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GRAIN SIZE TRENDS ASSOCIATED WITH HYDRODYNAMICS ALONG CHENNAI COAST, INDIA

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ABSTRACT

Grain size is an important property of sediment particles, affecting their entrainment, transport and deposition. An attempt has been made to determine the changes in grain size pattern from near shore to offshore region along the Chennai coast, India. The results revealed that sediments were moderately sorted to well sorted, symmetrical skewed to fine skewed, and very platykurtic to platykurtic. Grain size diameters showed a decreasing trend from nearshore to offshore areas. Relatively higher values of hydrodynamic characteristics such as waves, tides and currents obtained at Marina and Adayar regions. The differences in the grain sizes distribution patterns of the sediments between the northern and the southern parts of the region are mainly due to variable discharges through Coovum river at the northern part and Adyar river at the southern part. Except this fluvial influence, the local wave, tide and current action have also played an important role in the distribution of the coastal and nearshore sediments. Results of this study provide further insight for expensive dredging, pollution control and coastal management.

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INTRODUCTION

The study of grain size pattern in shallow marine sediments is closely related to the geology and hydrography of the adjacent land areas as well as the local climate. Grain size study of such sediments have clearly demonstrated that they are not only sensitive indicators of their environment of formation but also provide valuable insight into the regional hydrodynamics including patterns of sediment transport and deposition (Muzuka *et al.*, 2000). Grain size distributions at the beach in conjunction with beach slope parameters have been used globally to characterize areas that are under the impact of beach erosion or accretion (Anwar *et al.*, 1979).

Chennai is the fourth largest city in India and the capital of the Indian state of Tamilnadu located on the Coromandel Coast of the Bay of Bengal. Two rivers meander through Chennai, the Cooum River (or Kuvam) through the centre and the Adayar River to the south. The city is served by two major ports, Chennai Port, one of the largest artificial ports, and Ennore Port. Fishing harbours and a variety of coastal industries like nuclear thermal power plants, refineries, fertilizers, and marine chemicals are situated along the coast. Beach resorts, farmhouses, aquaculture ponds, theme parks, tourist spots, and artificial parks are mainly located on the southeast coast of Chennai. Fishing is the main occupation of the people living in the suburban coastline, whereas in the urban coastline, the occupation is not only fishing but also depends upon urban resources like industries and government and non-government organizations. Understanding the spatial variation of grain size characteristics in this region is important. First of all, such variation can be utilized in studies of sedimentary environments and sedimentary processes (Shi *et al.*, 2002). Secondly, this variation also can be used as a natural tracer to indicate how the sediments already deposited in the sea have been reworked by hydrodynamic processes (Liu *et al.*, 2000), as well as the temporal evolution caused by both natural and human-induced processes (Guillen *et al.*, 1997). Furthermore, grain size studies are paramount in understanding the engineering properties of sediment for harbor extension and maintenance dredging (Hein *et al.*, 1991). As heavy metals and petroleum hydrocarbons are preferentially associated with fine grained sediments, they also improve understanding of marine contaminants (Venkatachalapathy *et al.*, 2010 and 2011. In a view to understand the sediment grain size pattern along Chennai coast an attempt has been made to improve understanding of marine contaminants.

This present study were carried out with the following objectives: (1) to determine the hydrodynamic characteristics and bottom topography off Chennai coast,

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(2) to characterize the sediment grain size distribution pattern over the sampling area and (3) to deduce spatial distribution of grain size and transport processes of marine sediments, relating to hydrodynamic conditions.

MATERIALS AND METHODS

The study area is located between the longitudes of 80° 16' 20"E and 80°22' 20''E and the latitudes of 12°58' 00" N and 13° 15' 00" N coast of 30 km long coastal stretch from Thiruvottiyur to Thirvanmiyur. Surface sediment samples were collected from twenty one sites distributed over the Chennai coast from Thiruvottiyur to Thiruvanmiyur at 5, 10 and 15 m water depths during April 2009 by fishing trawler boat, using Van Veen grab sampler (Figure 1). The collected sediment samples were packed by self-packing polythene bags and were frozen at -4°C immediately until further analysis. Sediment grain size analysis was carried out using standard sieving and sedimentation techniques in the laboratory of the Integrated Coastal and Marine Area Management (ICMAM), Chennai. Grain size parameters such as mean grain size, standard deviation, skewness and kurtosis were calculated by using standard methods (Amaral, 1977).

