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Geochemical and textural characterization of minerals in Thondi coastal sediments along the southeast coast of India

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The physicochemical characterization of seven marine sediment samples was investigated and collected from different zones along with Thondi coastal sediments along the southeast coast of India. The study found that variation in physical parameters and mud contents were due to differences in sediment source. Results of Station 3 revealed the calculated average values as follows: Bulk density (BD) (1.3 g/cm^3), particle size distribution of - sand (50.5%), silt (31.5%), and clay (18%). Further, the water holding capacity (WHC) was observed to be 65.3%. These studies moderately describe the WHC of space or pores of the soil particles. The fine, well sored sediments contain BD, particle size distribution, and water holdinsg capacity. According to the chemical characterization, sediments were categorized into organic carbon (OC) (1.2%) and organic matter (OM) (2.0%) the area for land derived materials from surrounding rocks. Moderate significant linear correlations were observed between OC and TN, indicating the occurrence of these components in a common phase organic matter. Even though, in the correlation of the total phosphate in organic matter, these two elements was negatively correlated, indicating anthropogenic regions of phosphate exportation. The study found three well structured sediments of the bacterial community association and primary productivity.

Key words: Marine sediments, carbonate, anthropogenic, phosphate, primary productive.

INTRODUCTION

Marine ecosystem covers almost 70% of the earth's surface (Vijayakumar et al., 2007). Bottom sediments consist of particles that have been transported by water, air or glaciers from the site of their origin in a terrestrial environment and have been deposited on the floor of the ocean. Some sediments are uniform in particle size, some are mixed, some are biological in origin and others are geological. Much of this habitat (-83%) is greater than 1000 m depth (Grassle and Maciolek., 1992) so most marine sediments are located in a cold, lightless, high

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Abbreviations: BD, Bulk density; **CS,** clayey sand; **EC,** electrical conductivity; **mS,** muddy sand **OM,** organic matter, sM, sandy mud; **Oc,** organic carbon, **sC,** sandy clay; **zS,** silty sand; **TP,** total phosphorus; **TK,** total potassium; **TN,** total nitrogen; **WHC,** water holding capacity; **SOC,** soil organic carbon pressure habitat where food is delivered from distant surface waters. In addition to these particles, bottom of the sediments have surrounded materials produced from physical, chemical, and biological processes. Soil is the most extensively studied ecological niches (Imran et al., 2009).

The conventional paradigm for the behaviour of reactive materials in coastal marine ecosystems has been to identify the processes by which dissolved and particulate materials are associated with minerals settling of sediments. Because of the dynamic nature, estuarine processes are complex and their transformations often remain obscure. Turbulent mixing of fresh water and sea water can generate rapid changes in EC, pH, salinity, and trace element concentrations (Feely et al., 1981). Overlaid on this variability are the biological processes acting on time scales of seconds to days (Hedges and Keil, 1999). Hence, it is difficult to understand the origins, pathways, and fates of dissolved and particulate materials in coastal marine ecosystems and especially in estuaries. The sediments are major repositories for metals and besides providing the environmental status; they are also used to estimate the level of pollution in a region (Butron and Scott, 1992; Caccia et al., 2003).

The carbonate of sediments differs in their chemical and physical characteristics, such as absorbency, light dilution, surface structure, sorption and desorption characteristics and dissolution kinetics (Saber Al-Rousan, 2006; Schroeder and Purser, 1986). The considerate of the physicochemical characterization of marine soil in seagrass areas is important for the estimation of organic and inorganic nutrient fluxes between the bottom and the water column, which in turn influence the overall community of the nearby environs. The present study is essential in areas where heterogeneous sources of sediments prevail such as the Thondi regions along southeast coast of India and similar areas in the world. A knowledge of sediment composition delivers an important clue about the origin of the individual grains, while textural characteristics provide information about energy levels during transport and deposition (Saber Al-Rousan, 2006; Malcolm and Stanley, 1982; Libes, 1992).

Recently, Ramasamy and Karikalan (2010) has reported that, different coastal geomorphological landforms in Palk Strait, Southeast Coast of India by the high percentage of heavy minerals in Pudhupattinam (38.64%), ascribed it accurate coast line and lowest percentage of heavy minerals recorded at Thondi 0.86%. The landforms help to infer the various stages of sea level regression and transgression takes place in the study region. The present study investigated the physico-chemical characteristics of marine sediments along coastal geomorphological Thondi in Palk Strait, Southeast Coast of India. Sampling stations were chosen to represent sandy beaches, the coralline sand, and the admixture sediments. Sources of biogenic and terrigenous region in all localities are discussed. The physical charateristics (mean grain size, sand silt, and sand content) bulk density (BD), water holding capacity, and some chemical elemental association between OC, OM, total nitrogen (TN), total phosphorus (TP), total potassium (TK) of sediments have been examined.

