Research Journal of Chemical Sciences ISSN 2231-606X
Vol. **4(1),** 59-65, January **(2014)** *Res. J. Chem. Sci.*

Environmental Geochemistry of Surface sediments around the mangrove Forests of the Manakudy estuary, Southwest coast of India

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Available online at: www.isca.in, www.isca.me
Received 16th December 2013, revised 2nd January 2013, accepted 16th January 2014

Abstract

The mangrove ecosystems are highly productive intertidal forests distributed along the tropical coast and they stabilize the coastal zone from erosion and act as a buffer zone between land and sea. A study was carried out to investigate the distribution and monthly variation of textural characteristics and organic matter in surface sediments around the mangrove forests of the Manakudy estuary, which is in the southwest coast of India. Organic matter varied from 2.4% to 11.9%. Organic matter was high in Station 7 in all months because it was inside the mangrove forest. Calcium carbonate varied from 4.2-18%. It was high in station1 and station6. Sulphur was significantly negative correlation with organic carbon at 0.05 level. Manakudy mangrove sediments, sand is the major fraction and it is coarsely skewed and planty to extremly leptokurtic in nature.

Keywords: Manakudy estuary, mangroves, surface sediment.

Introduction

The mangrove and estuarine environments are influenced by continental and marine factors. Generally, the mangrove sediments are reducing in nature[1,2] and contain high amount of organic matter and ammonia [3]. Mangrove forest is considered to be one among the highly vulnerable ecosystems of the world and continuous anthropogenic activities ranging from deforestation to pollution threaten the survival of mangrove habitats throughout Asia[4,5]. Environmental geochemistry deals with the chemistry of solid earth, aqueous and gaseous components and life forms to assess heavy metal contamination impact on the planet's ecosystem. It predicts areas that could be at threat from natural and anthropogenic chemical intrusion and extends in to the realm of assessing physical, chemical and biological remediation technologies. Various studies on nutrients and organic carbon in the estuarine sediments have been carried out along the east coast of India[6]. On the west coast, cochin backwaters[7] and the Vembanad lake[8] have attracted great attention in this respect. The mangrove habitat is reffered to as an advancing coast, where the land advance toward the sea due to soil sedimentation[9]. Nasnolkar *et al.,* found that organic carbon contents showed seasonal fluctuations influenced by rainfall[10]. Higher values of organic carbon was found during the post monsoon period and it was attributed to influx of land run off containing considerable amount of terrigenous organic matter. Lin *et al.,* observed that organic carbon concentration in sediments is basically controlled by the deposition rate of the sediment, organic matter source, preservation potential and decomposition rate of organic materials during transport, burial and post – depositional diagenesis[11].

Goldhaber and Kalpan studied sulphur in sediments and found that the concentration levels are higher in the interior mangrove sediments than the estuarine sediments[12]. In this mangrove sediment, sulphate reduction was dominant and the mineralization processes was upto the depth of 1m.

Brewer and Dyrssen found that in Red sea Sediments the calcium carbonate content in the sediments of the area was highly variable[13]. The calcium carbonate in the shallow sharm sediments is predominantly of biogenic marine origin, although chemical and biochemical carbonate precipitation may be induced in the shallow, very saline and warm waters. On the other hand, the calcium carbonate distribution may also vary as a result of mixing between different sedimentary material of varying composition, such as mixing between marine carbonate and terrestrial siliciclastic.

The sand, silt, clay groups are commonly referred to as the soil separates. Soil texture is defined as the relative proportions of each class. However the specific diameter limits for each class may be different depending upon the organization making the definition[14]. The major features of particle size analysis are the destruction or dispersion of soil aggregates into discrete units by mechanical or chemical means and then the separation of the soil particles by sieving or sedimentation method.

Grain size parameters such as mean size (Mz) and standard deviation (SD) reflect the energy conditions of the depositional environment[15]. The difference in size distribution is mainly due to variation in wave energy reaching the point of sampling and extent of turbulence affecting the environment. Manakudy estuary receives significant amount of waters containing toxic metals from coconut husk retting and household garbage. A study has been done to determine the extent of calcium carbonate, organic compound, sulphur, sand, silt, clay and grain size in sediments in seven stations (S1,S2,S3,S4,S5,S6, and S7) around the mangrove forest of the Manakudy estuary situated on the southwest coast if India.

