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Research Article: ENVIRONMENTAL EARTH SCIENCE

Trace Element Accumulation and Depositional Environment of Surface Sediments, Off Rameshwaram, Gulf of Mannar, India

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Abstract: The aim of the present study was carried out to assess the depositional environmental condition and environmental geochemistry of surface sediments, off the Rameswaram Gulf of Mannar, India. Twenty surface samples were collected along the coastal areas of Rameswaram and sampling location were fixed using a hand held GPS. The sediments were medium to fine grained nature and very well sorted to moderately well sorted. The skewness is symmetrical to fine skewed and platykurtic to leptokurtic nature. The sediments were deposited under moderate to high energy, environmental condition and the sediments were predominantly transported by rolling, bottom and suspension mechanisms. The Linear discriminate function (LDF) value indicates that sediments deposited by aeolian and beach process under shallow marine environment. The distribution of trace elements is chiefly controlled by organic matter and calcium carbonate content. The enrichment factor (EF) indicates the no enrichment to the moderate enrichment nature of the sediments. The Geo-accumulation index (Igeo) values falling under uncontaminated to moderately contaminated sediments whereas Pollution Load Index (PLI) and Contamination Factor (CF) indicate the low contamination nature of the marine environment.

Keywords: *Depositional environment, Trace metals, Environmental pollution, Rameshwaram*

1. INTRODUCTION

Granulometric studies of the coastal sediments provide a wealth of information on the intrinsic properties of sediments and their depositional environment (Friedman, 1961; Visher, 1969; Beavington-Penney and Racey, 2004). The characteristics of the grain size distribution are related to source materials, process of weathering, abrasion, corrosion and sorting process during the transportation and deposition (Rajamanickam and Gujar, 1984). The study of coastal sediments for geochemical characteristics, environmental pollution is a widely utilized method of environmental quality assessment (Forstner and Wittmann 1979), since sediments incorporate contaminant concentration over time, rendering a long-term picture of influence of different actors (natural weathering, agriculture, urbanization, etc.) on aquatic systems. Several investigations have confirmed that sediments from coastal areas are prone to be contaminated by heavy metals; therefore, the evaluation of metal distribution in surface sediments is useful to measure contamination in the marginal marine environment (Jayaprakash et al. 2008; Pekey 2006). Estuarine and coastal sediments usually act as sinks of river borne metal released by weathering and human activities in terrestrial environments (Salomons and Fornster 1984). The total concentrations of heavy metal pollution in the coastal sediments are not considered as potential hazards of the coastal zone. The main sources of trace metals accumulated in marine sediments are a combined process of natural weathering and/or anthropogenic process. The potential availability of heavy metal in the coastal environment is dependent on the metal accumulation and the binding strength with sedimentary phases (Marins et al 1998). The aim of the present work is to assess the depositional environment and environmental pollution of surface sediments, Off Rameswaram Island, Gulf of Mannar, India.

2. STUDY AREA

The Rameswaram Island is located in the Gulf of Mannar, Southeast coast of India (9°15' to 9°20' N and 79°15' to 79°25'E; Fig. 1). The average elevation of the island is about 10 m above the mean sea level. It covers an area of 51.8 km^2. The Gulf of Mannar areas is a shallow embayment between Bay of Bengal and Indian Ocean. A major part of the Rameswaram Island is manifested with coral carbonate rocks which is overlained by quaternary sediments of fluvio-marine, marine facies and Aeolian sand dunes. This quaternary

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Fig1 Sample locations and study area map

alluvium is loose, not cemented and so acts as good groundwater reservoir. A major part of the Rameswaram Island is manifested with coral carbonate rocks which is overlain by quaternary sediments of fluvio-marine, marine forces and Aeolian sand dunes. This quaternary alluvium is loose, not cemented and so acts as good groundwater reservoir. The study area receives maximum rainfall during the northeast monsoon and experiencing dry tropical climate with low humidity with average monthly rainfall of 75.73 mm mostly from North East monsoon from October to January. The Gulf of Mannar received fresh water and riverine sediments through Thamirabarani River and the ephemeral streams such as Vaippar, Gundar, Karaimanayar and Nambiyar. The Gulf of Mannar region flourished 21 coral islands between Rameswaram and Tuticorin. This marine region is declared as a marine biosphere reserve by the Government of India. The annual average temperature of the study area is 30 to 38˚C.

