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Textural characteristics of beach sediments along Kalpakkam, south east coast of India

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Samples collected from foreshore region showed more variations in grain size as compared to mid-shore region samples. Median values varied from -0.08ø to 2.19 ø with an average of 1.04 ø (Std ± 0.65 ø). Mean value showed that samples were fine to coarse sand, whereas, only 1.8% of total samples were found as very coarse sand. During southwest monsoon the average mean size of the beach sediment was 0.98 ø, which is coarse sand in contrast to the medium sand observed during other seasons. Present study showed that, 81.7% of the samples were unimodal and 17.8% samples were bimodal. Sediment samples were very well sorted (0.18 ø) to poorly sorted (1.18 ø) and sorting characteristics decreased with increased wave energy. Skewness value indicated that 41% & 11% of the samples were positively skewed and negative skewed respectively, whereas, rest of the samples were symmetrical. All the beaches were dominated by mesokurtic sediment. Dominance of positively skewed sediment in the study area indicated the prevalence of low wave activity and longshore current. Presence of relatively high fraction of mesokurtic sediment indicated that the beaches along Kalpakkam by and large have uniform energy environment.

[**Keywords**: Beach sediment, Textural characteristics, Sorting, Skewness, Kurtosis, Kalpakkam coast]

Introduction

Size distribution of coarse elastic sediments reflects the fluidity (velocity) factor of the deposition and the energy factor of the environment (site) of deposition[1]. Granulometric studies of sediments provide a wealth of information on the intrinsic properties of sediment and their depositional environment[2-5]. The characteristic of the grain size distribution are related to source material, process of weathering, abrasion, corrosion and sorting process during the transportation and deposition[6]. Statistical analysis of beach sediment is relevant to identify the sedimentary environment. Mean size, sorting and skewness are the most useful parameters to describe the sediment characteristics[2, 7, 8]. The composition of littoral sediment and their textural characteristics depend on wave, wind, longshore current and source[9]. Grain size statistics are used to distinguish between high and moderate energy environment[10]. Change in any coastal process between the past and the present is reflected on the sediment characteristics. In this regard, the beach sedimentology plays a vital role in documenting the depositional history of the region[11]. Sedimentologists are particularly concerned about three aspects of grain size distribution in sediment i.e. a) techniques for measuring grain size and expressing it in terms of a grade scale, b) methods for quantifying grain size data and representing them in a graphical or statistical form and c) the genetic significance of these data[11]. Considerable amount of information on beacg sediment characteristics of east coast of India area available[1, 2, 8, 9, 12, 13, 14, 15,] however, information on this study area with the crucial nuclear establishment is scare. Considering the fact that , Kalpakkam region is a hub of nuclear establishments such as Madras Atomic Power Station (MAPS), Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI), Fast Breeder Test Reactor (FBTR), Kalpakkam Mini Reactor (KAMINI) and Fast Reactor Fuel Cycle Facility (FRFCF) etc., a study was designed to figure out the variations in textural characteristics of the beaches from Kalpakkam to Mahabalipuram, a stretch of 20km. Intertidal sediment samples were collected for one year and were analysed with an objective to identify the seasonal as well as longshore textural behavior of the beach sediments, which ultimately decides the stability/dynamism of the beach.

Materials and Methods

The study area is about 20km long, stretches between Mahabalipuram and Kaplakkam township (latitude 12^{0}31’-12^{0}34’N and longitude 80^{0}09’- 80^{0}11’E) (Figure 1). Beaches in this region are relatively flat and the foreshore is primarily composed of coarse sand. The coastal plain is characterized with a vegetation line – casuarinas, cashew nut, bushes, scrubs, grasses, etc. Geomorphic features such as dune sand, beach ridges, palaeo– lagoons, and palaeo tidal flats are found along the coastal region[16]. These features mostly formed due to the past and ongoing emergency of the coast[18]. Coastline is in NNE (North North East) direction, having beach width of 50-100m. Mean tidal range varied from 0.3 – 1.5 m. Coastal current at Kalpakkam has seasonal character. During South west monsoon (February to October) the current is northerly with a magnitude of 0.2 – 1.8 km/h and during North East monsoon (October to February) the current is southerly with a magnitude of 0.1 – 1.3 km/h. The wind speed varied from 10- 40 km/h. These monsoonal winds cause southerly (~ 0.5 million m3/y) & northerly (~ 1 million m3/y) littoral drift[19].

The study area is one of the most important and sensitive areas of the country housing strategic industrial installation very close to the coastal belt. Nuclear reactors Madras Atomic Power Station (MAPS) and Prototype Fast Breeder Reactor (PFBR), 500 MWe each, are located at a distance of 360 and 460m from the coastline respectively. Apart from the above reactors, more nuclear installations are being planned to be built in the future. The BoB at Kalpakkam, known to generate eddies and mesoscale features[20] and is more prone to cyclone. During the Indian ocean tsunami in December 2004 the water level at the Kalpakkam coast is reported to have reached a level up to +10.8m[21.] Thus, the present study will serve as baseline for future impact assessment with respect to textural characteristics of beach sediment as more and more anthropogenic activities are excepted to contribute adversely. Furthermore, the study will contribute in formulating the coastal management strategies, to protect the nuclear establishment.