Material and Methods

Description of the study area: Manakudy estuary which has an area of about 150 ha is situated about 8 kilometers northwest of cape comorin in Kanyakumari District. It is the confluence of river pazhayar, which has its origin from the western ghats. The Manakudy estuary is abound with varied habitats that include shallow open waters, sandy beaches, muddy flats, mangrove forest, river delta and sea grass. Mangroves are a significant ecosystem in the estuary with a luxuriant growth on the mud flats. The litter on the mangrove floor undergo humification and mineralisation and the nutrients are leached into the estuarine water due to surface run-off adding to the productivity of the estuary. To study the environmental geochemistry of surface sediments, seven stations were selected around the mangrove forest of the Manakudy estuary (figure 1).

Sample collection: Surface sediment samples were collected from January to June from seven stations selected around the mangrove forests along the course of Manakudy estuary. The sediment samples were collected using the Peterson grab. The collected sediment samples were dried and used for textural studies, organic carbon and calcium carbonate. Textural studies on the sediments were performed for sand, silt and clay distribution[16]. The silt content was measured by the pipette method of Krumbein and Petti John[17]. Organic carbon (OC) was determined by exothermic heating and oxidation with potassium chromate and concentrated sulphuric acid followed by titration of excess dichromate with 0.5N ferrous ammonium sulphate solution[18]. Calcium carbonate was determined following the procedure of Loring and Rantala[19]. Sulphur was determined by gravimetric method.