3. MATERIALS AND METHODS

Twenty surface sediment was collected from coastal areas of Rameshwaram Island, Gulf of Mannar, India. The surface sediments were repeatedly washed with distilled water for removal of salts and then dried. The hundred grams of dried sample were sub-sampled using the coning and quartering method. To remove carbonate and organic matter from the sediments, the sediments were treated with 10% dilute HCl and 6% H_2O_2 solution and washed with distilled water. The pre-treatment samples were subjected to sieving with ASTM test sieves of 8 inch diameter, with successive sieves stoked at ½ Ø intervals for 10- 20min. The grain size data were applied to calculate the Mean size (Mz), Standard deviation (σI), Skewness (SKI) and Kurtosis (KG) (Folk and Ward, 1957; Dinesh, 2009). Frequency curve, scatter plots and CM diagrams were drawn from a grain size data set. Sediment textural components (sand: silt: clay) were analyzed (Folk, 1968). Organic carbon and calcium carbonate analysis were performed by Loring and Rantala (1992) and Gaudette et al. (1974) methods. The elemental composition was analyzed after complete digestion procedures (Tessier et al. 1979). The digested liquid was adopted for trace element analysis (Fe, Mn, Cu, Zn, Co, Ni and Pb) in Atomic absorption spectrophotometer (Model No - Varian AA240FS) after centrifuge the liquid at 6000 RPM. The accuracy of the analytical procedures in the present study was assessed using the certified reference material MESS-1 (Table 1) from the National Research Council of Canada. The pollution indices were calculated for obtaining elemental composition to determine the environmental pollution status of the sediments.

TABLE 1
Comparison of MESS 1 certified values for total trace elements

Elements	MESS-1	Present values	Recovery %
Fe	3.1 ± 0.38	2.98	96.129
Mn	513 ± 25	490	95.517
Cr	71 ± 1.1	70.1	98.732
Cu	25.11 ± 3.88	23.9	95.181
Ni	29.5 ± 2.7	28.4	96.271
Co	10.8 ± 1.9	10.3	95.370
Pb	34 ± 6.1	32.9	96.765
Zn	191 ± 17	187.3	98.063

4. Results and Discussion

Sediment texture and Elemental distribution

The comparative abundance of sand, silt and clay contents, calcium carbonate percentage and Organic matter percentage are presented in Table 2. The distribution of sand and mud contents showing higher concentration of coarse sediments at near the shoreline is due to tidal effects (Muthuraj and Jayaprakash 2007). The textural distribution of the surface sediments in Trilinear plot reveals the predominance of sand particles (Fig. 2). The calcium carbonate content in the surface sediments ranges from 3.167% to 9.627% and with an average of 4.892%. The carbonate fraction percentage is depending on the availability of broken shell fragments. This conclusion is drawn from extensive field work observations. Organic matter (OM) in marine sediments may be derived from terrestrial, marine and anthropogenic sources. Organic matter content ranges from 0.1-1.7%. In general, less than 4% of organic matter indicate the low productive area and high percentage of organic matter, especially greater than 4% suggest the high productive areas (Bogner et al. 2005).

Trace elements

The element concentration (Fe, Mn, Cu, Cr, Co, Ni, Pb, Zn) and their mean values are shown in Table 3. The enrichment of Fe and Mn concentration is controlled by the distribution of ferromagnesian minerals supplied by the river input (Sagheer, 2004). The surface sediment concentration of Fe ranges from 33049 to 54835 μg g^{-1} with a mean value of 43210.82 μg g^{-1}. The moderate concentration of Fe and Mn in the surface sediments probably due low riverine input and protected nature of the coast. Mn concentration ranges from 204 to 551 μg g^{-1} with a mean value of 287.73 μg g^{-1}. The trace elements concentration ranges from 24.60 to 59.40 μg g^{-1} for Cu, from 23.20 to103.10 μg $g^{-1}$for Cr, from 4.90 to 36.80 μg g^{-1} for Co, from 7.28 to 107.32 μg $g^{-1}$for Ni, from 4 to 22.80 μg g^{-1} for Pb, from 20.05 to 38.32 μg g^{-1} (Table 3).

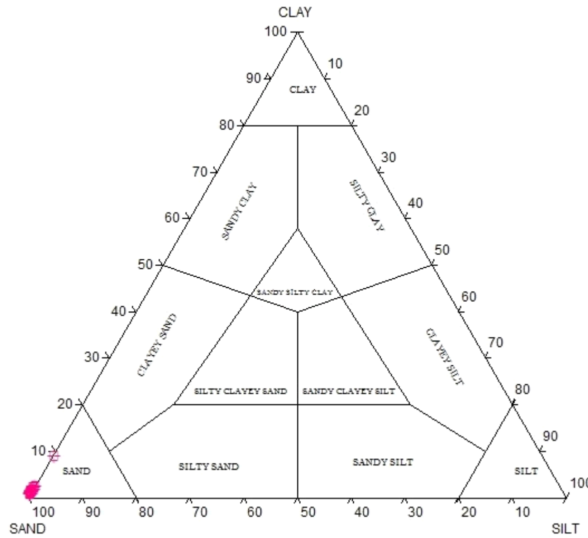

Fig 2 Ternary diagram for Sand-Silt-Clay distribution

TABLE 2
Textural characters, calcium carbonate, organic matter and sediment type in surface sediments off Rameswaram coast