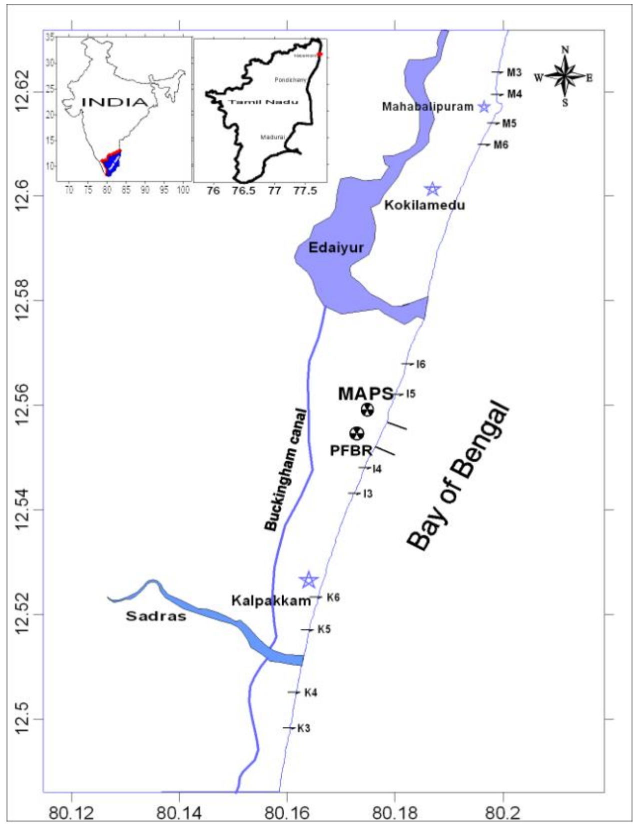

Fig. 1 - Study area map showing sampling locations

The sediment samples were collected from 12 stations at Foreshore (FS) and Midshore (MS) beaches (Figure 1) along Kalpakkam coastline at monthly intervals during February 2012 to February 2013. Samples were collected based on the nature, configuration and geomorphological setting of the coastline. Locations near Mahabalipuram were selected both sides of the shore temple (M3, M4 are on North side of the temple whereas, M5, M6 are on South side of the temple). Similarly, 4 locations each from IGCAR (I3, I4, I5 and I6) and Kalpakkam Township (K3, K4, K5 and K6) were also selected for the investigation. Sediment samples were collected at foreshore and mid-shore point of each station during lowest low tide. Foreshore sediments were collected by using a teflon screw corer and midshore samples were collected by hand, after removal of the upper few layers of the reworked sand. Samples were collected during lowest low tide. The collected sediment samples were washed with fresh water;

dead shells were removed and oven dried at 70^{O}C. A known weight (100 g) of each sample was sieved at intervals of ½ ø using an automatic sieve shaker (Retsch GmbH, Hann, Germany, Model-AS 200) and ASTM 20 cm diameter sieves (mesh no. 10 to 230) for 10 minutes. The graphical computational method of Folk and Ward[13] was used to calculate the grain size statistical parameters, viz. graphic mean, standard deviation, skewness, and kurtosis. Statistical analysis of the results and graphical analysis of the data were performed using GRADISTAT software[22] version 4.0, which is extremely versatile and has almost the same size scale (descriptive terminology) for sand as that used by[23-25].

Result and Discussions

Grain size distribution of monthly collected sediment samples are presented as cumulative distribution in Figure 2a, b & c. It is observed that the variation of grain size along MS was relatively less as compared to that of FS in spatial and temporal scale. The difference in grain size distribution at different locations could be due to the variations in wave energy experienced by different sampling locations as well as the beach morphology[8, 26].

Along the entire study region, the median values varied from -0.22 to 2.61 ø with an average of 1.04 ø (Std ± 0.65 ø) (Table 1). At Kalpakkam beach, the median value varied from -0.07 to 2.20 ø with an average of 1.01 ø (Std ± 0.62 ø), whereas at IGCAR beach and Mahabalipuram beach it varied from -0.13 to 2.20 ø and -0.03 ø to 2.16 ø with an average value of 1.01 ø (Std ± 0.66 ø) and 0.99 ø (Std ± 0.63 ø) respectively. It indicated that the average median size of the Mahabalipuram sediment sample is larger than that of IGCAR and Kalpakkam beach samples. Grain size was bigger along FS area as compared to MS area in 79.1% of samples at Kalpakkam, 79.5% of samples at IGCAR and 95.8% of the sample at Mahabalipuram.

The mean values of the grain size samples from three beaches varied between fine to coarse sand, whereas, 1.8% of total samples were found to be very coarse sand. All the three beaches were dominated by medium sand (54%), followed by coarse sand (40.4%). Mean values of grain size varied from -0.22 to 2.46 ø at IGCAR, -0.05 to 2.33 ø at Kalpakkam and -0.02 to 2.35 ø at Mahabalipuram with an average of 1.07 ø (Std ±0.54 ø), 1.19 ø (Std ± 0.57 ø) and 1.04 ø (Std ± 0.55 ø) respectively (Table 2). It was observed that 45.5% of the samples from IGCAR, 32.3% of samples from Kalpakkam and 43 % of samples from Mahabalipuram were coarse sand. Similarly, 51.1%, 60.4% and 52.1% of samples from IGCAR, Kalpakkam and Mahabalipuram respectively were medium sand (Table 3). During post-NE monsoon and northeast monsoon period, the beach sand was of medium size. Average mean size during post-monsoon and NE monsoon period was 1.22 ø and 1.03 ø respectively. However, during SW monsoon period the averages mean size of the beach sediment was found to be 0.98 ø, which is coarse sand. The variation of the beach sand with respect to SW monsoon was result of change in wave activity and current pattern occurring along the coast[27, 28].

Average grain size along FS area was 0.78, 0.91 and 0.69 ø at IGCAR, Kalpakkam and Mahabalipuram respectively, whereas the average grain size along MS was 1.36 , 1.46 and 1.40 ø at IGCAR, Kalpakkam and Mahabalipuram respectively. It shows that the grain size was relatively higher at FS region than that of MS region. The bigger grain size in FS could be due to the fact that small size particles are winnowed away by wave action.