MATERIALS AND METHODS

Description of sampling sites

The marine pelagic sediment (soil) sample was collected from seven different near sea shore zones from 8 to 10 cm depths and 1 km from the peninsular region at Latitude of 9°44’10” N to Longitude of 79°10’45”E, Thondi coastal regions in southeast coast of India (Figure 1). The soil sample was collected at random in sterile polyethylene bags (bought to the laboratory) and stored aseptically to avoid contaminations, and immediately transported to the laboratory. The sediment samples were kept aseptic for 7 days for further used for screening of potent microorganisms.

Analysis of physico-chemical characterization

The sediments were collected from seven different near shore localities from Thondi open sea (8 to 10 cm depth). Collected sediment samples were freed from pelagic regions of seagrass bed, then dried to constant weight at 60°C in a well ventilated oven. Regarding the particle size distribution analysis, 100 g of dry sediments from each station was (taken) and mechanically shaken in a set of analytical calibrated sieves arranged progressively finer downwards from 2 mm mesh. Sediment retained on each sieve was then weighed and the particle size distribution presented as Φ, which is equal to $-\log_2$ of the grain size diameter in mm (Jackson, 1973). The clay content was determined using the pipette method (Loizeau et al., 1994; Beuselinck et al., 1998). The BD was determined by Edward et al. (2001). Further, water holding capacity (WHC) was measured by following the method of Keen and Raczkowski (1921). Solid OC and organic matter (OM) content in the sediments were measured following the method of wet oxidation by Walkley and Black (1934), soil pH was measured based on the using pH electrode (Richards 1954; Grunzweig et al., 2003).

Electrical conductivity (EC)of soil was determined as described by Richards (1954) and Schofield and Taylor (1995), the determination of OC in the samples was carried out as following methods, where 0.2 g of the sediment was treated with H_2SO_4 (12 M) and K dichromate then titrated with a ferrous ammonium sulphate solution. The samples were initially treated with 1 N HCl to remove any inorganic carbon in the samples.

Kjeldahl digestion was used to determine the organic N in the sediments. Total Kjeldahl N is the sum of organic N, ammonia (NH_3), and ammonium (NH_4+) excluding NO_3- and NO_2-. This was converted to inorganic N (TN) by concentrated H_2SO_4 (12 M), which was measured as ammonium following the standard method of Strickland and Parsons (1972); the standard error of this procedure is less than 10%. Total phosphate (TP) was determined using the ignition method for particulate phosphate analysis (Anderson, 1976), where 0.2 g of the collected sediment was combusted in a furnace (450°C) and the ash was boiled in 1N HCl for 15 min. The sample was then diluted to 100 ml with distilled water and phosphate was measured spectrophotometrically (error less than 5%) following the method of Strickland and Parsons (1972) and the K content in the extract was determined by using flame photometer (Cole et al., 1968).