S.No	Sand	Silt	Clay	$CaCO_3$	OM	Textural class
1	93.901	0.02	0.978	4.229	0.872	Sand
2	93.983	0.01	0.84	4.902	0.265	Sand
3	94.11	0.012	0.399	5.134	0.345	Sand
4	92.527	0.134	1.722	5.286	0.331	Sand
5	93.157	0.052	0.9	5.278	0.613	Sand
6	94.125	0.009	1.712	3.601	0.553	Sand
7	94.232	0.088	1.024	3.778	0.878	Sand
8	93.401	0.07	1.304	3.513	1.712	Sand
9	95.068	0.016	0.707	3.728	0.481	Sand
10	92.816	0.139	1.945	4.744	0.356	Sand
11	95.108	0.006	0.869	3.548	0.469	Sand
12	94.927	0.01	1.161	3.586	0.316	Sand
13	93.519	0.013	0.939	5.404	0.125	Sand
14	94.742	0.003	1.023	3.747	0.485	Sand
15	94.891	0.005	0.932	3.656	0.516	Sand
16	94.992	0.007	0.904	3.167	0.93	Sand
17	84.775	0.598	7.85	5.504	1.273	Sand
18	88.063	0.342	1.179	9.627	0.789	Sand
19	89.598	0.009	0.9	8.488	1.005	Sand
20	94.172	0.017	0.547	3.91	1.354	Sand
Maximum	95.108	0.598	7.85	9.627	1.712	-
Minimum	84.775	0.003	0.399	3.167	0.125	-
Mean	92.817	0.098	1.640	4.892	0.704	-

TABLE 3
Elemental concentration (in ppm) of surface sediments, Off Rameswaram coast, Southeast coast of India

S.no	Fe	Mn	Cu	Cr	Co	Ni	Pb	Zn
1	44552	245	36.4	26.2	24.4	41.6	18	27.6
2	44403	204	36.9	23.2	10.3	41.04	14	23.48
3	44277	214	55.6	37.8	6.3	10.2	15.6	29.41
4	46852	338	50.5	53.1	8.9	14.36	15.4	30.69
5	45157	284	38.4	60.7	14.8	25.76	6	28.74
6	43803	272	35.3	63.1	6.8	11.6	12.4	24.6
7	34609	313	24.6	71.2	8.6	7.28	20.4	20.05
8	33049	253	26.7	52.3	11.2	8.24	4.4	21.28
9	35035	225	40.4	49.9	4.9	7.64	4	25.89
10	39259	426	52	103.1	14.2	8.52	10.8	38.32
11	44351	240	42.9	48.7	19	13.24	6.8	28.66
12	44092	249	59.4	38.6	16.9	17.88	5.6	31.68
13	33740	228	35.4	39.8	14.2	30.84	20	26.54
14	54835	235	45.6	46.3	7.4	37.16	17.2	27.79
15	53099	221	34.1	30.3	12.4	46.92	22.8	24.63
16	44971	251	32.1	31.8	15.9	41.28	21.2	20.38
17	42093	551	44.6	91.6	22.1	64.04	13.8	37.55
18	46490	344	42.2	68.2	23.6	84.76	15.4	33.15
19	43062	238	31.9	70.5	27.6	107.32	18.8	21.22
20	45025	244	56.3	73.3	36.8	82.32	12.4	28.95
Mean	43210.82	287.73	41.15	54.82	15.82	37.12	13.72	27.68

Index Calculations

Pollution indices of this study, the enrichment factor (EF), Geoaccumulation index (Igeo), contamination factor (CF) and pollution load index (PLI) was applied to assess heavy metal contamination in sediments.

Enrichment Factor (EF)

The enrichment factor (EF) (Szefer et al. 1998) permits to calculate the heavy metal contamination and it was calculated according to the following formula:

$$EF = \frac{(Metal/Fe)_{sample}}{(Metal/Fe)_{Background}} \quad (1)$$

Iron has been chosen as normalization element because of its origin being exclusively lithospheric (Bloundi et al. 2009). EF values were interpreted according to Acevedo-Figueroa et al. (2006) where EF <1 indicates no enrichment; 1-3 is minor; 3-5 is moderate; 5-10 is moderately severe; 10-25 is severe; 25-50 is very severe; and >50 is extremely severe. EF values indicate that the samples falling under no enrichment to the moderate enrichment of the sediments.

Geo-accumulation Index (Igeo)

The geoaccumulation index (Igeo) as defined by Muller, 1969. This index was used to quantify the extent of metal contamination associating with the sediments. The Igeo values were calculated using the following expression

$$Igeo = Log_2 \frac{Cn}{1.5 \times Bn} \quad (2)$$

where Cn is the measured concentration of the examined metal n in the sediments and Bn is the geochemical background concentration of the metal n of crustal average. The distinguished Muller's expression scale values are 0 – uncontaminated, 1 – uncontaminated to moderately contaminated, 2 – moderately contaminated, 3 – moderately to strongly contaminated, 4 – strongly contaminated, 5 – strongly to very strongly contaminated and 6 – very strongly contaminated. Based on the Muller's geo-accumulation index the study area sediments were falling under uncontaminated to moderately contaminate of the study area sediments.