Along the study region, 81.7% of the sample were unimodal, 17.8% samples were bimodal and only 0.3% of the sample (i.e only one sample) were trimodal/polymodal. IGCAR beach samples were unimodal (80.6%) to bimodal (19.3%), Kalpakkam samples were unimodal (82.2%) bimodal (16.6%) and polymodal (1%), whereas, Mahabalipuram samples were unimodal (82.2%) to bimodal (17.7%). Unimodal characteristic of the sediment sample was identified towards gentle beach slope with less wave activity. It was also observed that 65% of FS and 98.5% of MS samples were unimodal whereas 34.2% and 1.4% samples were bimodal (Table 3). The above data indicated that high wave activity in the foreshore region shaped the textural characteristics of the three beaches.

Sorting of sediment sample is a classification of grains according to their shape and size. Standard deviation (σ) measures the sorting of sediment and indicates the fluctuations in kinetic energy or velocity conditions of the depositing agent[1]. Sorting values of the collected beach samples reveled that the sediments samples were very well sorted (0.18 ø) to poorly sorted (1.18 ø) (Table 3). At IGCAR 52% of the samples were moderately well sorted, 34% moderately sorted (34%). 7% were poorly sorted, 6% were well sorted and 1% very well sorted. In Kalpakkam and Mahabalipuram, 47% and 51% of samples were moderately well sorted, 39% were moderately sorted and 10% and 9% were poorly sorted respectively. According to Chakrabarti [30] and Chaudhri et al[31], moderately sorted sands are predominant on the beaches of East & West coast of India. The variations in sorting characteristics are mainly attributed to the severity of wave action, water turbulence and current velocity. Results clearly indicated that as compared to FS, MS samples were well sorted which could be attributed to low wave energy activities. The land ward part of long shore current played an important role for sorting sediment along MS where more samples were found well sorted. Moreover, settling velocity of asymmetrical grains is less than the perfect spherical grains, which facilitates easy transportation of symmetrical grains to the upper part of the swash zone. It was observed that M4 (Mahabalipuram segment) showed the highest number of poorly sorted samples (21%) followed by K3 (17%) and K4 (13%) of Kalpakkam segment. It showed that wave action at these locations was relatively higher which might have facilitated deposition of mixed type of sediment grains. Present analysis shows that sorting sediment environment decreased with increased wave energy.

Skewness measures the degree of symmetry or asymmetry of the grain size distribution. Duane[31] observed that positive skewness characterizes a beach with deposition of sand whereas; negative skewness indicates erosion or non-deposition. Erosion and non-deposition of beach influenced by cyclic current pattern is indicative of the high energy environment prevailing there. The beach sediments varied in between very fine skewed to very coarse skewed (Table 3).

Along the study area, 48% samples were symmetric, 22% samples were very fine skewed, 19% samples were fine skewed, whereas 9% were coarse skewed and 2% were very coarse skewed. 75% of samples at IGCAR & Mahabalipuram and 79% of samples at Kalpakkam varied in between fine to coarse skewed, whereas the remaining samples were observed to be very fine skewed and very coarse skewed. Skewness characteristics indicated that about 41% of the total sediment samples from all the three beaches were positively skewed (fine skewed and very fine skewed) whereas 11% were the negatively skewed (coarse skewed and very coarse skewed) and 48% were non skewed (symmetrical) samples. Along the FS region, the fine sand is winnowed away by wave causing the sand to be coarse (negatively) skewed. The strong fine skewed sediments generally imply the introduction of fine material or removal of coarser fraction[2] or winnowing of sediments[31]. Results showed that depositional process (as inferred from number of positively skewed samples) was dominant at the Mahabalipuram beach followed by Kalpakkam and IGCAR segments in an annual cycle (Table 3). Similarly, erosion or non-deposition processes were relatively high at Kalpakkam as compared to the other two beaches. High wave activity has been known to increase the negative skewed sediment in a beach, whereas, longshore current & low wave activity support accumulation of positively skewed sediment. The dominance of positive skewed sediment in the study area thus indicated the prevalence of low wave activity and alongshore current.

Kurtosis is the measure of peakedness or flatness of samples related to normal distribution. Graphic Kurtosis represents the qualitative measure of the part of sediment already sorted elsewhere in a high energy environment and later transported to different low energy environments in the coastal areas and modified such as beach, shallow marine and fluvial environment. All the three beach samples of the present study varied between very platykurtic to very laptokurtic (Table 3). Most of the samples were platykurtic (23%), mesokutic (65%) and laptokurtic (8%), whereas, very platikurtic and very leptokurtic contain 3% and 2% of samples respectively. Friedman[32] suggested that extreme high or low value of kurtosis imply that part of sediment achieved its sorting elsewhere in a high energy environment. All the three beaches were dominated by mesokurtic samples. It has been reported that platykurtic to very platykurtic and leptokurtic to very leptokurtic sedimentary environments are due to extremely low and high energy environments respectively[8]. Thus, the present study area by and large can be categorized as uniform energy environment leading to dominance of mesokurtic grains in the beach sediment.

