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A study on textural parameters of beach sands along some parts of the Nellore coast, east coast of India: Implications to Depositional Environment

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ABSTRACT

An attempt has been made to evaluate the textural parameters and grain size distribution of coastal sands from Govindampalli to Durgarajupatnam, Nellore coast, east coast of India. The changes in textural parameters were studied by comparison of two seasons, i.e north east monsoon season (NE) in December 2015 and south west monsoon season (SW) in June 2016. A detailed account of textural parameters and grain size distribution of beach sands were carried out at each station in four microenvironments, by measuring various parameters like graphic mean size, graphic standard deviation, skewness, and kurtosis. To measure textural parameters, bivariate plots have been made to know the degree of freedom among various parameters. The analysis of textural parameters for two seasons indicates the prepotency of medium to fine grain and moderately well-sorted sediments with nearly symmetrical distribution. The textural parameters measurement and bivariate plots infer that prevailing intermittent energy conditions coalesced with rampant south west monsoon winds responsible for the platy to leptokurtic nature of sediments. In order to have a proxy on the mode of transportation and depositional environments CM (Percentile and Median) diagrams were plotted on the double logarithmic sheet, which suggests that sediments were transported by rolling, bottom suspension and rolling and graded suspension. Most of the sediments were deposited in tractive currents and beach environment regions. Factor analysis shows the dominance of mean size and kurtosis in NE monsoon season and skewness and kurtosis in SW monsoon season, where these parameters plays a dominant role in dispersal and distribution of sediments. Linear discrimination function (LDF) analysis shows high energy environments at the time of deposition of sediments.

Keywords: Textural studies; Beach sediments; Factor analysis; Linear discrimination function (LDF) analysis; Nellore coast.

INTRODUCTION

Granulometric studies are the fundamental sedimentological tools, which unravels the properties of sediment particles, transportation and their deposition in the sedimentary environments and provides vital information regarding its provenance and depositional conditions (Krumbein and Pettijohn., 1938; Folk and Ward, 1957). The size of the grain in the depositional environment is influenced by many factors like a wave and current activity, onshore and offshore movements, fluctuations in sea level, episodic storms, debouch of streams, rivulets, and rivers into the oceans or seas. In India, about 1.2×10^9 tons of sediment are carried by the rivers each year (Blott and Pye, 2001). A unique set of foreshore topography and shoreline morphology, is produced by the interaction of sediment supply, energy dispersal pattern, and geology of the area (Senapathi et al., 2011). Grain size parameters were studied between the Gosthani and Champavathi rivers confluence, east coast of India, Andhra Pradesh by Bangaru Naidu et al., (2016) who inferred energy levels and bimodal nature of sediments.

In recent years, many scientists carried out extensive research and emphasized the importance of grain size analysis to understand the grain size parameters and also to differentiate the depositional environments viz., fluvial, lacustrine, marine, estuarine etc., especially in the coastal region (Inman 1952; Passega 1957, 1964; Visher 1969; Veeraiah and Varadachari, 1975; Lingdholmn, 1987; Oaie et al., 2005). An attempt has been made to empathize the textural characteristics and grain size distribution of the sands in the present study area with reference to seasonal variations. This would involve understanding of the energy conditions of the depositional environments through textural parameters, factor analysis and linear discrimination function analysis (LDF).

STUDY AREA

The present study area of Govinadampalli to Drgarajupatnam lies between latitude 14°05′10″-14°01′30″ N and longitude 80°08′20″ - 80°09′36″ E, that belong to Survey of India topo sheet Nos. 66 B/4, 66 C/1

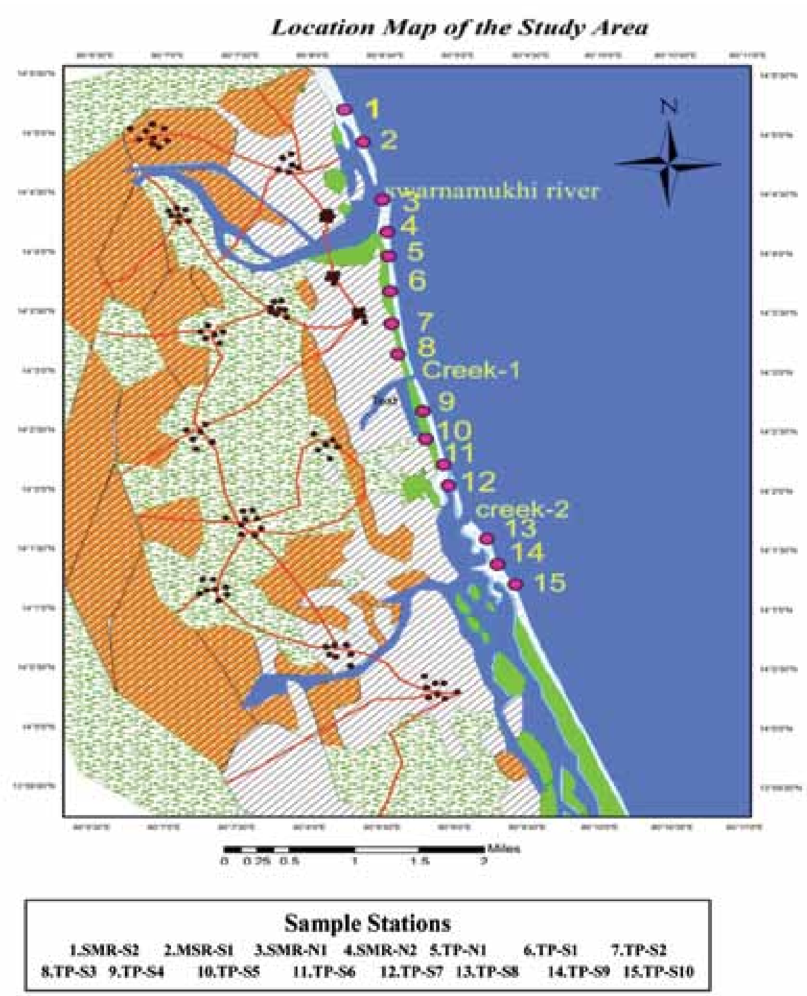

Figure 1. Location map of the study area.