Contamination Factor (CF)

The level of contamination of sediment by metal is expressed in terms of a contamination factor (CF) calculated as:

$$CF = \frac{Metal\ concentration\ \ sediment}{Backround\ values\ of\ metal}$$

Where C metal sample is the concentration of a given metal in river sediment and Cm background is the value of the metal equal to the world surface rock average given by Taylor (1964).

The CF was classified into four groups (Hokanson 1980; Savvides et al. 1995; Pekey et al. 2004). (1) 1 ≤CF low contamination factor (2) 1 ≤CF < 3 moderate contamination factor (3) 3 ≤CF < 6 considerable contamination factor (4) 6 ≥CF very high contamination factor. The metal accumulation levels in all areas of the sample sites exist in the order of Pb> Mn > Zn > Cr > Cu > Ni > Co. Moderate CF was observed in the case of Ni and Co, while low contamination was observed for men, Cu, Cr, Zn and Pb in the study area.

Pollution Load Index (PLI)

Pollution load index (PLI), for a particular site, has been evaluated using the following method proposed by Tomilson et al. (1980) and Caeiro et al. (2005). This parameter is expressed as;

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \ldots \ldots \times CF_n)1/_n$$

Where n is the number of metals and CF is the contamination factor. The PLI value of >1 is polluted, whereas <1 indicates no pollution (Harikumar et al. 2009). PLI varies from 0.01 to 0.47 with a mean value of 0.12. Based on this PLI result, most of the samples are found to be low contaminated into the marine environment.