Table 1: median size of the beach sediments at different locations during different seasons

Name of the beach	Station	Location of collection	Median size of the sediments in phi scale											
			Post monsoon				South west monsoon				North east monsoon			
			Min	Max	Ave	Std	Min	Max	Ave	Std	Min	Max	Ave	Std
IGCAR	I3	FS	-0.11	1.21	0.60	0.48	-0.08	0.37	0.14	0.22	-0.10	0.53	0.29	0.34
		MS	0.73	2.15	1.67	0.57	0.91	1.04	0.96	0.07	1.05	1.41	1.20	0.18
	I4	FS	-0.13	2.12	0.92	0.87	0.04	0.77	0.32	0.39	0.96	1.57	1.29	0.31
		MS	0.96	1.62	1.33	0.30	0.52	1.01	0.80	0.25	1.23	1.44	1.33	0.10
	I5	FS	-0.22	0.79	0.33	0.38	0.19	2.61	1.06	1.35	0.18	1.08	0.73	0.48
		MS	0.78	1.60	1.17	0.30	1.30	1.99	1.70	0.35	1.34	1.66	1.48	0.17
	I6	FS	0.18	1.08	0.69	0.34	-0.05	1.48	0.82	0.79	-0.05	1.84	1.05	0.98
		MS	1.07	1.92	1.61	0.35	1.14	1.46	1.34	0.18	1.28	1.39	1.35	0.06
KALPAKKAM	K3	FS	0.07	1.86	1.13	0.74	0.00	2.17	1.11	1.09	-0.08	0.10	0.00	0.09
		MS	1.10	1.95	1.62	0.36	1.75	1.81	1.78	0.03	0.84	1.51	1.10	0.28
	K4	FS	0.35	1.74	1.02	0.63	0.18	1.35	0.88	0.62	0.07	2.28	1.07	1.13
		MS	1.04	1.93	1.47	0.34	1.33	1.86	1.63	0.27	0.53	1.67	1.10	0.47
	K5	FS	0.37	2.06	1.16	0.66	-0.14	0.74	0.30	0.44	-0.15	0.51	0.25	0.29
		MS	1.40	1.94	1.69	0.23	1.02	1.53	1.31	0.26	0.77	1.79	1.23	0.53
	K6	FS	0.43	2.24	1.15	0.79	-0.08	1.17	0.51	0.63	-0.13	2.38	0.74	1.12
		MS	1.11	2.03	1.59	0.34	1.31	1.63	1.49	0.16	1.16	1.50	1.35	0.15
MAMALLAPURAM	M3	FS	0.18	0.98	0.68	0.30	0.23	0.63	0.47	0.21	0.11	1.58	0.87	0.61
		MS	1.33	1.94	1.55	0.26	1.16	1.50	1.32	0.17	0.92	1.83	1.38	0.41
	M4	FS	0.38	2.29	1.23	0.89	0.19	0.38	0.29	0.10	-0.03	1.60	0.49	0.74
		MS	1.52	2.11	1.77	0.23	0.69	1.35	1.01	0.33	0.71	1.78	1.31	0.50
	M5	FS	0.01	0.52	0.26	0.19	-0.08	0.80	0.39	0.44	0.03	0.34	0.23	0.15
		MS	1.07	1.91	1.45	0.40	0.74	1.20	0.99	0.23	1.07	1.31	1.21	0.10
	M6	FS	0.03	1.55	0.81	0.63	-0.14	0.99	0.25	0.64	0.03	1.62	0.58	0.74
		MS	1.15	1.82	1.49	0.28	0.88	2.02	1.30	0.63	1.08	2.50	1.58	0.63

Table 2: Discriptive statistics of grain size parameters for samples collected at various locations along Kalpakkam coast

Name of the beach	Location	Statistics	Grain size parameters (Phi)			
			Mean	Sorting	Skewness	Kurtosis
IGCAR	I3	Min - Max	0.00- 2.09	0.49 - 1.09	-0.14 - 0.60	0.68 - 1.48
		Ave	0.93	0.65	0.16	1.03
		SD	0.62	0.16	0.21	0.18
	I4	Min - Max	0.20 - 1.96	0.46 - 1.08	-0.32 - 0.72	0.68 - 1.50
		Ave	1.05	0.70	0.08	0.98
		SD	0.48	0.16	0.23	0.15
	I5	Min - Max	-0.22 - 2.46	0.18 - 1.17	-0.45 - 0.63	0.69 -1.74
		Ave	1.08	0.72	0.11	0.99
		SD	0.60	0.20	0.24	0.20
	I6	Min - Max	0.42 - 1.97	0.49 - 1.05	-0.24 - 0.75	0.72 - 1.30
		Ave	1.22	0.76	0.12	0.93
		SD	0.43	0.17	0.25	0.13
KALPAKKAM	K3	Min - Max	0.07 - 2.06	0.39 -1.13	-0.28 -0.76	0.65 - 1.27
		Ave	1.18	0.74	0.10	0.96
		SD	0.60	0.20	0.30	0.14
	K4	Min - Max	0.21 - 2.23	0.48 - 1.05	-0.38 - 0.57	0.62 - 1.59
		Ave	1.23	0.73	0.09	1.00
		SD	0.53	0.17	0.24	0.20
	K5	Min - Max	-0.05 - 2.00	0.40 - 1.17	-0.19 - 0.65	0.60 - 2.78
		Ave	1.11	0.76	0.14	1.01
		SD	0.58	0.18	0.24	0.41
	K6	Min - Max	-0.02 - 2.33	0.46 - 1.13	-0.26 - 0.56	0.68 - 1.56
		Ave	1.22	0.68	0.10	1.04
		SD	0.62	0.15	0.22	0.18
MAMALLAPURAM	M3	Min - Max	0.18 - 1.95	0.51 - 1.08	-0.17 - 0.44	0.72 - 1.27
		Ave	1.10	0.72	0.09	0.98
		SD	0.47	0.17	0.14	0.13
	M4	Min - Max	0.02 - 2.07	0.39 - 1.18	-0.43 - 0.62	0.57 - 1.20
		Ave	1.14	0.76	0.12	0.94
		SD	0.61	0.23	0.25	0.16
	M5	Min - Max	-0.02 - 1.85	0.36 - 1.04	-0.29 - 0.67	0.63 - 1.67
		Ave	0.86	0.73	0.18	0.97
		SD	0.48	0.18	0.25	0.19
	M6	Min - Max	-0.01 - 2.35	0.46 - 1.17	-0.36 - 0.61	0.66 - 1.93
		Ave	1.07	0.71	0.12	1.03
		SD	0.63	0.17	0.25	0.23