and C/5 on 1:50,000 scale. The major source of sediment is from Swarnamukhi river situated at northern tip of the investigation area (Figure 1). It passes through sacred Tirupathi hills, with no tributaries and later on, debauches into the Bay of Bengal. At the time of first survey i.e., in December 2015, two creeks were observed, one at Tupilipalem village and the other at Durgarajpatnam (Figure 1). From Govendampalli to Durgarajupatnam, the stretch is covered by Quaternary alluvium sediment, underlain by granitic rocks, intersected by phyllites, basic rocks, and metamorphic suite of schist rocks of Precambrian Age.

METHODOLOGY

One hundred and twenty sediment samples (60 in each season) were collected from 15 transects along the study area, in north east (Dec 2015) and south west monsoon season (June 2016) along the 11km stretch from Govindampalli to Durgarajupatnam coast. The sediment samples were collected by using Van Veen grab sampler and recorded location points using handheld GPS. The sediment samples were carefully stored in polythene bags, and 100gms of sample was taken out by using coning and quartering method, and then air dried. The samples were treated with diluted hydrochloric acid (HCl) and ammonia (NH_4) to remove carbonates and organic matter. Later, it is washed with dilute water and air owen dried. Then the samples were subjected to sieving by ASTM sieves with the ½ Ø intervals for 10 to 20 minutes by Ro-Tap sieve shaker for separating the grain with different sizes viz., 16μ, 25μ, 35μ, 45μ, 60μ, 80μ, 120μ, 170μ, 230μ and -230μ (pan). Sieved material was weighed separately and the fractions were properly tabulated for further analysis (Ingram 1970). Grain size parameters like mean size (Mz), standard deviation (SD), skewness (Sk), and kurtosis (K_G), were determined by using the GRADISTAT software (Tables 1a, b). The results obtained from the GRADISTAT software, which is used to draw CM (C=Percentile, M=Median) diagrams, frequency distribution curves, scatter plots. SPSS and graphic prism softwares were used to determine the factor analysis and LDF (Linear discriminate function) analysis respectively.

RESULTS

Grain size parameters

The grain size analysis was carried out and the results were compared, for the two seasons to evaluate the information regarding provenance and depositional conditions.

Graphic mean grain size (Mz)

The average size (ϕ) of the sediments is an indicator of energy conditions. The variations in ϕ represent the differential energy condition, which indicates the kinetic energy of the depositing agents. The grain size values at each measuring point for two seasons are given in Tables 1a and 1b. Grain size analysis was carried out at four microenvironments viz., dune, backshore, berm and foreshore at each station. The ϕ values show medium to fine grain in dune (1.066 φ -2.576 ϕ), backshore (1.506ϕ -2.607ϕ), berm (1.68ϕ -2.415 ϕ) and foreshore (1.14ϕ -2.09ϕ) in NE monsoon season (Table 1a) and in SW monsoon season, dune (0.697ϕ -2.827ϕ) show coarse to fine grain size (Table 1b) and the rest of the microenvironments i.e backshore (1.404ϕ-2.454ϕ), berm (1.642ϕ -2.381ϕ) and foreshore (1.38ϕ -1.96ϕ) show medium to fine grain size. The overall average graphic mean size of the sediment in the study area is 1.865ϕ and 1.801ϕ in NE and SW monsoon seasons respectively. It shows the predominance of medium size particles indicating intermittent energetic conditions (Folk and Ward, 1957).

Standard deviation (σ_1)

Graphic standard deviation (σ_1) quantifies the sorting of sediments in various microenvironments and it represents the wavering pattern of energy conditions of the depositional environment (Sahu, 1964). NE monsoon season shows well to moderately sorting in dune (0.433ϕ – 0.931ϕ), backshore (0.405ϕ -0.787ϕ) and berm (0.399ϕ-0.84ϕ) environments. The foreshore environment (0.62ϕ – 0.92ϕ) shows moderately to moderately well-sorted sediments (Table 1a). In SW monsoon season (Table 1b) dune, backshore, berm show well to moderately sorted sediments, with values ranging in between 0.34ϕ – 0.732ϕ, 0.405ϕ – 0.787ϕ, 0.408ϕ – 0.645ϕ, respectively. The foreshore environment show moderately well sorted to moderately sorted sediments, the value ranges from 0.67ϕ - 0.83ϕ. The average value of all microenvironments in both seasons. 0.649ϕ and 0.62ϕ, indicates moderately well-sorted sediments, which suggests partial winnowing conditions and an addition of sediments to the beach environments. A glance at standard deviation values in both NE and SW monsoon seasons reveals that dune, backshore, berm and foreshore environments, show moderately well sorted in nature, implying that aeolian activity is paramount in sorting of sediments, owing to the continuous panning action by waves and currents (Friedman 1967 ; Giosan et al., 2005).