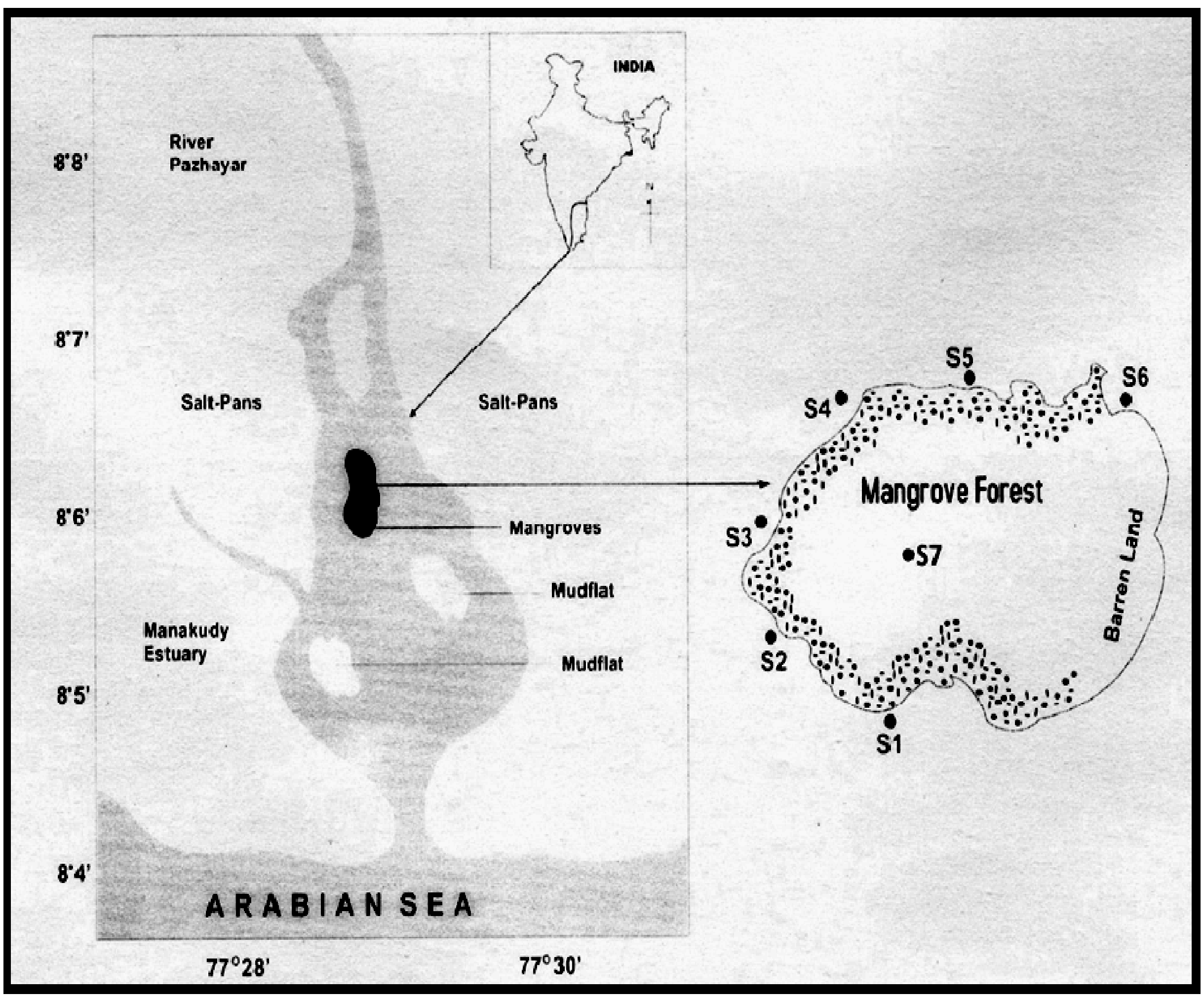

Figure- 1
Location of the study area

Results and Discussion

Box plot of calcium carbonate: A box plot is a graphical summary of data that is based on a five-number summary. A key to the development of a box plot is the computation of the median and the quartiles Q_1 and Q_3. The interquartile range, IQR= Q_3- Q_1 is also used. By using the interquartile range, limits are located. The limits for the box plot are 1.5(IQR) below Q_1 and 1.5(IQR) above Q_3 [20]. Data outside these limits are considered outliers. The location of the outlier is shown with the symbol *. A percentile is a measure used in statistics indicating the value below which a given percentage of observations in a group of observations fall. The 25th percentile is also known as the first quartile (Q_1), the 50th percentile as the median or second quartile (Q_2), and the 75th percentile as the third quartile (Q_3). In general, percentiles and quartiles are specific types of quantiles. Box plots provide to identify outliers. An outlier is an observation that lies an abnormal distance from other values in a sample from a data. From the figure 2, In January, Q_1=11.85, Q_3=15.50, median=14.00, IQR=3.65 and the limits are 6.38, 20.98. 0,4 values are outliers. In February, Q_1=11.10, Q_3=15.00, median=14.5, IQR=3.9 and the limits are 5.25, 20.85. In March, Q_1=9.3, Q_3=12.75, median=11.50, IQR=3.45 and the limits are 4.13,17.93. 2,5 values are outliers. In April, Q_1=9.3, Q_3=11.10, median=10.00, IQR=1.8 and the limits are 6.6,13.8. 6,5 values are outliers. In May, Q_1=9.25, Q_3=13.25, median=12.10, IQR=4 and the limits are 3.25,19.25. In June, Q_1=10.55, Q_3=12.80, median=12.60, IQR=2.25 and the limits are 7.18,16.18. 4,2 values are outliers. Calcium carbonate distribution vary as a result of mixing between different sedimentary material of varying composition, such as mixing between marine carbonate and terrestrial siliclastic. In this study, calcium carbonate was high in station 1 and station 6 in all months.

Correlation matrix: Correlation coefficient of sand, silt, clay, calcium carbonate, organic carbon, organic matter and sulphur at seven station from January to June was shown in table 1. Silt showed significant negative correlation with sand at 0.01 level. Clay showed significant negative correlation with sand and positively correlated with silt at 0.05 level. Organic matter showed significant positive correlated with organic carbon at 0.01 level. The high values of organic carbon may be due to the influx of land runoff containing a fairly good amount of terrigenous organic matter[21]. Reghunath and Murthy found that organic matter increases with silt percentage and mean grain size and decreases with increase in depth and sand percentage[22]. Sulphur was significantly negative correlation with organic carbon at 0.05 level. Recent estimates show that as much as 11% total organic carbon across the land-ocean interface in the tropics is of mangrove origin which explains that the carbon fixed by mangrove is potentially significant in the carbon biogeochemistry of the coastal zone[23]. Thus, the mangrove ecosystem is generally regarded as both as sink for nutrients and dissolved minerals and a source of organic matter[24].