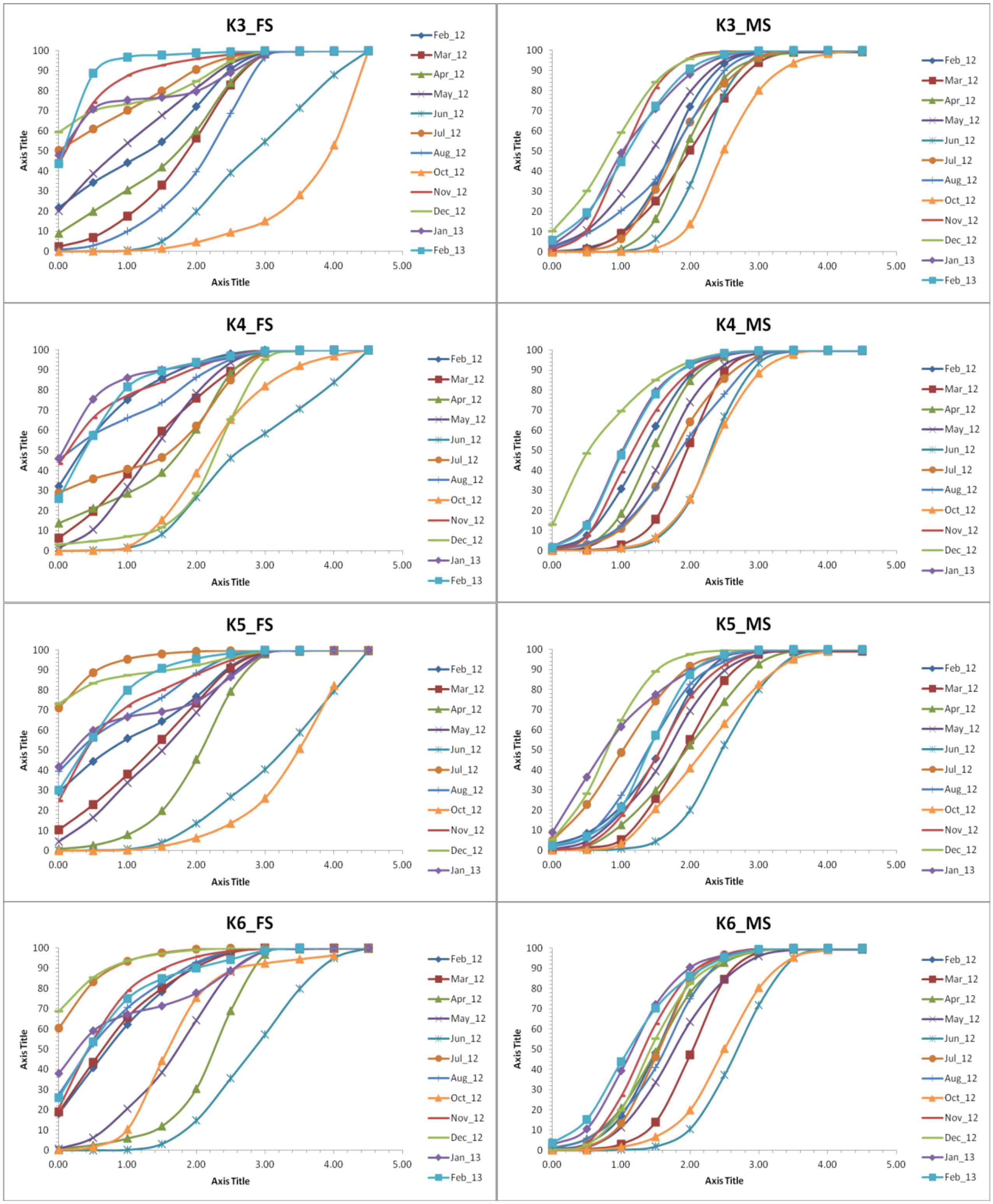

Fig. 2a- Cumulative percentage distribution of beach sediment samples along the Kalpakkam coast (Kalpakkam beach)

