Grain Size Distribution and Depositional Environment Studies of Core Sediments Near Thoothukudi Coast, Tamil Nadu, India

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Abstract- *Core sediments from Thoothukudi coast has been studied for textural parameters, transportation mechanism and depositional environment. Texturally sediments are mostly fine sand, well sorted to moderately well sorted, coarse skewed to near symmetrical and leptokurtic to very leptokurtic in nature. Abundance of the fine sand demonstrates the prevalence of moderately low energy condition in study area. Several geomorphic features has been discussed which are the signatures of the interaction of marine and Aeolian processes. Linear discriminate function analysis (LDF) of the sample indicates a shallow marine environmentof depositionunder turbidity action. The CM pattern of Thoothukudi coastal sediment shows a clustered distribution of sediments in the PQ sector, indicating a graded suspension and no rolling mode of deposition. The inference to be drawn from these studies is that the variation in sedimentological parameters is governed by wave dynamics and littoral transport of the sediments.*

Keywords- Textural parameters, Linear discriminate function (LDF), CM pattern, Rameswaram, Tamilnadu.

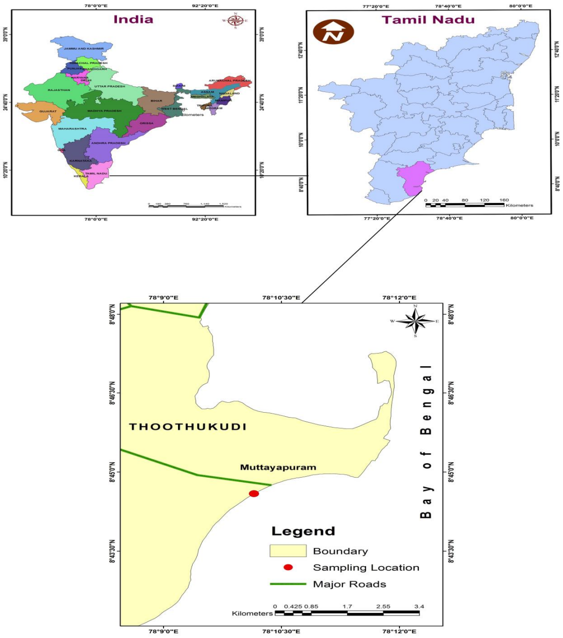
I. INTRODUCTION

The particle size and the morphology of sediments are the major tools to interpret the source or provenance of sediments, transportation modes and depositional environments (Greenwood, 1961; Friedman, 1967 and Pettijohn, 1984). As being a dynamic zone where air, land and water interact, the coastal zone is a focus of particular interest among the scientific community. Earlier studies have indicated that the south east coast of India is affected by natural disasters such as cyclone, induced surges and variability in river discharge, tsunami etc. resulting in triggering, reallocation and redistribution of the sediments in the beach region.Grain size is one of the most significant physical property of sediment and commonly used parameter for understanding the processes involved in transportation and deposition of sediments (Inman 1952; Folkand Ward, 1957; Mason and Folk, 1958; Friedman and Sanders, 1961;Krumbein andSloss, 1963; Nordstrom 1977)This helps in understanding the various processes affecting erosion and deposition. Thus, the knowledge of sediment size and textural parameters is one of the better tools to differentiate various depositional environments of recent as well as ancient sediments (Inman 1952; Dyer 1986; Folk 1974; Mason and Folk, 1958; Friedman 1961; Nordstrom 1977, Kumar et al. 2010). The aim of this study is to understand the textural parameters, transportation history and paleoenvironment of deposition of sediments near Thoothukudi harbour.