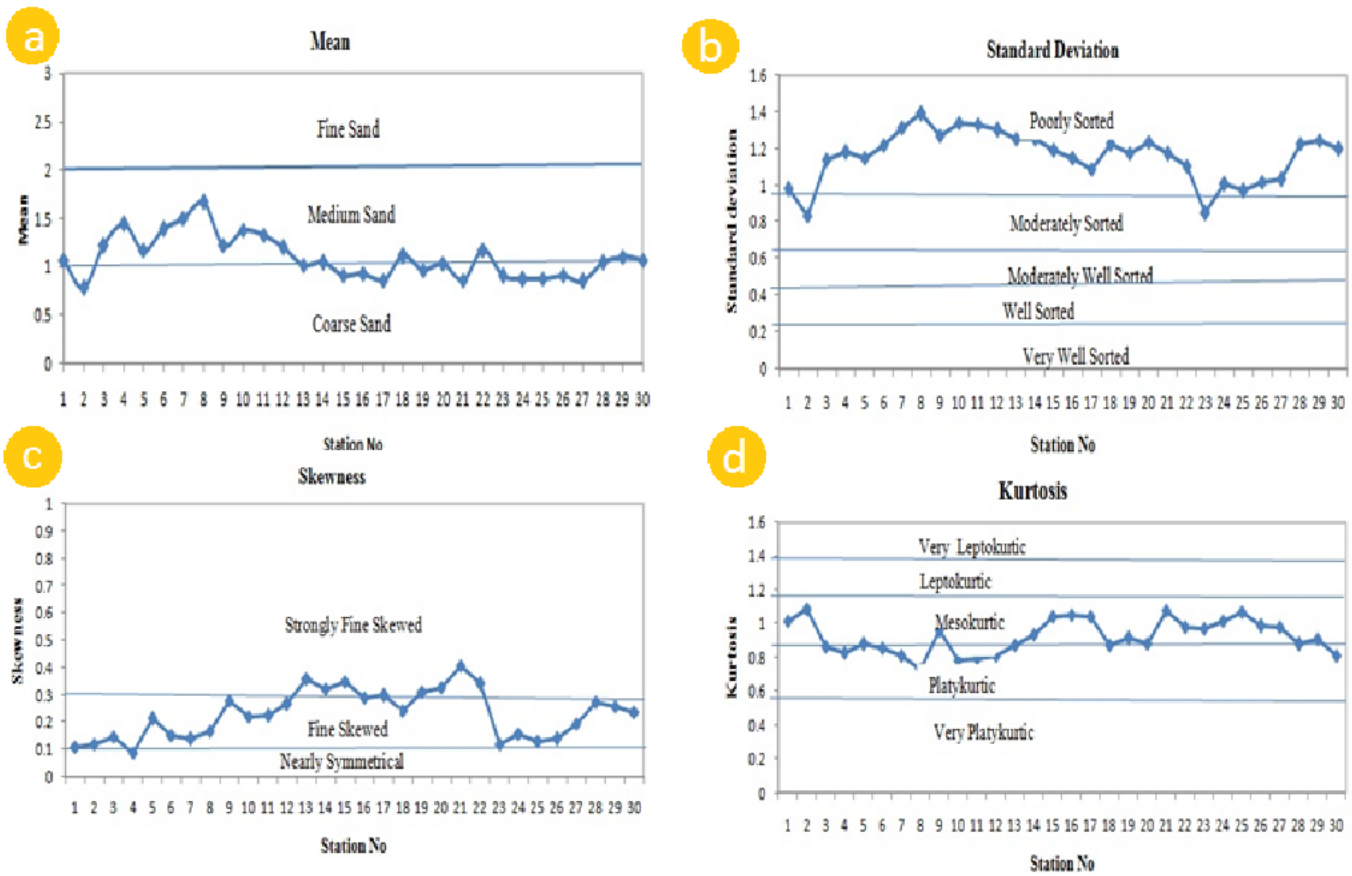

Fig 3 Bivariate plot for grain size (Mean, Standard Deviation, Skewness and Kurtosis) parameters

Correlation Relationship and Factor analysis

The elemental relationship of coastal sediments provides information about source of metals pathways in the geo-environment. The Pearson correlation matrix analysis was useful for confirming the new association and relationship between the metals and sediments. According to extracted results of Pearson correlation matrix, a negative correlation value obtained in all the samples between Fe vs studied elements, which indicates that the elements are derived from different sources such as natural and anthropogenic activities (Table 4). The correlation between silt vs clay, Mn, Cr, and Zn (r = 0.869, 0.899, 0.584, 0.600, $P<0.01$). The significant relationship between Clay vs Mn (r = 0.860, $P<0.01$), $CaCO_3$ vs Ni (r=0.645, $p<0.01$), Mn vs Cr, Zn (r=0.760, 0.61, $p<0.01$) suggest that they probably act as a carrier phase of these trace elements. Cu vs Zn (r=0.737, $p<0.01$), Co vs Ni (r=0.744, $p<0.01$) suggests that they probably act as a carrier phase of these trace elements.

Granulometric Analysis

Textural attributes of sediments, viz. Mean (Mz), sorting (SD), skewness (Ski) and kurtosis (KG) are widely used to reconstruct the depositional environment of sediments (Angusamy and Rajamanickam 2006). The relationship between size parameters and transport processes/depositional mechanisms of sediments has been established by exhaustive studies from many modern and ancient sedimentary environments (Folk and Ward 1957; Mason and Folk 1958; Table 5). The graphic mean size is the average size of the sediment represented by Ø mean size and it is an index of energy conditions. The mean values range from 0.72-2.54 Ø with an average value 1.68 Ø. The size of the grains shows the dominance of medium to fine sediments. It indicates that this coastal sediment deposited under high energy, environmental conditions (Folk and Ward (1957) (Fig.3a). The graphic standard deviation (σ1) was helpful to study the sorting of sediments, and it indicates the fluctuation in the kinetic energy (Sahu, 1964). Sorting has an inverse relation with Standard deviation. Standard deviation indicates the difference in kinetic energy associated with mode of deposition. The standard deviation of the present samples ranges in between 0.07 Ø – 1.29 Ø, with an average of 0.64 Ø. The sediments are of predominantly moderately sorted nature. The variations in the sorting values are may be due to the continuous addition of finer/coarser materials in varying proportions (Fig.3b).

TABLE 4
CORRELATION MATRIX *(R)* OF TOTAL TRACE ELEMENTS IN SURFACE SEDIMENTS (*N* = 13) RAMESWARAM COAST, SOUTHEAST COAST OF INDIA

Parameters	Sand	Silt	Clay	$CaCO_3$	OM	Fe	Mn	Cu	Cr	Co	Ni	Pb	Zn
Sand	1.000												
Silt	-.887**	1.000											
Clay	-.752**	.869**	1.000										
$CaCO_3$	-.719**	.428	.109	1.000									
OM	-.365	.331	.299	.024	1.000								
Fe	.032	-.059	-.058	.060	-.205	1.000							
Mn	-.753**	.899**	.860**	.254	.241	-.112	1.000						
Cu	-.011	.102	.082	.010	-.316	.326	.165	1.000					
Cr	-.576**	.584**	.504*	.313	.326	-.248	.760**	.159	1.000				
Co	-.399	.231	.134	.368	.493*	.122	.160	.177	.278	1.000			
Ni	-.571**	.288	.154	.645**	.387	.337	.092	-.023	.173	.774**	1.000		
Pb	-.098	-.003	-.024	.198	-.076	.309	-.041	-.299	-.187	.083	.389	1.000	
Zn	-.459*	.600**	.516*	.244	-.197	.169	.671**	.737**	.495*	.211	.023	-.269	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The graphic Skewness indicate the symmetrically of the distribution of the sediments specifically predominance of coarse or fine sediments. The negative value denotes coarser material in coarser-tail, especially coarse skewed. But the positive value represents more fine material in the fine-tail (fine skewed).