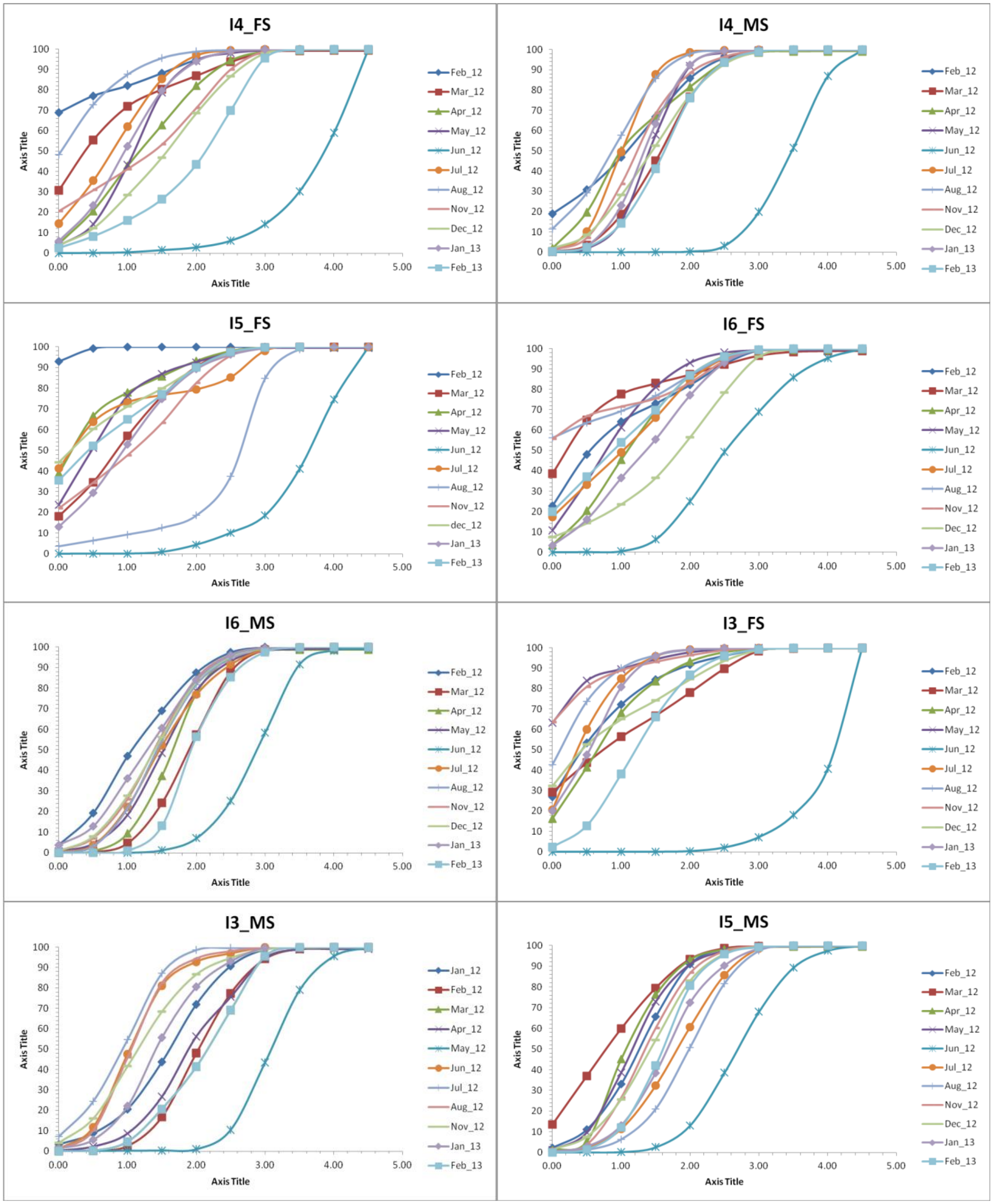

Fig. 2b- Cumulative percentage distribution of beach sediment samples along the Kalpakkam coast (IGCAR beach)