II. STUDY AREA

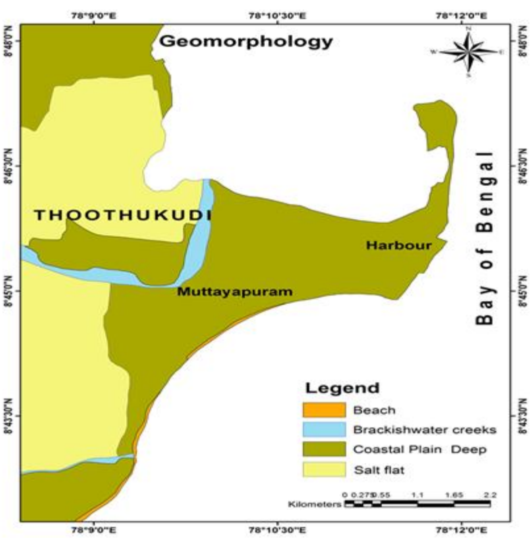
Studies were carried out nearThoothukudi harbour, Thoothukudi district, Tamil Nadu.Tuticorin, also known as Thoothukudi is a major port and industrial city of Tamil Nadu. The study area falls in the latitudinal and longitudinal extensions of 8°40’- 8°55’ N and 78°0’ -78°15’ E on survey of India toposheet no. 58 L/2 (Map-1). The region around Thoothukudi shore is home to rare marine flora and fauna as a part of Marine Biosphere Reserve and consists of several coral reef islands off the coastline. During the past decades, there has been a drastic surge in industrial development along this coast. The discharges from the thermal plants and excessive brine run off from the salt pans impact the sedimentation as well as flora and fauna to a larger extent.

Gneiss, charnockite and quartzite of Archaean age, calcareous sandstone and shale limestone of tertiary age, and alluvium of recent age underlie the Thoothukudi area. The Archaean groups of formation are crystalline or metamorphic, and finely foliated with a general NW–SE trend (Balasubramanian, 1993). The formations that include quartzite as ridges are weathered, jointed and fractured. Recent to sub-recent sand occupies the coastal areas. It consists of coarse and calcareous grit, sandstone and shale limestone. Opaque minerals like zircon, monazite, tourmaline, apatite, and rutile make their appearance in order of dominance.



Map -1 Showing Study Area Map

The coastline of Tuticorin district can be divided into southern and northern part, having the harbour at centre. Present study which is falling under the southern sector, provided with an enormous amount of sediment from the erosion of headlands from Tiruchendur, Manapad and Periyathalai regions. The cuspate delta of River Tamirabarani indicates powerful long-shore current with depositing nature. Presence of Harbour and fringing reef barriers are responsible for the redistribution and trapping of the sediment loads. Predominance of recent alluvium deposits are chiefly controlled by the Holocene transgression and regression activities.



Map-2 Showing Geomorphology Map

The beach sediments surrounding study area chiefly consisting terrigenous and calcareous detritus, a heterogeneous mixture mainly composed of quartz sand, biogenic carbonate and shell fragments derived from local source. As a part of Gulf of Mannar, the representative coastal features such as bays, lagoons, estuaries, salt flat, cliffs, dunes, coral terraces, wave cut features, etc. are common along this belt. The features like salt flat, brackish water creek, coastal plain deep are prominently found in the study area (Map-2). The region has loose red dry soil (Teri) with thorny shrubs and salt pans. The major soil types found are black cotton, red soils, river alluvium, calcareous soil, and saline mangrove soil. Although the unconsolidated sedimentation make the aquifers porous and permeable, saline water intrusion is the biggest problem in entire district. It is one of the oldest port cities of India and majority of population are engaged in salt production, industrial and fishing activities. It experiences a tropical dry climatic condition with mean annual temperature 300c whereas frequent rain showers are feeble during NE monsoon with mean annual precipitation is 675. 71 mm.

III. METHODOLOGY

Sampling has been carried out during month of June 2016 by core sampling method using PVC (Polyvinyl Chloride) pipe of 2.5 inch diameter and of one meter length. The core samples then capped and carefully carried to the laboratory for further analysis. The exact sampling locations were noted with the help of Global Positioning System (GPS) receiver. The core Sample was sub sampled with 5cm interval and transferred to clean dry polythene bags for laboratory analysis. In order to get true representative samples for sieve analysis, the air-dried samples were subjected to coning and quartering and amount of the sample was reduced to 100 gm. These representative samples were then washed with distilled water to remove salt content and further treated with 10% dilute hydrochloric acid to remove organic content. Later these samples were washed frequently with distilled water and dried in hot air oven at 60°c temperature. Sieve analysis was carried out using a series of standard ASTM test sieve (From #25 to #325 sieve sizes) of quarter phi interval to get uniform size fractions in Ro-Tap sieve shaker for 20 minutes. The grain size data acquired after sieving is processed to calculate all the statistical parameters such as Mean (Mz), Standard Deviation (σI), Skewness (Ski) and Kurtosis (KG).Linear discriminant function (Sahu, 1964) was used for understand depositional environment of the sediments. CM plot prepared as suggested by Passega to understand the transportation mechanism. The G-Stat software package was used for obtaining the CM diagram.