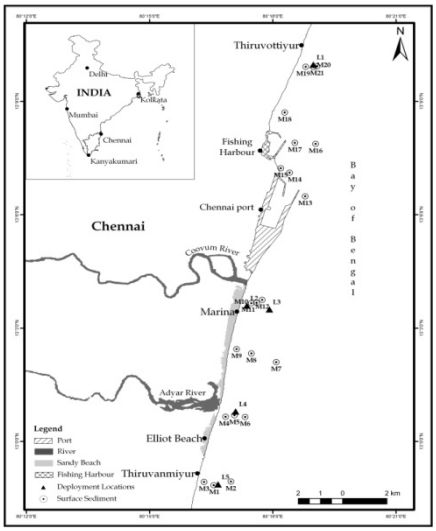

Fig.1 study area showing the sampling and deployment locations

Differential Global Positioning System (DGPS) fixed on boat. The data were recorded digitally and stored on laptop for further processing. Although the echo-sounder provided essential hydrographic information during survey operations, these soundings were tide corrected and presented. The wind speed and wind direction were measured using an automatic weather station. Fifteen days wave, tide and current measurements were obtained at five field sites off Chennai. Wave and tide measurements were carried out using Valeport wave and tide gauges. The current speed and direction was measured using Aanderaa RCM9 current meter.

RESULTS AND DISCUSSION

Hydrodynamics

The bottom topography of Chennai coast has given in Figure 2.

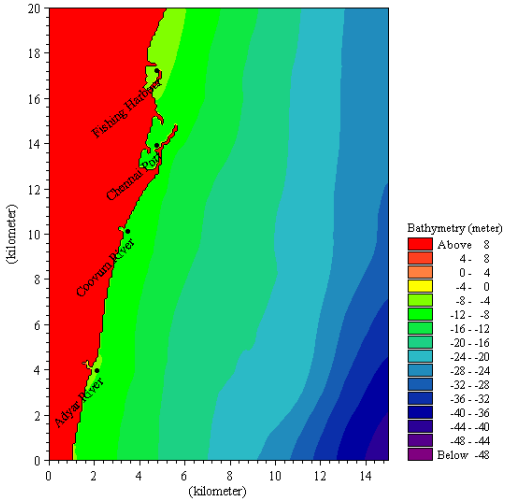

Fig.2 The bathymetric map showing the sea bed off Chennai

The depth of Chennai coast ranged from 5 to 44 m. During the study period, the observed wind speed and wind direction varied from 0.1 to 4.9 m/s and from 26˚ to 346˚, respectively. The average wind speed and wind direction was 1.6 m/s and 204˚. Tides in this region were predominantly semi-diurnal, with a tidal range of 1.17 m. The maximum wave heights (H_{max}) and the significant wave heights (the average height of the one-third highest waves, H_s) was found to be 2.38 m and 1.51 m, respectively at Marina. The minimum, maximum and mean values of wave parameters are presented in Table 1.

Table 1 Details of wave characteristics off Chennai

Parameter	L1	L2	L3	L4	L5 (9 days data)
	Min-Max (Mean)	Min-Max (Mean)	Min-Max (Mean)	Min-Max (Mean)	Min-Max (Mean)
Significant wave height H_s (m)	0.37-1.08 (0.66)	0.33-1.51 (0.74)	0.34-1.23 (0.70)	0.27-0.98 (0.57)	0.39-0.98 (0.66)
Maximum Wave Height, Hmax (m)	0.58- 1.69 (1.04)	0.52-2.38 (1.18)	0.54-1.93 (1.11)	0.43-1.54 (0.91)	0.61-1.53 (1.03)
Mean Period (T_1)	4.71-12.12 (9.40)	5.11-13.5 (9.62)	5.56-14.27 (9.65)	5.66-11.75 (8.94)	7.59-12.70 (10.53)
Peak Period (T_p)	3.61-17.07 (11.16)	3.45-18.28 (11.59)	3.45-18.28 (11.34)	3.88-14.22 (10.47)	8.83-17.07 (12.38)
Zero Upcross Period (T_z)	4.36-11.70 (8.82)	4.59-12.72 (8.88)	4.98-13.64 (8.97)	5.16-11.16 (8.30)	6.67-12.04 (9.88)
Significant Wave Period ($T_{1/3}$)	3.79-17.92 (11.72)	3.63-19.2 (12.17)	3.63-19.2 (11.91)	4.07-14.93 (10.99)	9.27-17.92 (12.99)
Wave Energy Density (E)	87.20-729.87 (291.85)	69.93-1452.58 (376.65)	75.058-953.23 (332.08)	47.92-607.74 (221.89)	94.78-599.75 (281.25)

respectively. This observation was well in accordance with the earlier study by kankara et al., 2011.

Table 2 Observed current magnitude and direction at mooring locations

Locations	SW-monsoon		
	Average Current Speed (cm/sec)	Maximum Current Speed (cm/sec)	Predominant Current Direction
Loc-1	18	36	NNE
Loc-2	15	35	NNE
Loc-3	17	40	NNE
Loc-4	21	41	NNE
Loc-5	15	32	NNE

Sediment grain size parameters

Grain size distribution of surface sediments collected from Chennai coast demonstrated that mean grain size values varied between 0.04 and 0.51 phi; sorting ranged from 0.38 to 0.71 phi; skewness from -0.17 to 0.59; and kurtosis from 0.48 to 1.77. Based on the classification scheme used herein (Table 3) it was found that the sediments were moderately sorted to well sorted, symmetrical skewed to fine skewed, and very platykurtic to platykurtic.