Skewness (Sk)

Skewness evaluates the symmetry of sediments distribution i.e., prepotency of coarser and finer material. The positive and negative values refer to fine material in the fine tail and coarser material in coarser tail respectively. In the NE monsoon season, the skewness values varies from very coarse to very fine skewed in dune (-0.287ϕ to 0.497ϕ), but in backshore (-0.226ϕ to -0.11ϕ), berm (-0.315ϕ to 0.037ϕ) and foreshore environments (-0.2ϕ to 1.85ϕ), shows coarser to fine skewed sediment distribution (Table 1a). Most of the sediment samples show coarser to fine skewed and depict deposition of sediments in high to low energy environments (Nageswara Rao et al., 2005). Altogether, the average value (-0.059ϕ), indicates nearly symmetrical distribution.

In SW monsoon season, the skewness values of dune (-0.11ϕ to 0.241ϕ), backshore (-0.226ϕ to 0.109ϕ) shows coarser to fine skewed distribution and berm (-0.15ϕ to -0.011ϕ) shows nearly symmetrical and foreshore (-0.193ϕ to 0.053ϕ) show, coarser to near symmetrical distribution of sediments. The overall average value (-0.078ϕ) of the skewness in the study area is nearly symmetrical in nature (Table 1b).

Kurtosis (K_G)

Kurtosis (K_G) ascertains the peak distribution which depicts the mixed (coarse and fine) sediment population distribution and it also gives the ratio of sorting of sediments in the tails as well as in the central portion of the curve (bell-shaped curve). The wide spectrum of kurtosis values reflects the characteristic flow of the depositional medium (Seralathan and Padamalal, 1994; Bangaru Naidu et al., 2016). In NE monsoon season most of the microenvironments i.e., backshore (0.736ϕ – 1.101ϕ), the berm (0.732ϕ – 1.109ϕ) and foreshore (0.72v – 1.07ϕ) exhibits platy to mesokurtic in nature and dune (0.686ϕ – 1.123ϕ) sediment samples of all stations falls under platy to leptokurtic category. The dominance of platy and leptokurtic nature reflects immaturity and maturity of the sand in the depositional environment respectively.

In SW monsoon season all sediment samples shows platy to leptokurtic in nature except foreshore. The extreme high and low kurtosis values reflects that the part of sediments achieved its sorting elsewhere in a high-energy environment (Friedman,1961). The average value of both seasons (0.926ϕ and 0.95 ϕ) represents subsequent accession of coarser and fine material, after the winnowing action and retention of their original character during deposition (Avramidis et al., 2012).

Table 1a. Textural parameters of coast sand from Govindampalli to Durgarajupatnam during north east monsoon season.

SS	DUNE				BACKSHORE				BERM				FORESHORE			
	Mz	SD	S_K	K_G	Mz	SD	S_K	K_G	Mz	SD	S_K	K_G	Mz	SD	S_K	K_G
TP-N-1	2.37	0.46	-0.11	0.99	2.02	0.67	-0.17	0.84	1.68	0.84	-0.12	0.84	1.61	0.92	-0.03	0.75
TP-S-1	2.09	0.55	-0.03	0.94	2.21	0.56	-0.14	1.00	2.42	0.45	-0.17	1.00	1.51	0.88	-0.11	0.87
TP-S-2	1.63	0.93	0.07	0.68	1.41	0.64	-0.04	0.92	2.06	0.56	-0.04	0.92	1.71	0.87	-0.16	0.91
TP-S-3	2.27	0.51	-0.1	0.95	1.96	0.57	-0.08	1.06	2.10	0.54	-0.16	1.06	1.64	0.77	-0.01	0.85
TP-S-4	2.57	0.43	-0.19	1.23	2.19	0.48	-0.09	0.93	2.26	0.65	-0.30	0.93	2.09	0.67	-0.2	0.92
TP-S-5	1.97	0.59	-0.05	0.88	2.38	0.47	-0.15	0.98	2.25	0.59	-0.32	0.98	1.14	0.79	0.25	1.07
TP-S-6	2.19	0.53	-0.17	0.96	2.43	0.46	-0.21	1.10	2.32	0.52	-0.22	1.10	1.72	0.66	-0.08	1
TP-S-7	1.06	0.85	0.50	0.91	2.02	0.62	-0.17	0.96	2.26	0.54	-0.26	0.96	1.72	0.92	-0.06	0.85
TP-S-8	1.18	0.79	0.42	0.78	1.66	0.73	-0.07	0.74	2.22	0.40	0.04	0.74	1.33	0.83	0.16	0.81
TP-S-9	1.96	0.69	-0.19	0.94	1.77	0.71	-0.17	0.89	2.09	0.58	-0.20	0.89	1.48	0.85	-0.02	0.84
TP-S-10	1.52	0.69	0.01	0.84	1.64	0.69	-0.09	0.90	1.88	0.60	-0.13	0.90	1.64	0.67	1.85	1.04
SMR-S-1	2.06	0.74	0.09	0.90	2.45	0.41	-0.23	1.07	2.08	0.65	-0.25	1.07	1.57	0.84	0.18	0.72
SMR-S-2	1.56	0.66	0.07	0.88	1.87	0.59	-0.07	0.87	1.80	0.65	-0.08	0.87	1.57	0.81	0.04	0.79
SMR-N-1	1.96	0.59	-0.13	0.90	2.22	0.52	-0.13	0.98	2.04	0.54	-0.09	0.98	1.56	0.66	0.06	0.94
SMR-N-2	2.35	0.56	-0.28	1.11	1.42	0.79	-0.01	0.82	2.10	0.58	-0.23	0.82	1.79	0.62	-0.08	0.9
Minimum	1.06	0.43	-0.28	0.68	1.41	0.41	-0.23	0.74	1.68	0.40	-0.32	0.74	1.14	0.62	-0.2	0.72
Maximum	2.57	0.93	0.50	1.23	2.45	0.79	-0.01	1.10	2.42	0.84	0.04	1.10	2.09	0.92	1.85	1.07
Average Mean	1.91	0.65	0.01	0.93	1.97	0.59	-0.12	0.94	2.10	0.58	-0.17	0.94	1.60	0.78	0.21	0.88