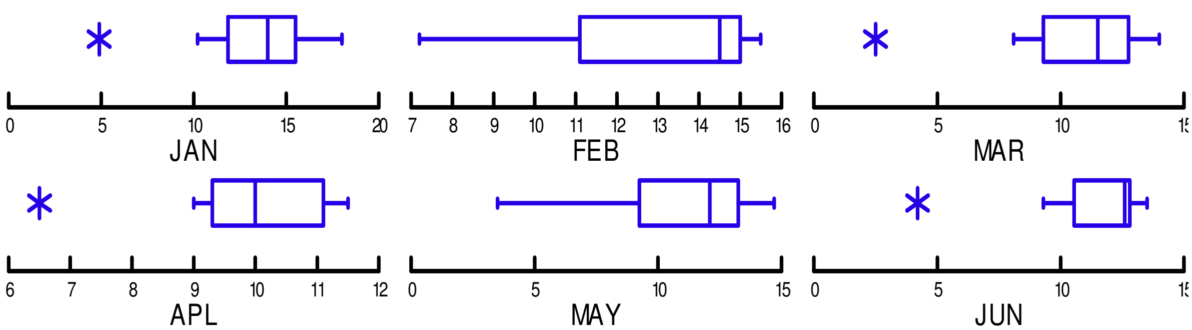

Figure- 2
Box plot for calcium carbonate in seven stations from January to June

Table-1
Correlation coefficient of sand, silt, clay, calcium carbonate, organic carbon, organic matter and sulphur at seven station from January to June

	Sand (%)	Silt (%)	Clay(%)	Calcium carbonate (%)	Organic carbon (%)	Organic matter (%)	Sulphur (%)
Sand (%)	1	-	-	-	-	-	-
Silt (%)	-1.000**	1	-	-	-	-	-
Clay (%)	-0.873*	0.864*	1	-	-	-	-
Calcium carbonate (%)	-0.249	0.236	0.464	1	-	-	-
Organic carbon (%)	-0.209	0.200	0.379	0..082	1	-	-
Organic matter (%)	-0.217	0.208	0.387	0.085	1.000**	1	-
Sulphur (%)	-0.052	0.049	0.084	0.599	-0.698*	-0.698	1

**correlation is significant at the 0.01 level (2-tailed), *correlation is significant at the 0.05 level (2-tailed)

Organic matter Vs Sand, Silt, and Clay: Organic matter content is commonly associated with the amount of silt and clay present in the sediment. Fine sediment particles have larger relative surface areas than coarse particles and can adsorb colloidal and dissolved organic matter forming sedimentary complexes. Once deposited, these complexes are capable of incorporating organic matter into the bottom. Relationship between Organic matter Vs Sand, Silt, and Clay was shown in figure 3. The range of organic matter suggested that the sediments are low to moderately organic in nature. Sediments with organic matter values exceeding 1% was usually called organically rich [25]. Organic matter varied from 2.4% to 11.9%. Organic matter was high in Station 7 in all months because it was inside the mangrove forest. The significant negative relationship of sand with both silt and clay may probably suggest that the sources for these particles are different though clay and silt may come from same source as indicated by their positive association. Organic matter was related to sand (r^2 = 0.047, r = 0.217, p<0.001), silt (r^2 = 0.043, r = 0.208, p< 0.001) and clay (r^2 = 0.150, r = 0.387, p <0.001). These relationships clearly imply that the finer fractions of sediment have more tendencies to accumulate organic matter rather than larger ones[26].