IV. RESULT AND DISCUSSION

The most frequently used statistical parameters like mean (Mz), standard deviation (σI), skewness (Sk_i) and Kurtosis (KG) were calculated using percentile value. In the present work, these four parameters are used to represent grain size characteristics of sediments.

Mean (M_Z)

Mean grain diameter, the most widely used distribution parameter, is regarded by most authors (Folk, Ward, 1957; Passega, 1964) as an indicator of the average energy of the transport and as sedimentation agent. In the study area, the vertical mean size ranges between 2.207 Φ (45-50cm depth) and 2.9Φ (90-95cm depth) with average mean of 2.692Φ (Table-1). The mean size indicates that all of the samples belong to Fine sand category. This suggests that the sediments were deposited under low energy condition, as sediments usually become finer with decrease in energy of the transporting medium (Folk, 1974; Eisema, 1981). The variation in mean size is a reflection of the changes in energy condition of the depositing media and indicates average kinetic energy of the depositing agent (Sahu, 1964).

Standard Deviation

Graphic standard deviation measures sorting of sediments and indicate the fluctuation in energy conditions of depositional environment but it does not necessarily measure the degree to which the sediments have been mixed (Spencer, 1963).The values obtained in the study area vary between 0.382Φ (35-40cm depth) and 0.598Φ (95-100cm depth) with average mean of 0.441Φ (Table-1). The standard deviation values suggest that most of the sample belongs to well sorted (80%) character which indicate the winnowing or back and forth motion by the depositing agent.Presence of Moderately well sorted (20%) character indicates low to fairly high energy current (Friedman, 1961; Blott&pye, 2001).

Skewness

It is used to determine the symmetry of the distribution, i.e. predominance of coarser or finer sediments. The negative value denotes coarser material in coarser tail i.e., coarse skewed, whereas, the positive value represent more fine material in the fine tail i.e., fine skewed.Skewness value of the study area ranging between -0.338Φ (10-15cm depth) to 0.549Φ (40-45cm depth) with an average of -0.1Φ (Table-1). Accordingly most of the samples are coarse skewed (50%) and near symmetrical (35%) in nature. The negative skewness indicates high energy nature of the beach deposits in general (Friedman, 1961) and multidirectional sediment transport (Martins 1965). Near symmetrical nature of sediments indicate variation in energy condition during deposition.

Kurtosis

The graphic kurtosis (KG) is the peakedness of the distribution and measures the ratio between the sorting in the tails and central portion of the curve. According to (Cadigan1961), it is also a function of internal sorting or distribution. Kurtosis value of the sediments in study area ranges from 0.714Φ (45-50cm depth) to 1.691Φ (20-25cm depth) with an average of 1.326Φ (Table-1).Most of the samples in the study area belong to leptokurtic (50%) and very leptokurtic (35%) nature whereas a few samples show platykurtic (10%) behaviour. Leptokurtic to very leptokurtic nature of sediments implies that the sediments were sorted in high or low energy environment and transported to a new environment with reversal of energy to mix either with fine or coarse sediments depending upon the energy condition. The variation in kurtosis value indicates reflection of the flow characteristics of the depositing medium (Cardigan, 1961).

Table -1 Graphic measure from grain size analysis sediments

Depth	Mean	St.dev	Skewness	Kurtosis	Remarks
5	2.813	0.400	-0.084	1.544	FS,WS,NS,VLK
10	2.727	0.436	-0.215	1.421	FS,WS,CS,LK
15	2.550	0.540	-0.338	1.101	FS,MWS,VCS,LK
20	2.687	0.388	-0.261	1.306	FS,WS,CS,LK
25	2.783	0.413	-0.145	1.691	FS,WS,CS,VLK
30	2.683	0.426	-0.289	1.420	FS,WS,CS,LK
35	2.760	0.412	-0.213	1.561	FS,WS,CS,VLK
40	2.773	0.382	-0.130	1.366	FS,WS,CS,LK
45	2.807	0.416	-0.065	1.678	FS,WS,NS,VLK
50	2.207	0.402	0.549	0.714	FS,WS,VFS,PK
55	2.490	0.505	-0.067	0.747	FS,MWS,NS,PK
60	2.807	0.390	-0.032	1.512	FS,WS,NS,VLK
65	2.600	0.428	-0.187	1.164	FS,WS,CS,LK
70	2.673	0.405	-0.195	1.230	FS,WS,CS,LK
75	2.860	0.392	-0.025	1.477	FS,WS,NS,LK
80	2.767	0.581	-0.149	1.505	FS,MWS,CS,VLK
85	2.683	0.493	-0.136	1.340	FS,WS,CS,LK
90	2.883	0.422	0.111	1.378	FS,WS,FS,LK
95	2.900	0.385	-0.048	1.588	FS,WS,NS,VLK
100	2.390	0.598	-0.090	1.027	FS,MWS,NS,MK
MIN	**2.207**	**0.382**	**-0.338**	**0.714**	
MAX	**2.900**	**0.598**	**0.549**	**1.691**	
AVG	**2.692**	**0.441**	**-0.100**	**1.326**	