Mz= Mean Size, SD=Standard deviation, S_K= Skewness, K_G= Kurtosis

Table 1b. Textural parameters of coast sand from Govindampalli to Durgarajupatnam during southwest monsoon season.

SS	DUNE				BACKSHORE				BERM				FORESHORE			
	Mz	SD	S_K	K_G	Mz	SD	S_K	K_G	Mz	SD	S_K	K_G	Mz	SD	S_K	K_G
TP-N-1	1.91	0.69	-0.07	0.95	1.68	0.67	-0.17	0.98	1.76	0.61	-0.07	0.99	1.38	0.67	-0.01	0.96
TP-S-1	1.71	0.54	-0.02	0.88	1.89	0.56	-0.14	0.98	1.64	0.57	-0.03	0.94	1.55	0.73	-0.04	0.86
TP-S-2	2.06	0.55	-0.07	0.96	1.98	0.57	0.11	0.96	1.80	0.54	-0.05	0.99	1.56	0.82	0.05	0.9
TP-S-3	1.79	0.70	-0.08	0.91	1.62	0.64	-0.08	0.86	1.80	0.56	-0.04	1.04	1.61	0.76	-0.06	0.9
TP-S-4	0.70	0.55	-0.09	1.01	1.61	0.48	-0.09	0.92	1.87	0.51	-0.02	1.03	1.59	0.74	-0.02	0.99
TP-S-5	2.23	0.58	-0.11	1.04	1.94	0.47	-0.15	1.01	1.67	0.65	-0.01	0.96	1.38	0.72	0.05	0.93
TP-S-6	2.06	0.69	0.08	0.81	1.51	0.46	-0.21	0.96	1.74	0.63	-0.07	0.96	1.87	0.69	-0.16	1
TP-S-8	2.83	0.59	0.24	1.09	1.70	0.73	-0.07	0.74	1.97	0.54	-0.11	1.11	1.64	0.77	-0.17	0.87
TP-S-9	0.95	0.61	0.08	0.98	1.72	0.71	-0.17	0.73	1.84	0.57	-0.13	1.04	1.62	0.76	-0.07	0.93
TP-S-10	1.44	0.59	0.10	0.92	1.94	0.70	-0.09	0.91	1.79	0.56	-0.04	1.12	1.66	0.79	-0.19	0.83
SMR-S-1	1.27	0.65	0.12	0.89	1.81	0.41	-0.23	1.13	1.87	0.64	-0.08	0.91	1.75	0.83	-0.15	0.77
SMR-S-2	1.38	0.59	0.12	0.94	1.94	0.59	-0.07	0.99	1.87	0.64	-0.07	0.91	1.96	0.74	-0.11	0.85
SMR-N-1	1.31	0.50	0.01	1.01	1.87	0.52	-0.13	0.91	2.13	0.51	-0.05	0.97	1.81	0.74	-0.12	0.88
SMR-N-2	2.06	0.73	-0.10	0.80	1.92	0.79	-0.01	0.92	1.96	0.59	-0.10	1.02	1.93	0.72	-0.1	0.93
Minimum	0.70	0.50	-0.11	0.80	1.51	0.41	-0.23	0.73	1.64	0.51	-0.13	0.91	1.38	0.67	-0.19	0.77
Maximum	2.83	0.73	0.24	1.09	1.98	0.79	0.11	1.13	2.13	0.65	-0.01	1.12	1.96	0.83	0.05	1
Average Mean	1.69	0.61	0.01	0.94	1.79	0.59	-0.11	0.93	1.84	0.58	-0.06	1.00	1.66	0.74	-0.07	0.89

Mz= Mean Size, SD=Standard deviation, S_K= Skewness, K_G= Kurtosis

Scatter plots

The geological significance of the size parameter can be well understood by correlating two variables viz., Mean size vs Standard deviation, Mean size vs Skewness, Mean size vs Kurtosis etc. Owing to the fact that the grain size parameter is environmentally sensitive, it is often used to interpret the various facets of depositional environments (Rammohan Rao et al., 1982). Scatter plots are very helpful to understand the various depositional environments.

Mean size vs standard deviation

The scatter plot between Mean grain size vs Standard deviations evidently show that all the microenvironments show negative relation, signifying that increase in sorting of sediment with decrease in grain size (fine size). In the NE (Figure 2a) season, all environments show negative relation with moderately sorted grains and fine sand sediment as dominant constituents (Mohan and Rajamanickam., 1998). Most of the sediment samples in SW monsoon season show moderate sorting except dune and backshore environment that shows positive relation, signifying increase in sorting of sediments(Figure 3a). Coarse sand is dominant constituent in dune and foreshore environments.