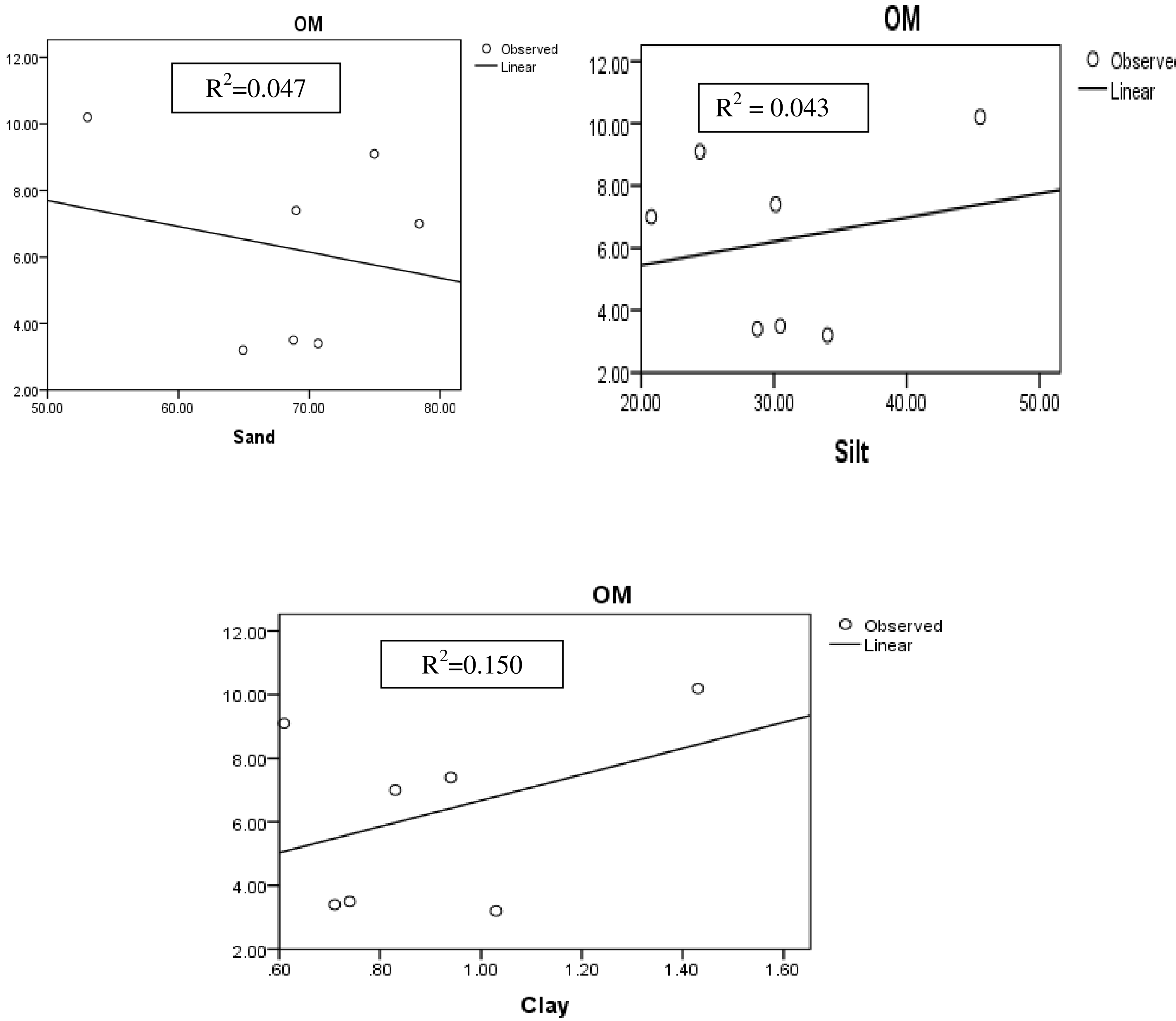

Figure- 3
Relationship between Organic matter Vs Sand, Silt, and Clay (Percentage)