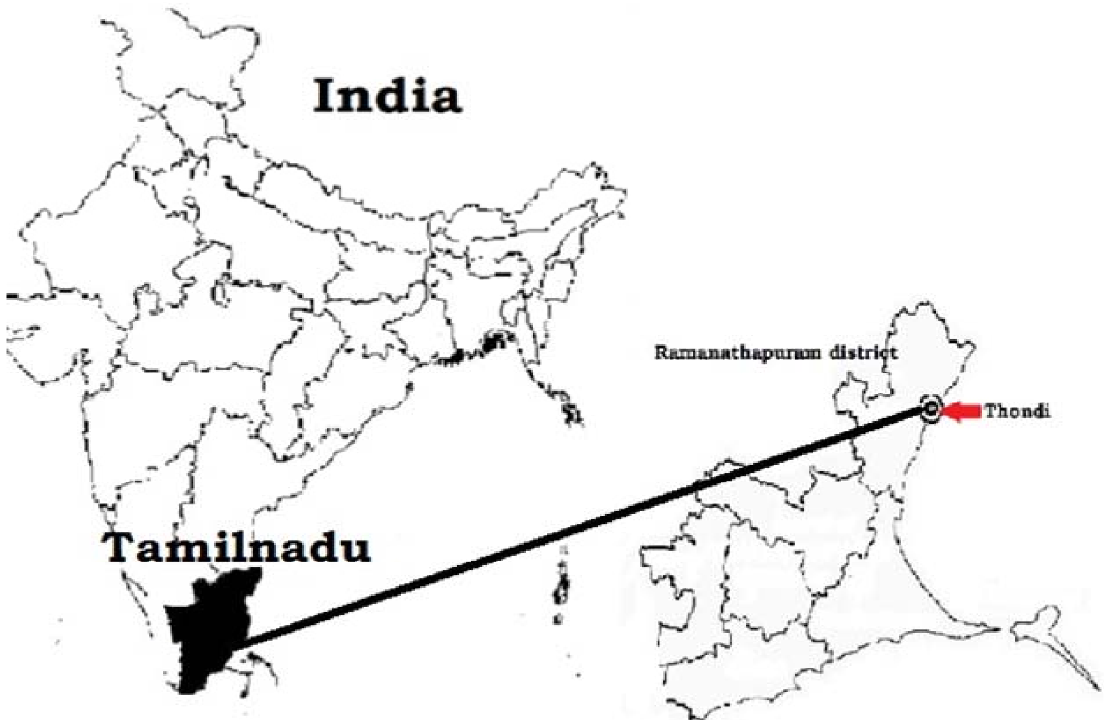

Figure 1. Seashore soil sample collection site at Thondi region in Southeast Coast of Tamil Nadu, India.

RESULTS AND DISCUSSION

Physical sediment characteristics

The environment of deposition is of great importance in determining the physical characteristics of the sediments. The variations in textural properties and mud contents could be ascribed to the variety of sediment sources, their response during currents and waves, and the seasonal variability and activity of benthic fauna. The marine pelagic sediments along the Thondi coast of the Palk Bay in southeastern India have been studied by several authors (Velsamy et al., 2013; Ramesh et al., 2006; Thangaradjou et al., 2010; Palanichamy and Rajendran, 2000; Bardarudeen et al., 1996; Ramanathan et al., 1999). Studies are focused on the texture, mineralogy, geochemistry, sedimentation rate, chemical composition, heavy metal content, and distribution.

BD is dependent on soil texture and the densities of soil mineral (sand, silt, and clay) and OM particles, as well as their packing arrangement. A medium textured mineral soil that is in good structural condition for microorganisms and plant growth contains about 50% total pore space on volume basis. This pore space is important for gas exchange (O_2 and CO_2) between the soil, atmosphere, water storage, and movement. The total pore space consists of the pore spaces between adjacent sand, silt, and clay particles and those between aggregates. Therefore, texture and structure are the main factors governing the amount of pore space in soil (Bashour and Sayegh, 2007). In this, result of sediment mass accumulation rate was calculated from the mass and volume measurements of BD ranged from 1.0 to 1.5 g/cm^3 at the Stations 1 to 7. The results of the BD analysis are shown in Table 1 and Figure 2. The Station 3 values were observed at 1.3 g/cm^3. Bashour and Sayegh (2007) calculated that, the weight per unit volume or BD of the soil has decreased. The BD of fine texture mineral soils ranges from about 1.0 to 1.3 g/cm^3, and that of sandy soils ranges between 1.3 and 1.7 g/cm^3. The BD of organic soils is usually much less than that of mineral soils and may be as low as 0.4 g/cm^3 (Femke et al., 2006).

Bardarudeen et al. (1996) investigated the physicochemical properties of 21 marine sediment samples collected at 50 m intervals along the intertidal zone in the Kumarakam mangrove area of the southwest coast of India. Sediments are characterized by the abundances of silt and sand with minor amounts of clay. The size of the sediments ranges from 0.205 to 0.098 mm. Magesh et al. (2011) studied the grain-size composition (sand-silt-clay ratios) of the surface sediments that have been classified; it is inferred that around 36% of the samples consist of clayey sand (cS), followed by muddy sand (mS) and sandy mud (sM), each with 20% respectively. Sandy clay (sC) and silty sand (zS) contribute 10 and 6% respectively, whereas clay (C) and sandy silt (sZ) each contribute almost 3%. This

Table 1. Analysis of physical sediment characteristics.

