavy metals in Ennore Estuary, South East Coast of India. *Environmental Chemistry and Ecotoxicology*. 2020;**2**:182-193
- [12] Kesavan K, Murugan A, Venkatesan V, Vijay Kumar BS. Heavy metal accumulation in molluscs and sediment from Uppanar Estuary, Southeast coast of India. *An International Journal of Marine Sciences*. 2013;**29**(2):15-21
- [13] Milliman JD, Syvitski JPM. Geomorphic/tectonic control of sediment discharge to the ocean: The importance of small mountainous rivers. *The Journal of Geology*. 1992;**100**:525-544
- [14] Sholkovitz ER. The aquatic chemistry of rare earth elements in rivers and Estuaries. *Aquatic Geochemistry*. 1995;**1**:1-34
- [15] Elliott M, Whitfield AK. Challenging paradigms in estuarine ecology and

management. *Estuarine, Coastal and Shelf Science*. 2011;**94**:306-314

[16] Valle-Levinson A. 1.05 Classification of estuarine circulation. *Treatise on estuarine and coastal science*. 2011:75-86

[17] Patra S, Liu CQ, Wang FS, Li SL, Wang BL. Behavior of major and minor elements in a temperate river estuary to the coastal sea. *International Journal of Environmental Science and Technology*. 2012;**9**:647-654

[18] Gebhardt AC, Schoster F, Gaye Haake B, Beeskow B, Rachold V, Unger D, et al. The turbidity maximum zone of the Yenisei River (Siberia) and its impact on organic and inorganic proxies. *Estuarine, Coastal and Shelf Science*. 2005;**65**:61-73

[19] Darren A, Chevis A, Johannesson KH, Burdige DJ, Cable JE, Martin JB, et al. Rare earth element cycling in a sandy subterranean Estuary in Florida, USA. *Marine Chemistry*. 2015;**176**:34-50

[20] Bradley S, Gosen V, Verplanck PL, Seal RR, Long KR, Gambogi J. Rare-earth elements chapter 0 of critical mineral resources of the United States—Economic and environmental geology and prospects for future supply. *USGS: Science for a Changing World Year*. 2017. pp. 862. DOI: 10.3133/pp1802

[21] Subramanian V, Van Grieken R, Van't Dack L. Heavy metals distribution in the sediments of the Ganges and Brahmaputra. *Environmental Geology and Water Sciences*. 1987;**9**:93-103

[22] Borole DV, Krishnaswami S, Somayajulu BLK. Uranium isotopes in rivers, estuaries and adjacent coastal sediments of western India: Their weathering, transportation and oceanic budget. *Geochimica et Cosmochimica Acta*. 1982;**46**:125-137

[23] Seralathan P, Seetharamaswamy A. *Geochemistry of the modern deltaic*

sediments of the Cauvery River, East Coast of India. *Indian Journal of Marine Sciences*. 1987;**16**:31-38

[24] Ramanathan AL, Vaithyanathan P, Subramanian V, Das BK. *Geochemistry of the Cauvery Estuary, East Coast of India*. *Estuaries*. 1993;**16**:549-474

[25] Govindasamy C, Arulpriya M, Ruban P, Meenakshi VR. Hydro-chemical evolution of Palk Strait region, Bay of Bengal. *Journal of Tropical Life Science*. 2012;**2**:2-3

[26] Angusamy N. Placer deposits of Southern Tamil Nadu Coast, India. *Marine Georesources and Geotechnology*. 2006;**24**:77

[27] Chandramohan P, Jena BK, Sanil V, Kumar. Littoral drift sources and sinks along the Indian coast. *Current Science*. 2001;**81**:3

[28] Chandrasekar N. 9th International Conference on Geomorphology of the International Association of Geomorphologists (IAG). *Landform Analysis*, New Delhi. 6-11 Nov 2017. DOI: 10.12657/landfana.035.001

[29] Spencer KL. *Estuarine Deposited Sediments: Sampling and Analysis*. In: *Estuarine and Coastal Hydrography and Sediment Transport*. Cambridge: Cambridge University Press; 2017. pp. 153-178. DOI: 10.1017/9781139644426.007

[30] Environment Canada. *Guidance Document on Collection and Preparation of Sediments for Physicochemical Characterization and Biological Testing*. Ottawa: Environmental Protection Series. Environment Canada; 1994

[31] Simpson SL, Batley GE, Chariton AA, Stauber JL, King CK, Chapman JC, et al. *Handbook for*

Sediment Quality Assessment. Bangor: CSIRO; 2005

[32] Aggarwal SK. Thermal ionization mass spectrometry (TIMS) in nuclear science and technology – A review. *Analytical Methods*. 2016;**8**:94

[33] Harikrishnan N, Ravisankar R, Suresh Gandhi M, Kanagasabapathy KV, Prasad MVR, Satapathy KK. Heavy metal assessment in sediments of east coast of Tamil Nadu using energy dispersive X-ray fluorescence spectroscopy. *Radiation Protection and Environment*. 2017;**40**:21-22

[34] Grundl TJ, Haderlein S, Nurmi JT, Tratnyek PG. Introduction to aquatic redox chemistry. In: ACS Symposium Series. Washington, DC: American Chemical Society; 2011

[35] Ramesh R, Ramanathan AL, James RA, Subramanian V, Jacobson SB, Holland HD. Rare earth elements and heavy metal distribution in the estuarine sediments of east coast of India. *Hydrobiologia*. 1999;**397**:89-99

[36] Rengarajan R, Sarin MM. Distribution of rare earth elements in the Yamuna and Chambal rivers, India. *Geochemical Journal*. 2004;**38**:551-569

[37] Britoa P, Pregoc R, Mil-Homensa M, Caçadorb I, Caetanoa M. Sources and distribution of yttrium and rare earth elements in surface sediments from Tagus estuary, Portugal. Available from: https://digital.csic.es/bitstream/10261/159056/1/Sources_distribution_yttrium.pdf

[38] Ramanathan AL, Subramaniam V, Ramesh R, Chidambaram S, James A. Environmental geochemistry of the Pichavaram mangrove ecosystem (tropical), southeast coast of India. *Environmental Geology*. 1999;**37**:223-233

[39] Hema A, Richardmohan D, Srinivasalu SK. Trace metals in the sediment cores of estuary and tidal zones between Chennai and Pondicherry, along the east coast of India. *Indian Journal of Marine Sciences*. 2002;**31**:141-149

[40] Chandrasekaran A, Mukesh MV, Chidambaram S, Singarasubramanian SR, Rajendran S, Muthukumarasamy R, et al. Assessment of heavy metal distribution pattern in the sediments of Tamirabarani river and estuary, east coast of Tamil Nadu, India. *Environmental Earth Sciences*. 2015;**73**(5):2441-2452. DOI: 10.1007/s12665-014-3593-y

[41] Govindasamy C, Kannan L. Rotifers of the Pitchavaram mangroves (Southeast Coast of India): A hydrobiological approach. *Mahasagar*. 1991;**24**(1):39-45

[42] Biksham G, Subramanian V. Elemental composition of Godavari sediments (Central and Southern Indian Subcontinent). *Chemical Geology*. 1988;**70**:275-286

[43] Raj S, Jee PK, Panda CR. Textural and heavy metal distribution in sediments of Mahanadi Estuary, East Coast of India. *Indian Journal of Geo-Marine Sciences*. 2013;**42**(3):370-374

[44] Ramalingam K, Thangavel B. Seasonal distribution of heavy metal in the sediments from Uppanar estuary (East coast of India). *Journal of Aquatic Biology*. 2004;**19**:112-119