Frequency Curves

Frequency curve exhibit the pictorial representation of actual weight percentage of different fraction of sediments. According to (Friedman and Sander, 1978) the size factor mode is the peak of a simple frequency curve. The mode is important statistical parameter, especially the sediments containing several subpopulations each of which has its own mode. The presence of several modes in sand suggests that the particles have been derived from several parent deposits. In such multi-population (polymodal) sands, the phi value and magnitude give information on fraternization of sediments. Change in the mode reflects the history of the sand. The frequency distributions for most of the samples of Mandapam area dominated with unimodal (75%) nature with a few displays bimodal (25%) distribution at different depths. The unimodal character indicate single source of deposition whereas bimodal distributions indicate mixing of sediments from two different sources and observed at middle segment below 50cm depth. Dominant presence of 2.75Φ and 3.25Φ size suggests the possibility of keeping a specific environment of segregation under a similar force of hydrodynamic condition (Figure-1).

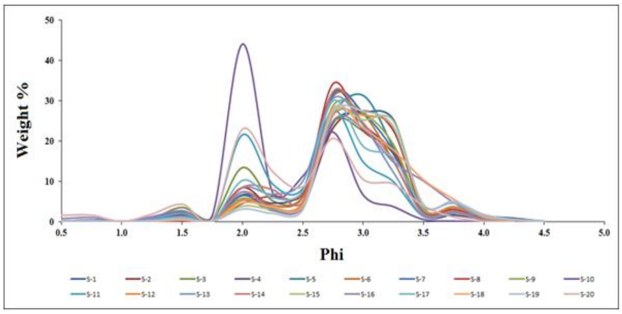


Figure-1 Showing frequency distribution of sediments

V. LINEAR DISCRIMINANT FUNCTION (LDF)

According to Sahu (1964), the variations in the energy and fluidity factors seem to have excellent correlation with the different processes and the environment of deposition. However, as there is strong penchant to find out the total effect of the various parameters on the grain size variations in the beaches, the process and environment of deposition has been deciphered by Sahu's linear discriminant functions of Y1 (Aeolian, beach), Y2 (Beach, shallow agitated water) , Y3 (shallow marine, fluvial) and Y4(Fluvial Deltaic and Turbidity). Linear Discriminant Function (LDF) value study area indicates that sediments were deposited by Aeolian and Beach process under shallow marine condition under turbidity environment (Table-2).

Table -2 Showing linear discriminant function values (Sahu, 1964)