No. of sample	Bulk density (g/cm^3)	Sand (%)	Silt (%)	Clay (%)	WHC (%)
S-1	1.0	60.2	24.0	15.8	62.2
S-2	1.2	49.0	30.0	21.0	59.1
S-3	1.3	50.5	31.5	18.0	65.3
S-4	1.1	44.2	42.8	13.0	68.0
S-5	1.4	70.0	20.8	09.2	52.8
S-6	1.4	74.9	21.0	04.1	57.1
S-7	1.5	69.8	24.1	06.1	53.0

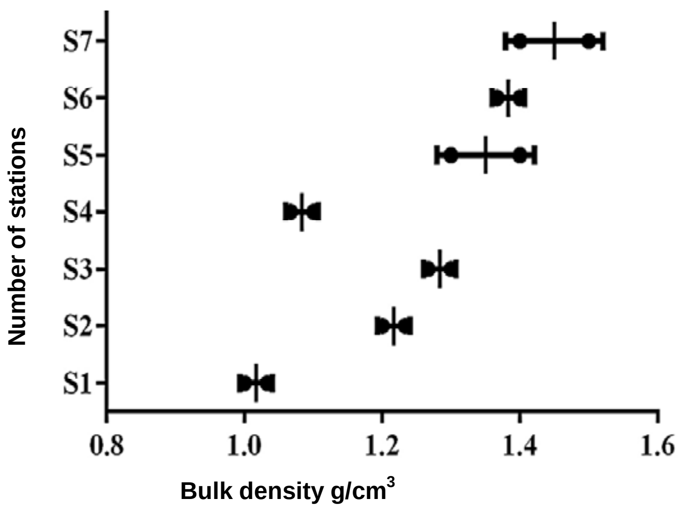

Figure 2. Bulk density analyses of collecting marine sediments.

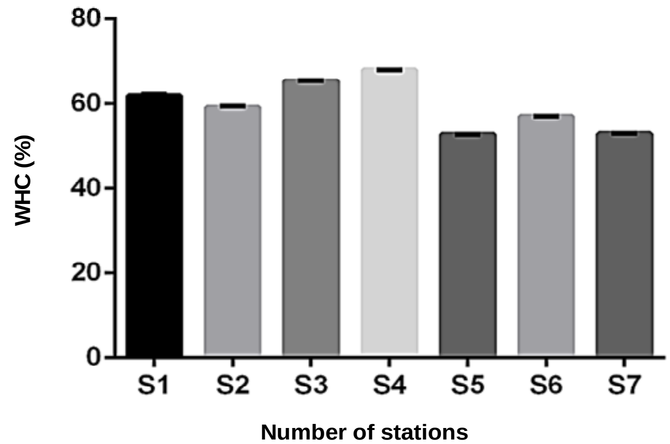

Figure 4. Water holding capacity analysis of collecting marine sediments.

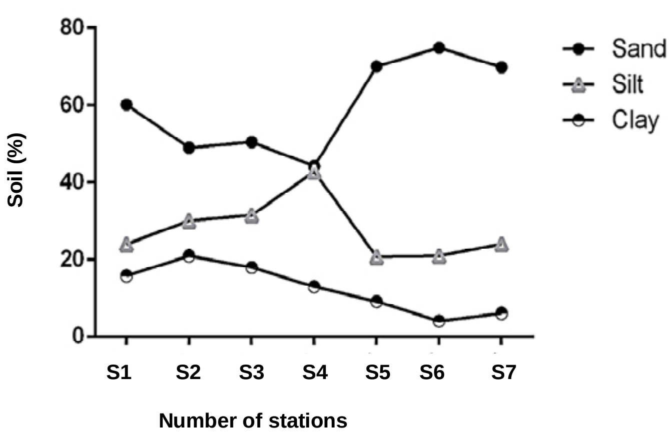

Figure 3. Particle size measurement of collecting marine sediments.

composition revealed that, the Tamiraparani estuarine system is essentially a low energy environment. According to the results of the particle size distribution were as shown (Figure 3 and Table 1). The Station 3 grain size of the sediments along the sites studied ranged from sand (50.5%), silt (31.5%), and clay (18%). These separate fractions were classified in sM represented by the soil texture triangle (Flemming, 2000; Folk et al., 1970). Whereas, the sediments are the fine sand, predominantly minerals sorted (homogeneous), negatively skewed, and ply to extremely leptokurtic in nature from sM. Basack and Purkayastha (2009) found the particle size distribution curve was plotted from which it was found that, the soil consists of 14% sand, 27% silt, and 59% clay, by weight from Visakhapatnam, eastern coast of India.