Mean size vs skewness

The scatter plot between Mean grain size and skewness reveals, negative relation in all microenvironments in NE monsoon season (Figure 2b). Generally, increase in mean size value (fine material) exhibits negative skewness. Negative skewness of sediments takes place in high-energy conditions (Angusamy and Rajamanickam, 2006). In SW monsoon season, berm and foreshore shows negative skewness which means that sediments were subjected to high energy conditions. Dune and backshore doesn't show any significant relation with mean size and skewness (Figure 3b).

Mean size vs kurtosis

In NE monsoon season the bivariate plots between mean grain size vs kurtosis values, reveal positive correlation with leptokurtic nature in dune, backshore, berm environments with fine sand as dominant material except foreshore environment (Figure 2c). In SW monsoon season all the environments except dune, show positive relation with leptokurtic nature (Figure 3c).

Standard deviation vs skewness

The scatter plots between standard deviation and skewness in NE monsoon season show positive relationship at all microenvironment levels, signifying increase in skewness, decrease in sorting, this may be due to littoral and alongshore currents, with moderate grain size sediments (Venkatramanan et al., 2011) (Figure 2d). In NE monsoon season berm environment, showing negative relation, signifies moderately sorted with coarse skewness. In SW monsoon season, the plot (Figure 3d) dune environs disclose negative relationship and the backshore and berm, show positive relation further signifying decrease in skewness with increase in standard deviation. However in the foreshore environment shows no relation between standard deviation and skewness.

Standard deviation vs kurtosis

The scatter plot between standard deviation vs kurtosis showing platy to mesokurtic nature, indicates negative relationship between standard deviation with kurtosis. Kurtosis values decrease with increase in sorting of sediments with moderately sorted sediments. In the foreshore environment, there is no relationship between standard deviation and kurtosis (Figure 2e). In SW monsoon season, majority of the samples show platy to leptokurtic nature and moderately well-sorted sediments (Figure 3e).

Skewness vs kurtosis

In NE and SW monsoon seasons, the scatter plots between skewness vs kurtosis shows positive values which implies very fine skewed symmetry (Figure 2f). In NE monsoon season the skewness and kurtosis values show negative relation in dune, backshore, berm and foreshore environments. In SW monsoon season such plot shows positive relationship between two variables except backshore and berm environments (Figure 3f).

CM diagrams

Based on range, size and energy level of transportation, CM diagrams aid in understanding, analyzing the mechanism and mode of transportation of sediments and gives an insight into depositional environments, factors responsible for the formation of clastic sediments. The plotting and interpretation of CM plot are adopted from Passagea. (1957, 1964). C represents one percentile of the grain size distribution plotted against to the M value which represents the median size of the sediment sample on double logarithmic paper. The CM diagrams of NE and SW seasons (Figures 4a and 4b; 5a and 5b) depicts that sediment transported for rolling bottom suspension and rolling and graded suspension representing their deposition by tractive currents and beach processes. Bottom suspension and rolling and graded suspension and rolling mode of transportation is predominant in both NE and SW monsoon seasons.

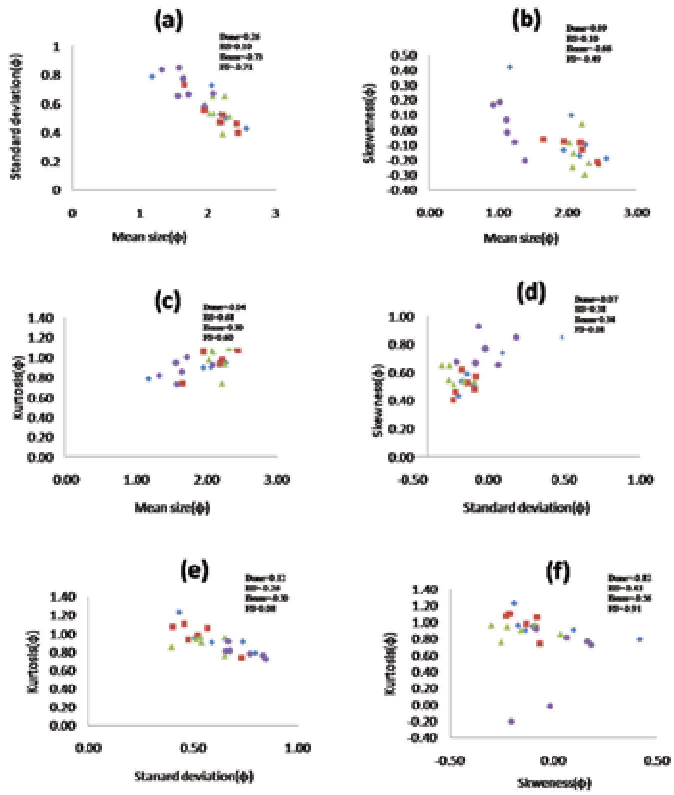

Figure 2. Scatter plots of grain size parameters (a) mean size vs standard deviation, (b) mean size vs skewness, (c) mean size vs kurtosis, (d) skewness vs standard deviation, (e) standard deviation vs kurtosis and (f) skewness vs kurtosis of Govindampalli – Durgarajupatnam coastal sands (NE monsoon season).