Table 4 showed the distribution of mean grain size parameters off Chennai. It is obvious that the mean grain size exhibits a decreasing trend in phi from near shore to offshore with increasing depth. This distribution shows a high degree of heterogeneity, according to the localization of the supply sources, to the energy of the environment and to the transport processes. Variation in skewness and kurtosis can be explained by the mixture of various grain size populations in the sediment (Bartholdy *et al.*, 2007). The skewness and kurtosis parameters have only local significance, but they are useful for the characterization of different sedimentary environments. Skewness is a parameter that responds to transport direction and supply sources. A highly negative skewness appears in the transition zones due to the mixture of fine and coarse grain sizes. The statistical parameters of sediment grain size for the entire coast is given in Table 4. Sediment grains with small diameter were mainly distributed offshore and generally were poorly sorted and finely skewed. In contrast, coarser sediments appeared in the near shore area, tended to be better sorted, and coarsely skewed.

Relationship between grain size and hydrodynamics

The properties of sediments may have changed due to grain size variation and dynamic nature of sediment transport and redistribution induced by natural and anthropogenic influences. Moreover, this variation also can be used as a natural tracer to indicate how the sediments already deposited in the coast, have been reworked by hydrodynamic processes. In the study area, significant inverse relationship was obtained between mean grain size and water depth, except near the littoral area. This behavior is contributed by the tidal currents, long shore currents and the geomorphology of the area. Grain size distribution can be affected by multiple factors, including sediment sources and hydrodynamics. Sediments tend to become finer in the direction of transport as a result of decrease in current velocity along the transport path. The observed decrease in grain size from nearshore to offshore in this present study can be attributed to the high wave energy and a progressive current velocity. The coarse grain sizes obtained from Marina and Adayar regions could be due to high wave energy conditions, whereas the lower grain sizes obtained in Coovum and northern part of the study area could be attributed to a reduced current velocity owing to estuarine bottom friction in shallow coastal waters and variations in bathymetry.

Table 3 Descriptive terminology for the sediment grain size properties (Blott *et al.*, 2001)

Sorting		Skewness		Kurtosis	
Very well sorted	<0.35	Very fine skewed	>1.30	Very platykurtic	<1.70
Well sorted	0.35 – 0.50	Fine skewed	0.43 – 1.30	Platykurtic	1.70 – 2.55
Moderately well sorted	0.50 – 0.70	Symmetrical	-0.43 – 0.43	Mesokurtic	2.55 – 3.70
Moderately sorted	0.70 – 1.00	Coarse skewed	-0.43 – -1.30	Leptokurtic	3.70 – 7.40
Poorly sorted	1.00 – 2.00	Very coarse skewed	<-1.30	Very leptokurtic	>7.40
Very poorly sorted	2.00 – 4.00				
Extremely poorly sorted	>4.00				

Table 4 Grain size parameters of sediments off Chennai

Sample	Mean (Mz)	Sorting (Σi)	Skewness (Ski)	Kurtosis (Kg)
M1	0.188	0.574	0.463	0.476
M2	0.137	0.518	0.514	0.594
M3	0.038	0.470	0.586	1.769
M4	0.476	0.711	0.089	0.889
M5	0.457	0.669	-0.083	0.717
M6	0.137	0.532	0.533	0.625
M7	0.059	0.375	0.412	0.682
M8	0.087	0.451	0.496	0.574
M9	0.116	0.514	0.545	0.611
M10	0.296	0.496	0.326	0.756
M11	0.374	0.565	0.088	0.692
M12	0.512	0.662	-0.172	0.673
M13	0.390	0.649	-0.080	0.784
M14	0.189	0.583	0.517	0.680
M15	0.156	0.522	0.369	0.741
M16	0.125	0.416	0.436	0.895
M17	0.133	0.522	0.589	0.758
M18	0.168	0.610	0.593	0.735
M19	0.217	0.617	0.526	0.703
M20	0.364	0.669	0.477	0.695
M21	0.411	0.709	0.393	0.597

CONCLUSION

The spatial distribution of sediment grain size parameters along the Chennai coast reveals particular granulometric characteristics. The grain size diameters tend to decrease from nearshore to offshore areas. Sediments were moderately sorted to well sorted, symmetrical skewed to fine skewed, and very platykurtic to platykurtic. Hydrodynamic characteristics such as waves, tides and currents showed relatively higher values at Marina and Adayar regions compare to rest of the stations. Variations in grain size distributions indicated that local hydrodynamics, seabed topography and human activities contributed to the reworking and redistribution of sediments. Results of this study provide further insight for costly dredging, pollution control and coastal management.

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