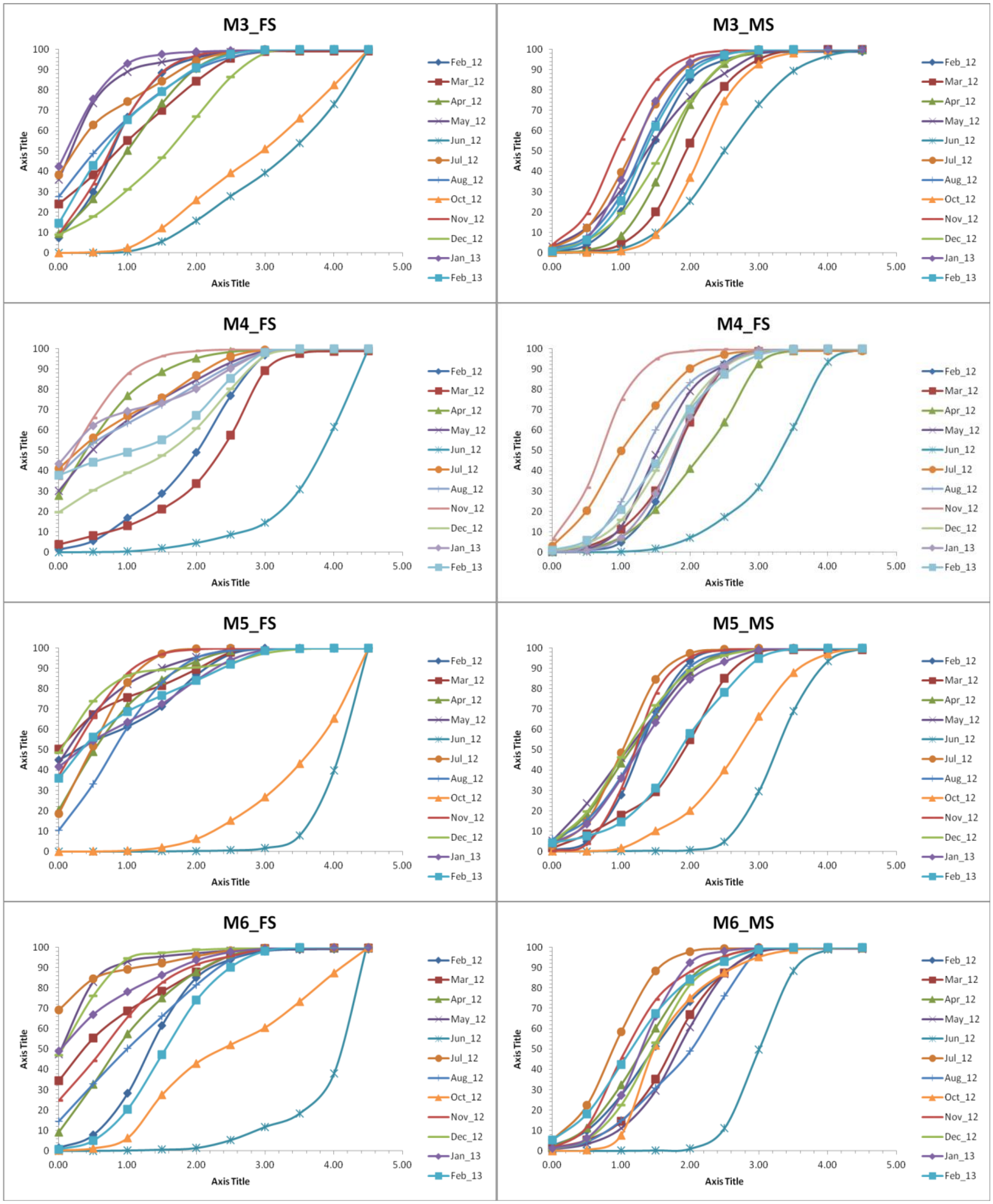

Fig. 2c- Cumulative percentage distribution of beach sediment samples along the Kalpakkam coast (Mahabalipuram beach)

Table 3: Summary of grain size statistical properties (in percentage of the total number of samples for each location and beaches)

Statistical properties	IGCAR					Kalpakkam					Mamallapuram				
	I3*	I4*	I5*	I6*	Total***	K3**	K4**	K5**	K6**	Total***	M3**	M4**	M5**	M6**	Total***
Mean (phi)															
VCS	0	0	5	0	1	0	0	4	4	2	0	0	4	4	2
CS	59	41	50	32	45	33	25	42	29	32	46	42	50	38	44
MS	32	59	45	68	51	63	71	54	54	60	54	54	46	54	52
FS	9	0	0	0	2	4	4	0	13	5	0	4	0	4	2
VFS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sorting (phi)															
VWS	0	0	5	0	1	0	0	0	0	0	0	0	0	0	0
WS	5	9	0	9	6	4	0	4	8	4	0	0	0	4	1
MWS	64	55	50	41	52	38	46	50	54	47	63	46	33	63	51
MS	23	32	41	41	34	42	42	38	33	39	33	33	58	29	39
PS	9	5	5	9	7	17	13	8	4	10	4	21	8	4	9
VPS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EPS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Skewness (Sk)															
VFS	27	23	18	18	22	21	21	21	21	21	13	25	33	25	24
FS	27	0	18	23	17	21	17	21	25	21	21	29	13	17	20
S	32	68	59	50	52	42	46	54	38	45	63	33	46	46	47
CS	14	5	0	5	6	17	13	4	17	13	4	13	8	8	8
VS	0	5	5	5	3	0	4	0	0	1	0	0	0	4	1
Kurtosis (KG)															
VP	0	0	0	0	0	4	8	8	0	5	0	8	4	4	4
P	14	27	23	36	25	21	13	25	17	19	25	25	25	21	24
M	73	68	73	59	68	63	63	54	67	61	71	54	71	63	65
L	14	5	0	5	6	13	13	8	13	11	4	13	0	8	6
VL	0	0	5	0	1	0	4	4	4	3	0	0	0	4	1
EL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

*No. of samples - 22 (FS+MS), ** No. of sample - 24 (FS+MS), *** No. of sample - 280

Bivariate scatter plots of grain size parameters

Bivariant scatter plots of textural parameters of sediment are used by sedimentologists to find out the information related to the depositional environment, particularly to demarcate the overlapping of closely related depositional environment, which are based on the statistical parameters of beach sediment[8, 12, 33-35].
The relationship between mean (ø) grain size and sorting of Kalpakkam coast is given in Figure 3. It clearly indicated that most of the samples with medium sand are moderately well sorted and samples with coarse sand are moderately sorted. Griffths[36] explained that both mean grain size and sorting are hydraulically controlled, so that in all sedimentary environments the best sorted sediments are of fine sand size range. Results of this study (fig. 3) showed some covariance between mean grain size and sorting with an obvious general trend of increasing sorting values with increase in mean grain size. The bivariate plot of kurtosis vs. skewness (Figure 4) is a powerful tool for interpreting the genesis of sediments, by quantifying the degree of normality of its size distribution[37]. Present data showed (fig. 4) that, most of the samples are near symmetry to mesokurtic. This suggests that the dominance of medium grain size population and the subordinate of coarse and fine grain size, gives symmetric skewness. However, some of the beach sediments of Kalpakkam coast showed mixing of different grain size with varying skewness. Figure 5 shows the relation between skewness and sorting for Kalpakkam coastal sediments. It shows that most samples belong to moderately well sorted with fine skewed. Generally, most beach sediments are slightly negatively skewed due to the presence of a small proportion of coarse grains[37]. Friedman[38]showed that most sands are leptokurtic with and either positively or negatively skewed.

Conclusion

The beach sediments along Kalpakkam coast were found to be fine to coarse sand, and only 1.8% were very coarse sand. During SW monsoon the average mean size of the beach sediment was observed to be 0.98 ø, which is coarse sand in contrast to the medium sand observed during the other seasons. All the samples collected from foreshore region showed more variations in grain size as compared to mid-shore samples. Median values varied from -0.08ø to 2.19 ø with an average 1.04 ø (Std ± 0.65 ø). The study showed that, 81.7% of the samples were unimodal, 17.8% samples were bimodal and only 0.3% of the sample were trimodal/polymodal in nature. Sediment samples were very well sorted (0.18 ø) to poorly sorted (1.18 ø) and sorting character of sediment environment decreased with increased wave energy at this location. Dominance of positive skewed sediment in the study area indicated the prevalence of low wave activity and longshore current. Relatively high fraction of mesokurtic sediment in the beach also depicted that the beaches along Kalpakkam by and large has a uniform energy environment.