Sl.No.	Depth	Mean	StdDev	Skewness(Ski)	Kurtosis(KG)	Y1	Remarks-Y1	Y2	Remarks-Y2	Y3	Remarks-Y3	Y4	Remarks-Y4
1	5	3.223	0.400	-0.084	1.544	-10.910	Aeolian	60.964	Beach	-0.482	ShallowMarine	2.261	turbidity
2	10	0.222	0.436	-0.215	1.421	-0.089	Beach	15.966	Beach	-1.602	ShallowMarine	0.084	turbidity
3	15	2.550	0.540	-0.338	1.101	-8.021	Aeolian	59.077	Beach	-1.827	ShallowMarine	1.722	turbidity
4	20	2.687	0.388	-0.261	1.306	-9.032	Aeolian	51.953	Beach	-0.552	ShallowMarine	1.878	turbidity
5	25	2.783	0.413	-0.145	1.691	-9.301	Aeolian	54.771	Beach	-0.701	ShallowMarine	1.939	turbidity
6	30	2.683	0.426	-0.289	1.420	-8.903	Aeolian	53.923	Beach	-0.825	ShallowMarine	1.889	turbidity
7	35	2.760	0.412	-0.213	1.561	-9.222	Aeolian	54.357	Beach	-0.700	ShallowMarine	1.923	turbidity
8	40	2.773	0.382	-0.130	1.366	-9.356	Aeolian	52.995	Beach	-0.487	ShallowMarine	1.942	turbidity
9	45	2.807	0.416	-0.065	1.678	-9.377	Aeolian	55.310	Beach	-0.715	ShallowMarine	1.956	turbidity
10	50	2.207	0.402	0.549	0.714	-7.278	Aeolian	45.166	Beach	-0.786	ShallowMarine	1.527	turbidity
11	55	2.490	0.505	-0.067	0.747	-7.942	Aeolian	55.734	Beach	-1.524	ShallowMarine	1.694	turbidity
12	60	2.807	0.390	-0.032	1.512	-9.455	Aeolian	53.933	Beach	-0.532	ShallowMarine	1.964	turbidity
13	65	2.600	0.428	-0.187	1.164	-8.601	Aeolian	52.736	Beach	-0.863	ShallowMarine	1.802	turbidity
14	70	2.673	0.405	-0.195	1.230	-8.932	Aeolian	52.619	Beach	-0.675	ShallowMarine	1.882	turbidity
15	75	2.860	0.392	-0.025	1.477	-9.698	Aeolian	54.866	Beach	-0.530	ShallowMarine	2.002	turbidity
16	80	2.767	0.581	-0.149	1.505	-8.625	Aeolian	65.494	Beach	-2.168	ShallowMarine	1.880	turbidity
17	85	2.683	0.493	-0.136	1.340	-8.675	Aeolian	57.969	Beach	-1.364	ShallowMarine	1.838	turbidity
18	90	2.883	0.422	0.111	1.378	-9.690	Aeolian	56.830	Beach	-0.738	ShallowMarine	2.008	turbidity
19	95	2.900	0.385	-0.048	1.588	-9.801	Aeolian	55.135	Beach	-0.471	ShallowMarine	2.039	turbidity
20	100	2.390	0.598	-0.090	1.027	-7.206	Aeolian	60.909	Beach	-2.451	ShallowMarine	1.980	turbidity

VI. C-M PLOT

Passega (1957)introduced C-M plot to evaluate the hydrodynamic forces working during the deposition of the sediments. It is a relationship of 'C' i.e. coarser one percentile value in micron and 'M' i.e. median value in micron on log-probability scale. Passega (1964), divided the CM pattern into different sector namely NO, OP, PQ, QR, and RS for different mode of transport. The plotted result of sediment shows that most of the samples fall in PQ sector indicatinggraded suspension and no rolling condition of deposition (Figure-2).

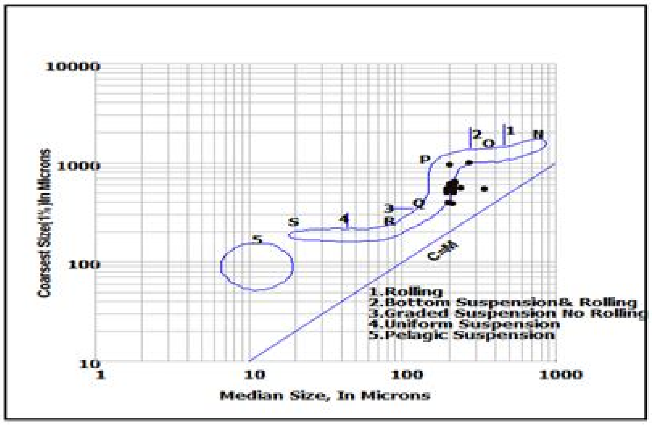


Figure- 2 Showing CM diagram (Passega, 1964)

VII. CONCLUSION

The textural parameters of coastal sediments nearThoothukudi harbour indicates mostly fine sand, well sorted, coarse skewed to near symmetrical and leptokurtic to very leptokurtic in nature. Dominance of fine sand infers moderately low energy conditions of deposition. The sediment, in general, show dominantly coarse skewed to near symmetrical in nature. Leptokurtic to very leptokurtic nature of sediments implies that the sediments were sorted in high or low energy environment and transported to a new environment with reversal of energy to mix either with fine or coarse sediments depending upon the energy condition. Linear

Discriminant Function (LDF) value of the study area indicates that sediments were deposited by Aeolian and Beach process under shallow marine condition under turbidity environment. The plotted result of sediment shows that most of the samples deposited bygraded suspension and no rolling condition of deposition.

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