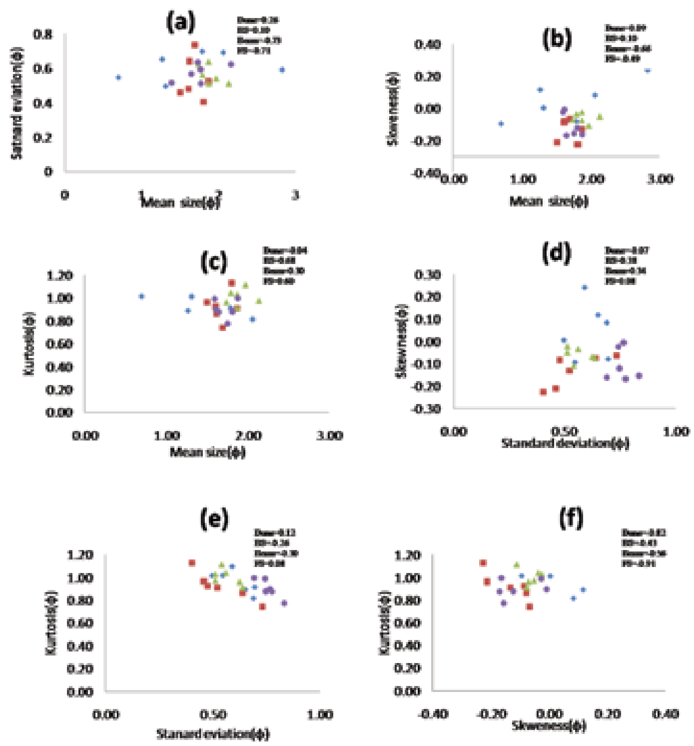

Figure 3. Scatter plots of grain size parameters (a) mean size vs standard deviation, (b) mean size vs skewness, (c) mean size vs kurtosis, (d) skewness vs standard deviation, (e) standard deviation vs kurtosis and (f) skewness vs kurtosis of Govindampalli – Durgarajupatnam coastal sands (SW monsoon season).

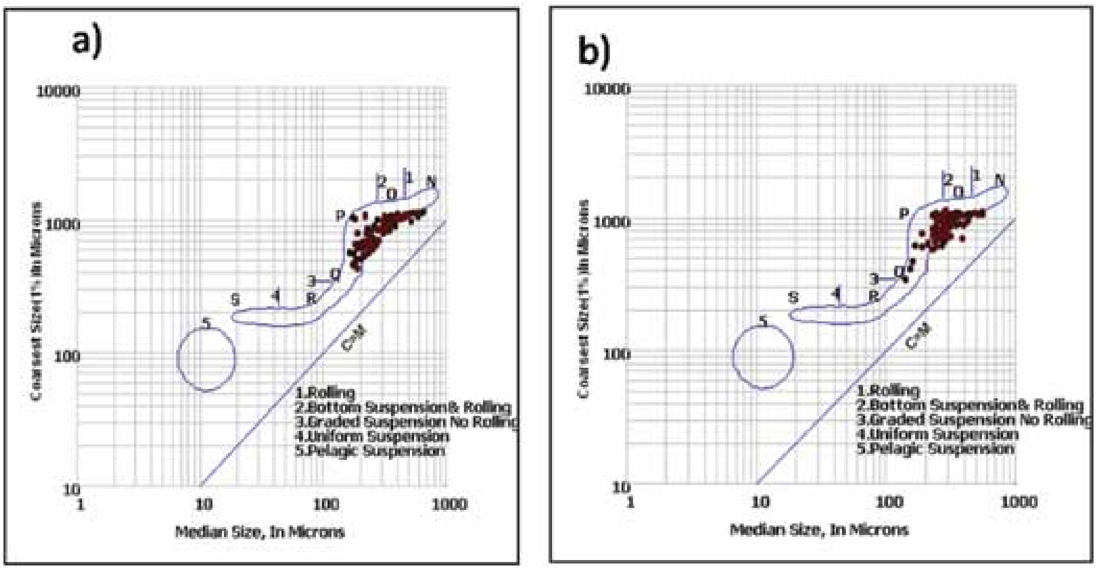

Figure 4. CM diagram showing mode of transportation of sediments (a) NE monsoon season (b) SW monsoon season.

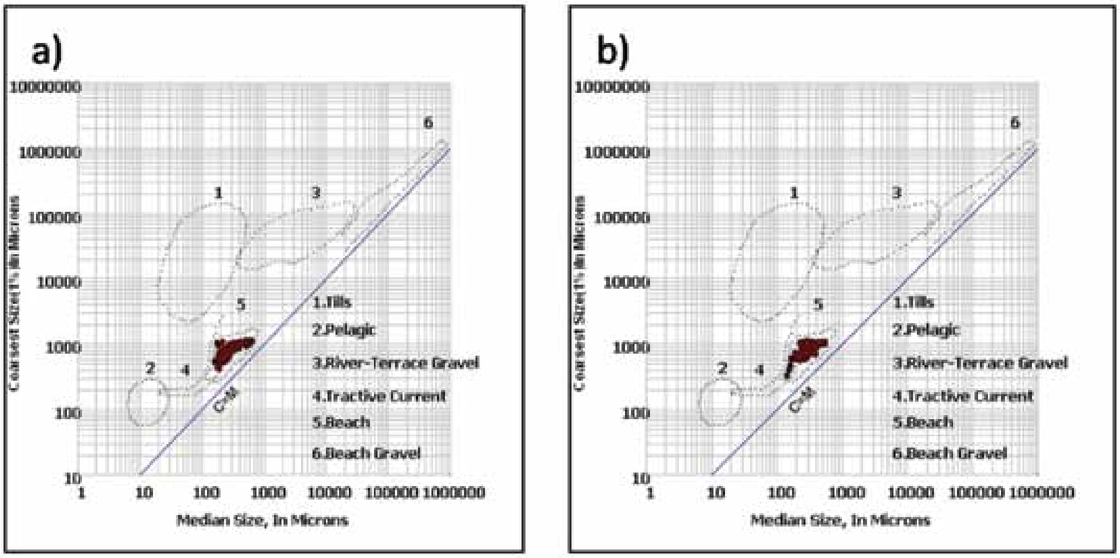

Figure 5. CM diagram showing depositional environments of sediments. (a) NE monsoon season (b) SW monsoon season.