Skewness values range in between -0.377 Ø and 0.305 Ø with an average value of -0.03 Ø. The positive skewness of sediments is indicates the deposition of the sediments in sheltered low energy, whereas negative skewness of sediments indicates deposition at high energy environments (Rajasekhara Reddy et.al., 2009). The negative skewness indicates the high energy nature of the beach deposits and multi directional sediment transport (Friedman, 1961; Martins 1965) (Fig.3c). The graphic kurtosis is indicate the peakedness of the distribution and measures the ratio between the sorting in the tails and central portion of the curve. The values of graphic kurtosis range from 0.72 Ø to 1.31 Ø, with an average of 1.00 Ø. The most of the samples are falling under mesokurtic nature. The extreme high or low values of kurtosis suggest that part of the sediment achieved its sorting elsewhere in a high energy environment (Friedman, 1962). The variation of kurtosis values is a reflection of the flow characteristics of the depositional medium (Ramamohan Rao et.al., 1982; Seralathan and Padmalal, 1994; Fig.3d). The bivariate relationship of specific size-parameters is significant to interpret various aspects of deposition environment, as the textural parameters of the sediments are often environmentally sensitive (Folk and Ward, 1957; The bivariate plot standard deviation vs skewness medium sand to fine-sand its indicate beach environment (Fig.4a). The skewness vs mean, skewness Vs standard deviation plot reveals that the dominant influence of beach environment in inner shelf processes of sediments (Fig.4b).

The CM pattern of the was plotted using the values of first percentile (C) and medium (M) of size distribution (in microns). CM pattern represents a complete model of tractive current (deposition process) as shown by Passega (1964) which consists of several segments such as NO, OP, PO, OR and RS indicating different modes of sediment transport (Fig.5). Most of the sediment samples falling under 'NO' segment, which indicate sediments are mostly of < 200mm size. The deposited sediments transported by rolling and bottom suspension process. Variations in the energy and fluidity factors seem to have excellent correlation with the different processes and the environment of deposition Passega (1964). The process and environment of deposition were deciphered by Sahu's linear discriminate functions of Y1 (Aeolian, beach), Y2 (Beach, shallow agitated water), Y3 (Sh. Marine, fluvial) and Y4 (Fluvial Deltaic and Turbidity). Based on Y1 value, aeolian process contributes 80% followed b,y 20% from beach environment. Likewise, Y2 value suggests that 70% sediments contributed from beach followed by 30% of the sample from a shallow agitated water process. 100% of the sample fall under shallow marine and turbidity condition with reference to Y3 and Y4 respectively (Table 6).

TABLE 5
GRAPHIC MEASURE FOR GRANULOMETRIC STUDIES OF THE SURFACE SEDIMENTS, OFF RAMESWARAM COAST

S.No	Mean		Standard Deviation		Skewness		Kurtosis	
1	1.524	Medium Sand	0.073	Moderately Sorted	-0.029	Symmetrical	1.172	Leptokurtic
2	1.19	Medium Sand	0.649	Moderately Well Sorted	-0.095	Symmetrical	1.077	Mesokurtic
3	1.365	Medium Sand	0.602	Moderately Well Sorted	0.035	Symmetrical	1.181	Leptokurtic
4	2.255	Fine Sand	0.757	Moderately Sorted	-0.155	Coarse Skewed	0.784	Platykurtic
5	1.876	Medium Sand	0.732	Moderately Sorted	0.277	Fine Skewed	0.729	Platykurtic
6	2.454	Fine Sand	0.61	Moderately Well Sorted	-0.377	Very Coarse Skewed	1.133	Leptokurtic
7	2.4	Fine Sand	0.778	Moderately Sorted	-0.346	Very Coarse Skewed	0.853	Platykurtic
8	2.337	Fine Sand	0.686	Moderately Well Sorted	-0.356	Very Coarse Skewed	0.911	Mesokurtic
9	1.613	Medium Sand	0.439	Well Sorted	0.114	Fine Skewed	0.923	Mesokurtic
10	2.009	Fine Sand	0.482	Well Sorted	0.113	Fine Skewed	1.007	Mesokurtic
11	1.949	Medium Sand	0.445	Well Sorted	0.191	Fine Skewed	1.068	Mesokurtic
12	1.43	Medium Sand	0.601	Moderately Well Sorted	0.03	Symmetrical	1.151	Leptokurtic
13	1.392	Medium Sand	0.718	Moderately Sorted	-0.09	Symmetrical	1.052	Mesokurtic
14	1.479	Medium Sand	0.47	Well Sorted	0.131	Fine Skewed	1.062	Mesokurtic
15	0.82	Coarse Sand	0.517	Moderately Well Sorted	0.021	Symmetrical	0.894	Platykurtic
16	1.553	Medium Sand	0.544	Moderately Well Sorted	-0.002	Symmetrical	1.038	Mesokurtic
17	2.239	Fine Sand	0.957	Moderately Sorted	-0.377	Very Coarse Skewed	1.085	Mesokurtic
18	1.428	Medium Sand	1.219	Poorly Sorted	0.089	Symmetrical	0.736	Platykurtic
19	1.817	Medium Sand	0.831	Moderately Sorted	-0.119	Coarse Skewed	0.809	Platykurtic
20	0.723	Coarse Sand	0.8	Moderately Sorted	0.305	Very Fine Skewed	1.318	Leptokurtic
Max	2.454	-	1.219	-	0.305	-	1.318	-
Min	0.723	-	0.073	-	-0.377	-	0.729	-
Mean	1.683	-	0.646	-	-0.032	-	1.001	-