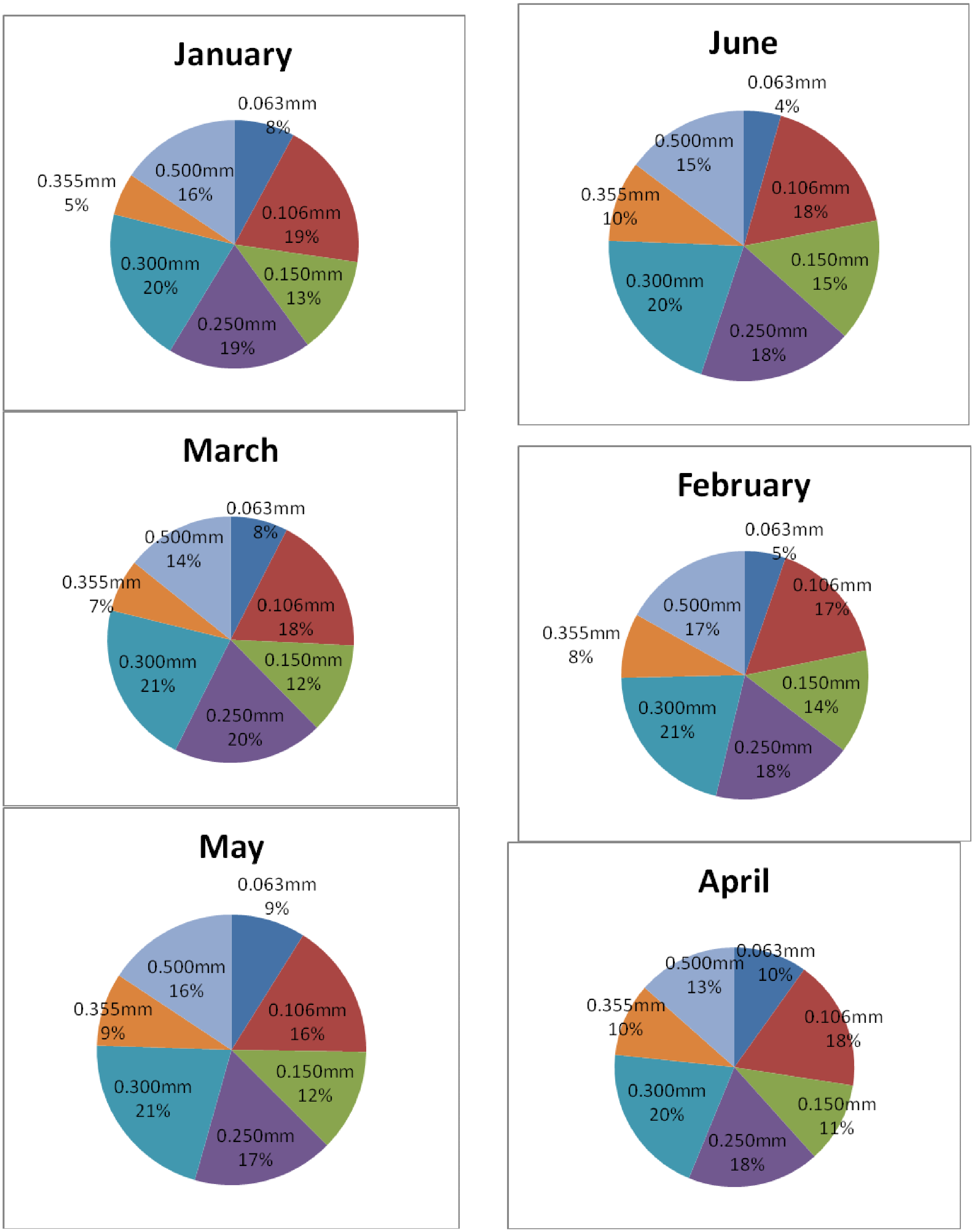

Figure- 4
Percentage of Grain size distribution of sediment from January to June

Grain size: Grain size distribution data helps in determining the textural and depositional characteristics of the environment. Percentage of Grain size distribution of sediment from January to June was shown in figure 4. The grain size in sediments showed seven types of grain with dimensions 0.06mm, 0.106mm, 0.150mm, 0.250mm, 0.300mm, 0.355mm, 0.500mm. The percentage composition of the grain size distribution was shown in figure 4. 0.06mm size was low in June (4%) high in April (10%). 0.106mm size was low in January (19%) but high in May (16%). 0.150mm was low in April (11%) but high in June (15%). 0.250mm size was low in May (17%) but high in March (20%). 0.300mm size was low in January, April, and June (20%) but high in February, March, and April (21%). 0.355mm size was low in January (5%) but high in April and June (10%). 0.500mm size was low in April (13%) and high in February (17%).