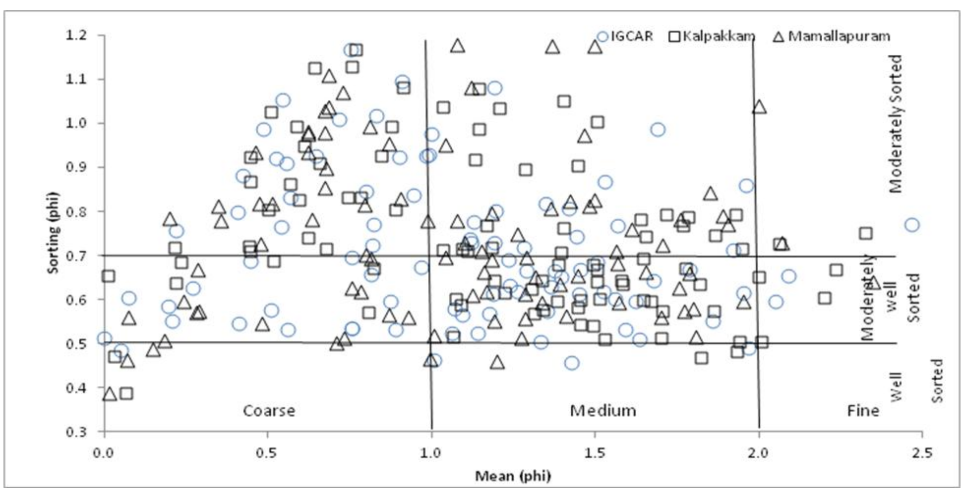

Fig. 3- Bivariate plot showing the relationship between mean and sorting of beach sediment samples collected along Kalpakkam coast

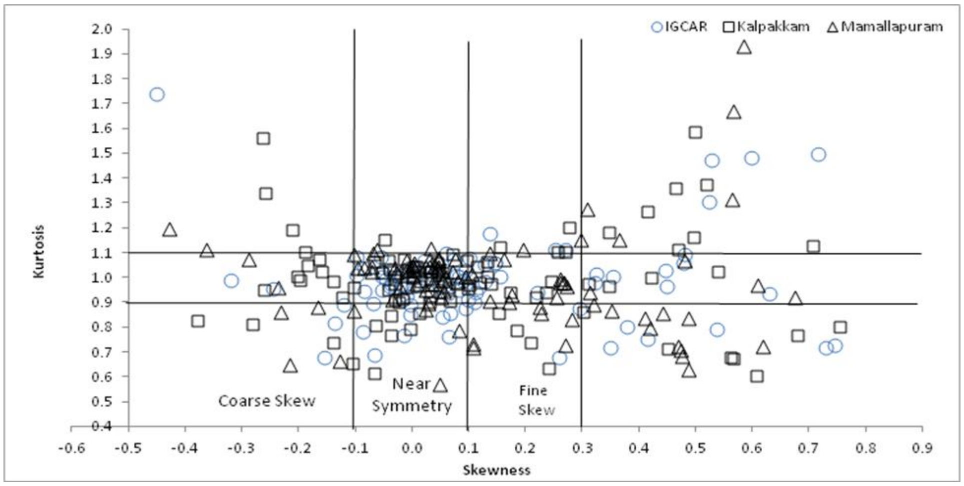

Fig. 4- Bivariate plot showing the relationship between Kurtosis and Skewness of beach sediment samples collected along Kalpakkam coast

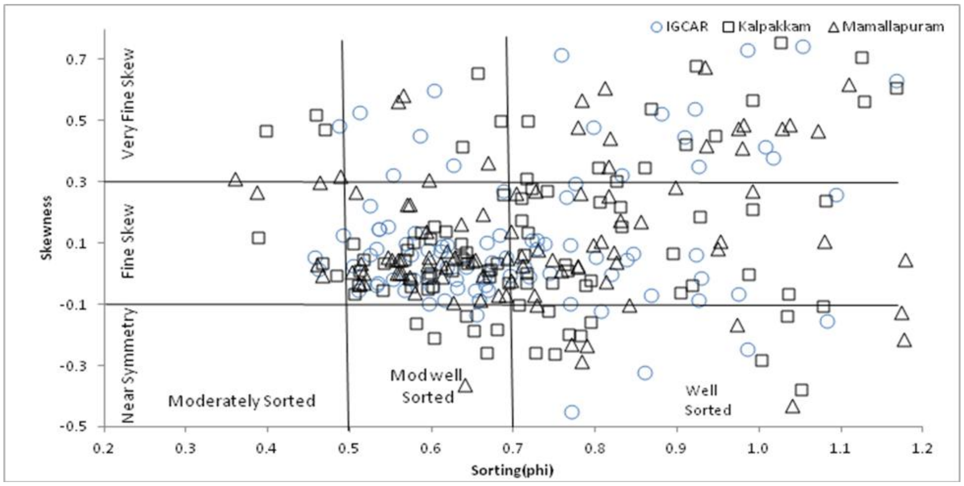

Fig 5- Bivariate plot showing the relationship between Skewness and Sorting of beach sediment samples collected along Kalpakkam coast

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