Factor Analysis

Factor analysis was carried out to know the significant parameters contributing the distribution and deposition of sediments in the investigation area.NE and SW monsoon seasons (Table 2a and 2b) show mainly two factor assemblages which are contributing in dispersal and deposition of sediments. Factor analysis shows a total variance of 85.59% and 67.46% for the NE and SW monsoon seasons respectively. In NE monsoon season, first factor assemblage accounted for about 53.69% with substantial loading attributed to kurtosis (K_G) and mean grain size (Mz) assemblage (Table 2a), and second factor component (uncorrelated pairs of element to the first factor assemblage) is skewness (S_K) attributes to 31.89% of variance. Whereas in case of SW monsoon season, majorly two components attribute in a dispersal of the sediments i.e., kurtosis (K_G) and skewness (Sk) with 41.26% and 26.20% of the variance. In NE monsoon season mean size and kurtosis and in SW monsoon season kurtosis and skewness plays dominant role in dispersal and distribution of sediments in the investigation area and the same has been figuratively expressed in Figure 6.

Linear discriminate function analysis (LDF)

Linear discriminate function analysis plays a key role to explain and understand the depositional environments

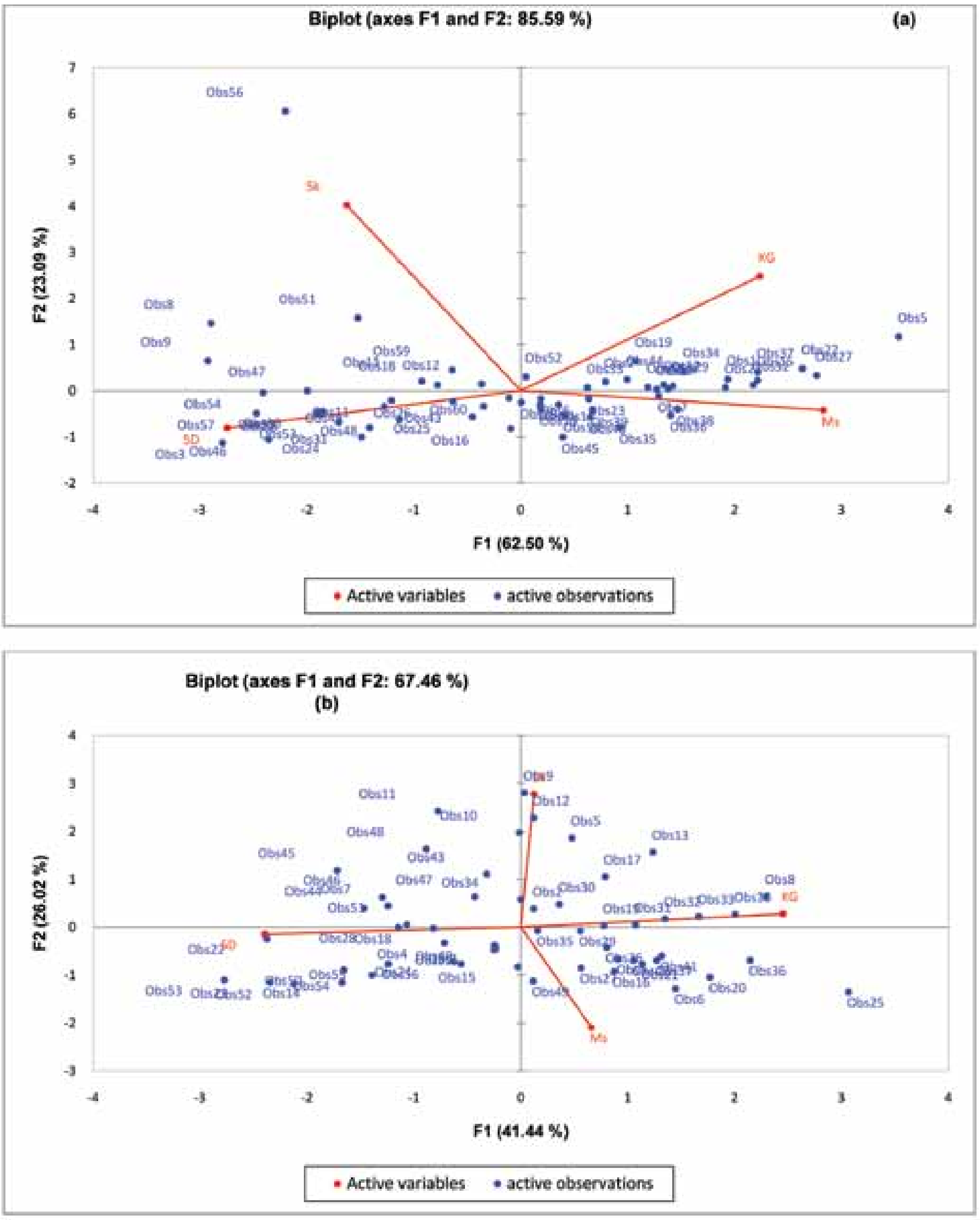

Figure 6. Factor analysis for the (a) NE monsoon and (b) SW monsoon season sediments.