Statistical analysis: Skewness and Kurtosis: The mangrove and estuarine environments are influenced by continental and marine factors. A fundamental task in many statistical analyses is to characterize the location and variability of the data set. The sand and silt comprises about 75-95% of the total sediment fractions and the rest is clay. Friedman and Sanders stated that wave action and tidal currents are enough to produce the development of sandy sediment in the intertidal zones[27]. In Manakudy mangrove sediments, sand is the major fraction. Skewness (Ski) measures the asymmetry of a frequency distribution. Skewness values range between -0.01 to 2.09 (table2). In sand, positive skewness was obtained in April (0.36) comparing other months. Positive skewness of sediments indicates the unidirectional transport (channel) or the deposition of sediments in sheltered low energy environment. In silt negative skewness was obtained in April (-0.35). Kurtosis values range between -0.05 to 4.70 (table 2). In clay, skewness and kurtosis were high in May (2.09, 4.70 respectively). Extreme high or low values of kurtosis imply that a part of the sediment achieved its sorting elsewhere in a high energy environment. Most of the months, the skewness and kurtosis values were less than one. The influence of fluvial and marine activities in this marine ecosystem is evident from the abundance of moderately coarse materials and poor to well sorted grains with skewness less than one (Reineck and Singh, 1980). Positive kurtosis indicates a peaked distribution and negative kurtosis indicates a flat distribution. As the kurtosis statistic departs further from zero, a positive value indicates the possibility of a leptokurtic distribution (that is, too tall) or a negative value indicates the possibility of a platykurtic distribution (that is, too flat, or even concave if the value is large enough). Soil samples from Manakudy mangrove sediments had pronounced peaks in the clay fraction in March, May, and June. Variation in the kurtosis values is a reflection of the flow characteristics of the depositing medium, the dominance of finer size of very platykurtic nature of the sediments reflecting the maturity of the sand. This may due to the aggregation of sediment particle size by compaction and the variation in the sorting values are likely due to continuous addition of finer/coarse materials in varying proportions. Majority of the months falls under plantykurtic nature of distribution.

Table - 2
Statistical analysis of sand, silt, clay of Manakudy mangrove sediments

Months	Parameter	SD	Variance	Skewness (G1)	Kurtosis (G2)	Skewness	Kurtosis
January	Sand	8.11	65.77	-0.53	-0.24	Very coarse skewed	Plantykurtic
	Silt	8.02	64.38	0.49	-0.33	Very fine skewed	Plantykurtic
	Clay	0.30	0.093	0.24	-1.69	Fine skewed	Plantykurtic
February	Sand	8.02	64.41	-0.72	-1.43	Very coarse skewed	Plantykurtic
	Silt	7.93	62.93	0.70	-1.36	Very fine skewed	Plantykurtic
	Clay	0.45	0.206	0.06	-2.14	Fine skewed	Plantykurtic
March	Sand	10.68	114.24	-0.78	-0.05	Very coarse skewed	Plantykurtic
	Silt	10.41	108.51	0.75	-0.18	Very fine skewed	Plantykurtic
	Clay	0.35	0.126	1.47	1.55	Very fine skewed	Leptokurtic
April	Sand	6.91	47.827	0.36	-0.40	Very fine skewed	Plantykurtic
	Silt	6.73	45.364	-0.35	-0.36	Very coarse skewed	Plantykurtic
	Clay	0.23	0.054	-0.01	-1.48	Very coarse skewed	Plantykurtic
May	Sand	9.52	90.65	-0.21	-1.97	Very coarse skewed	Plantykurtic
	Silt	9.39	88.30	0.14	-2.12	Very fine skewed	Plantykurtic
	Clay	0.34	0.117	2.09	4.70	Very fine skewed	Extremely leptokurtic
June	Sand	16.74	280.31	-0.97	-0.46	Very coarse skewed	Plantykurtic
	Silt	16.40	268.97	0.95	-0.52	Very fine skewed	Plantykurtic
	Clay	0.376	0.141	1.76	3.18	Very fine skewed	Very leptokurtic

Conclusion

The Manakudy mangrove sediments are under pressure from the anthropogenic sources like sewage and domestic waste has resulted in initiation of organic load build up in it. Manakudy mangrove sediments, sand is the major fraction and it is coarsely skewed and planty to extremly leptokurtic in nature. Soil samples from Manakudy mangrove sediments had pronounced peaks in the clay fraction.

Acknowledgement

The second author (SPK) is thankful to UGC for financial support through major research project. The authors thank the authorities of Women's Christian College for providing necessary facilities.

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