TABLE 6
LINEAR DISCRIMINATE FUNCTION VALUES (SAHU, 1964) OF THE SURFACE SEDIMENTS, OFF RAMESWARAM COAST

Sl.No.	Y1	Remarks-Y1	Y2	Remarks-Y2	Y3	Remarks-Y3	Y4	Remarks-Y4
1	-5.419	Aeolian	24.206	Beach	0.388	Shallow Marine	1.097	Turbidity
2	-2.688	Beach	46.304	Beach	-3.351	Shallow Marine	0.689	Turbidity
3	-3.53	Aeolian	45.18	Beach	-2.786	Shallow Marine	0.839	Turbidity
4	-5.926	Aeolian	72.953	Sh. Agitated water	-4.377	Shallow Marine	1.396	Turbidity
5	-4.712	Aeolian	64.574	Beach	-4.159	Shallow Marine	1.138	Turbidity
6	-7.38	Aeolian	62.864	Beach	-2.56	Shallow Marine	1.621	Turbidity
7	-6.325	Aeolian	77.341	Sh. Agitated water	-4.618	Shallow Marine	1.488	Turbidity
8	-6.598	Aeolian	67.504	Sh. Agitated water	-3.456	Shallow Marine	1.496	Turbidity
9	-5.043	Aeolian	37.912	Beach	-1.228	Shallow Marine	1.086	Turbidity
10	-6.31	Aeolian	46.713	Beach	-1.462	Shallow Marine	1.356	Turbidity
11	-6.223	Aeolian	43.521	Beach	-1.179	Shallow Marine	1.326	Turbidity
12	-3.766	Aeolian	46.119	Beach	-2.756	Shallow Marine	0.886	Turbidity
13	-3.06	Aeolian	55.664	Beach	-4.119	Shallow Marine	0.797	Turbidity
14	-4.461	Aeolian	37.667	Beach	-1.513	Shallow Marine	0.978	Turbidity
15	-1.937	Beach	30.399	Beach	-2.108	Shallow Marine	0.484	Turbidity
16	-4.447	Aeolian	43.755	Beach	-2.15	Shallow Marine	1.001	Turbidity
17	-4.6	Aeolian	95.228	Sh. Agitated water	-7.385	Shallow Marine	1.246	Turbidity
18	0.404	Beach	119.994	Sh. Agitated water	-7.241	Shallow Marine	0.431	Turbidity
19	-3.928	Aeolian	73.818	Sh. Agitated water	-5.531	Shallow Marine	1.033	Turbidity
20	-0.211	Beach	53.371	Beach	-5.4	Shallow Marine	0.264	Turbidity

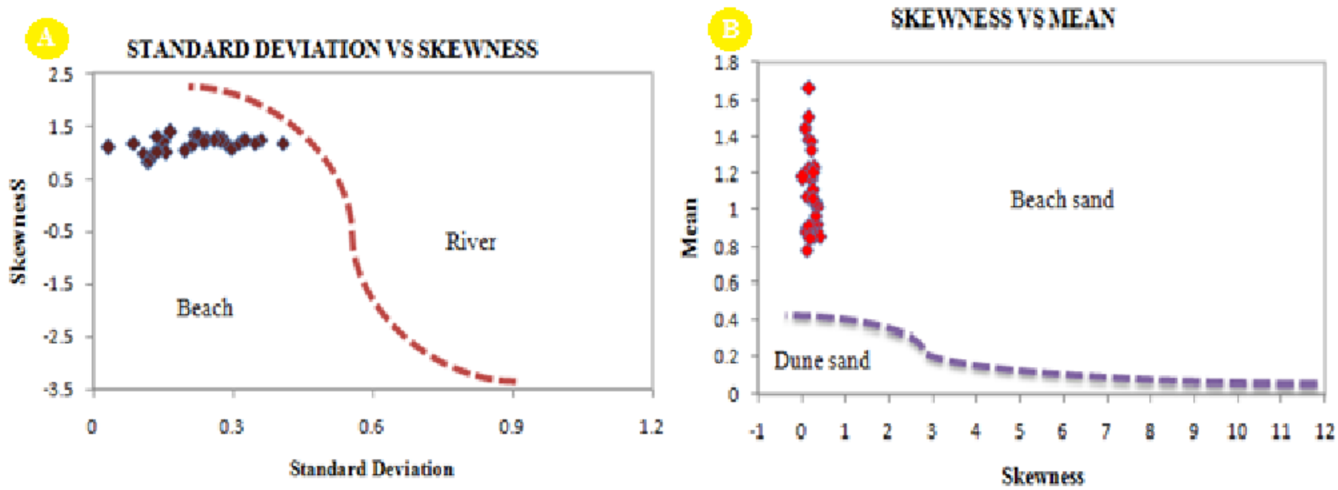

Fig 4 Bivariate plot for depositional environment (Standard Deviation vs Skewness and Skewness vs Mean)