Table 2. Factor analysis for (a) NE monsoon season and (b) SW monsoon season.

Parameters	**Factors (NE monsoon Season)**		**Factors (SW monsoon Season)**	
	1	**2**	**1**	**2**
Mean Size	0.778	-0.514	0.175	-0.634
Standard deviation	-0.872	0.284	-0.883	0.052
Skewness	-0.093	0.961	0.132	0.802
Kurtosis	0.880	0.920	0.907	-0.016
Total	2.148	1.276	1.650	1.048
% of Variance	53.69	31.89	41.26	26.20
Cumulative %	53.69	85.59	41.26	67.46

Table 3. Linear discriminate function analysis of sediments.

NE MONSOON SEASON				SW MONSOON SEASON		
Environments	Y1	Y2	Y3	Y1	Y2	Y3
Dune	-2.4712	75.1440	-3.1589	-1.7479	68.4797	-2.7813
BS	-1.2747	73.8841	-4.8035	-1.7576	66.1101	-1.9559
Berm	-4.0494	105.3245	-5.6338	-2.0832	68.3246	-2.0804
Foreshore	-1.1542	83.1091	-2.3386	-0.9808	77.1682	-3.9383

of beach sediments, (Sahu, 1964). Linear discriminate function analysis has explained to interpret the fluctuations of energy and fluidity factors correlated with different processes and sediment deposition.

To distinguish environment of deposition the following equation has been applied:

$$Y1 = -3.5688M + 3.7016r2 - 2.0766SK + 3.1135KG \text{ ------(1)}$$

Here Y is ≥ -2.7411, environment of deposition is beach, and if Y is ≤ -2.7411, environment of deposition is Aeolian.

$$Y2 = \text{Shallow marine} = 15.6534M + 65.7091r2 + 18.1071SK + 18.5043KG \text{ ------------ (2)}$$

Here Y is ≥ 63.3650, environment of deposition is shallow marine, and if Y is ≤63.3650, environment of deposition is beach.

$$Y3 = 0.2852M - 8.7604r2 - 4.8932SK + 0.0428KG \text{ -----(3)}$$

Here Y is ≥-7.4190, environment of deposition is shallow marine, and if Y is ≤-7.4190, environment of deposition is fluvial.

(M= mean, r = standard deviation, SK= Skewness and KG= kurtosis)

In NE monsoon season 75% samples fall in Y1 environment, (dune, backshore and foreshore) that indicate littoral processes and berm environment shows 25% samples fall in aeolian condition (Table 3).In bothY2 and Y3 environments total samples belong to shallow marine condition. In SW monsoon season most of the samples fall in Y1 environment as a result of littoral process. Both Y2 and Y3 environments most of the samples fall in shallow marine condition (Table 3). The variations of the energy conditions correlated with the tractive currents.

DISCUSSION

The textural parameters reveals most of the samples showing medium to fine grain in all micro environments, which results by the existence of intermittent energy conditions in north east monsoon season. But in south west monsoon season, most of the samples exhibits coarse to fine grains in dune region and medium to fine grain in backshore, berm and foreshore environments. The wide spectrum of grain size of sediment indicates the differential energy conditions at different environments. However, in both seasons the standard deviation values show, well to moderately sorting in dune, backshore and berm environments. It indicates removal of fine material leading to better sorting of sediments. Moderately well to poorly sorting in foreshore environment signifies the dominance of winnowing and panning action by waves and currents. Skewness value ranges in between very coarse to very fine symmetry depicting the prevalence of high to low energy conditions. The average skewness values in both seasons (Table 1a and 1b) indicate the nearly symmetrical distribution. The dominance of platy to leptokurtic nature reflects immaturity as well as maturity of the sediments in the depositional environments. The average values in both seasons reveal the presence of mixed population (both coarse and fine) in the study area. CM plots throw a light on the modes of transportation of sediments and depositional environments. They reveal that sediments were dominantly transported by rolling, rolling and bottom suspension and graded suspension and most of the sediments were deposited by tractive currents and beach processes. Factor analysis was carried out to know the distribution and deposition of the beach sediments. Mean size and kurtosis parameters play dominant role in NE monsoon season where as skewness and kurtosis plays dominant role in dispersal and distribution of sediments in SW monsoon season. Correlation between CM (C=Percentile, M=Median) plots and LDF (Linear discriminate function) analysis establishes the fact that littoral processes with tracative action played vital role in deposition of sediments in shallow marine condition, with an exception at berm microenvironment, where sediments were deposited by aeolian activity in NE monsoon season.

CONCLUSION

Comparison of two season's average values of various parameters viz., mean size, standard deviation, skewness and kurtosis reveal medium to fine grain size, moderately well-sorted sediments, nearly symmetrical distribution and platy to leptokurtic in nature respectively. CM plots of both seasons reveals that sediments were dominantly transported by rolling, rolling and bottom suspension and graded suspension and most of the sediments were deposited by tractive currents and beach processes. Similarly factor analysis results show that mean size and skewness parameters plays dominant role in dispersal and distribution of sediments in NE and SW monsoon respectively. LDF(Linear discriminate function) analysis reveals that in NE monsoon season, sediments were deposited by beach processes and aeolian activity where as in SW monsoon season, only beach processes play major role in deposition of sediments in shallow marine condition.

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Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

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