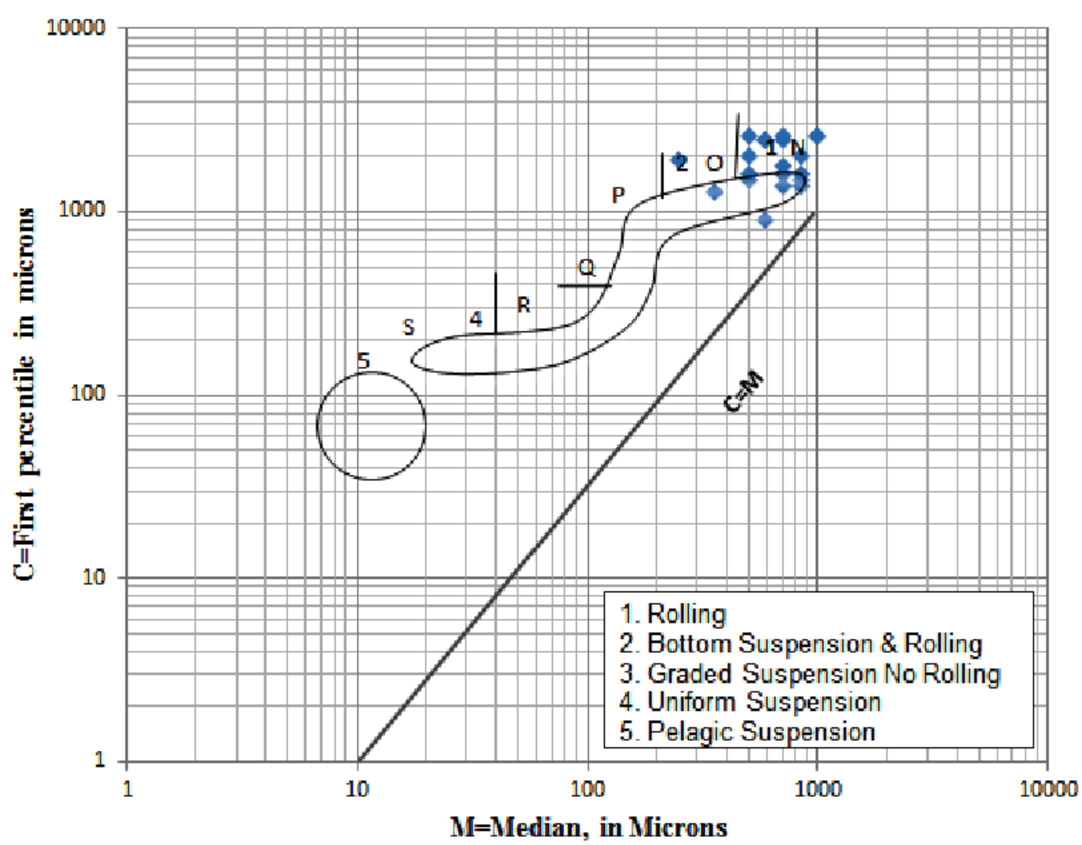

Fig 5 CM Pattern (One percentile vs Median)

5. CONCLUSION

The textural characteristics analysis, Metal pollution index (MPI), Geo-accumulation index (Igeo) and Enrichment Factor (EF) was performed in surface sediments of Rameshwaram sediments to infer the geochemical and depositional environmental changes. The sand, silt, clay ratios reveal that all the sample falling under sand nature. The elevated content of $CaCO_3$ is probably due to the availability of small coral rubbles and shell fragments with the marine sediments. Likewise, rich organic matter content is chiefly contributed from the seagrass and mangrove debris. The granulometric values indicate that the medium to find sand with high energy condition, standard deviation reveals that the sediment is well sorted to very well sorted, skewness suggest that the sediments is coarse to nearly symmetrical, and kurtosis values show the leptokutic to mesokurtic nature of the sediemnts. The CM diagram indicates the sediments are transported by rolling and bottom suspension process. Linear discriminate function (LDF) value indicates that sediments deposited by aeolian and beach process under shallow marine and turbidity environment of the basin. The factor loading reveals that the Mn and Fe oxy-hydroxides are responsible for trace elements accumulation. Based on the index calculations of the coastal sediments are grouped under uncontaminated to moderately contaminate category.

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