Veihmeyer and Hendrickson (1931) defined the field capacity or the WHC as the amount of water held in the soil after the excess gravitational water has drained away and after the rate of downward movement of water has materially ceased. Stage of field capacity is attained in the field after 48 to 72 h of saturation. It is the upper limit of microorganisms' available soil moisture. Further, the WHC was determined, In this result of WHC, Table 1 and Figure 4 showed the range of values for all samples in each site. The Station 3 values were observed at 65.3%. These studies moderately describe the WHC of space or pores of the soil particles. This water was available to the microbes growing in the soil mixture.

Table 2. Determination of chemical sediment characterization.

Number of station	pH	EC(dS/m^{-1})	SOC (%)	OM (%)	N (%)	P (%)	K (%)
S-1	7.8	0.4	3.9	6.7	0.705	0.010	1.453
S-2	8.1	0.4	1.6	2.7	0.529	0.011	1.504
S-3	7.5	0.5	1.2	2.0	0.614	0.058	1.103
S-4	7.9	0.5	0.4	0.7	0.584	0.018	1.117
S-5	8.6	0.5	0.8	1.4	0.389	0.012	1.224
S-6	8.9	0.5	0.4	0.7	0.299	0.091	1.106
S-7	8.2	0.6	4.0	6.9	0.321	0.031	1.688

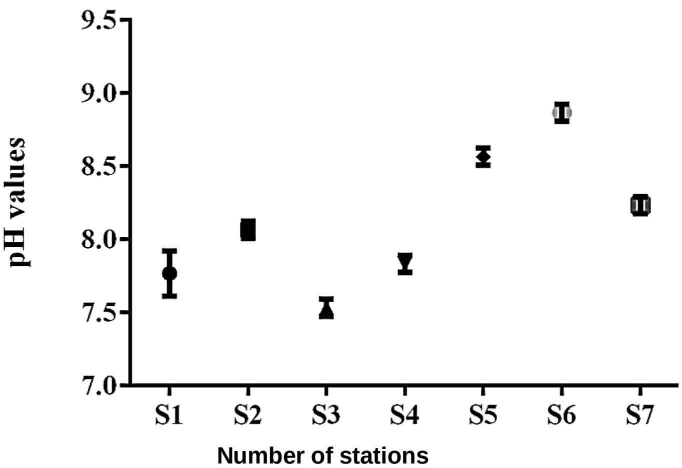

Figure 5. pH measurement of collecting the marine sediments.

Moreover, the OM and particle size affect a soil's ability to retain moisture.

Chemical sediment characteristics

Mahananda et al. (2010) revealed that, there was no great difference found in pH values in seasonal analysis which indicates the alkaline nature of marine water which may be due to high temperature which causes reduction in the solubility of CO_2. While soil acidification is beneficial in the case of alkaline soils, it degrades land when it lowers crop productivity and increases soil vulnerability to contamination and erosion. Soils are often initially acidic because their parent materials were acid and low in the basic cations (calcium, magnesium, K, and sodium). Since, most of the chemical reactions in aquatic environment are controlled by any change in its value, anything either highly acidic or alkaline would kill marine life. Aquatic organisms are sensitive to pH changes and biological treatment requires pH control or monitoring. In these, results of pH values ranged from 7.5 to 8.9 in the Stations 1 to 7. Among in the studied area, results were varied from all stations showed (Table 2). The highest values were observed at Station 6 ranging between 8.9 in this station of sediments which indicates often highly basic, badly structured, and easily detached seagrass from surface clay. Although, the neutral pH was observed at the Station 3 between the ranged of 7.5 (Figure 5 and Table 2). These pH values were indicative of carbonate rich soil. This was depending on the concentration of calcium carbonates that may result in well-structured soils of bacterial community association.

The need for an improved ability to “see into the earth” has resulted in the use of geophysical techniques, especially the EC method, in environmental investigations. The major challenge in the use of EC measurements however is the interpretation of the electrical response. This is due to the lack of adequate understanding of the relationships between the physical factors controlling the behaviour of geomaterials (earth materials) and their measurable electrical parameters. In this results, it was observed that, the EC measurements accurately predict the maximum past pressure. The Marines sediments were determined by EC which shows the amount of soluble (salt) ions presented for each sediment. The total soluble salts are due to the different ionic conductivities of the various salts and the effect of the soil particles. An estimated value for the percentage total soluble salts is obtained by multiplying the EC at all collected Stations 1 to 7, the values were observed between 0.4 to 0.6 for 25°C (dS/m^1). Although, the Station 3 was observed at 0.5 (dS/m^{-1}) showed in Table 2 and Figure 6.

The moderate soil organic carbon (SOC) contents were found at the Stations 3 (Figure 7), which are expected since these sites are host to a seagrass and coral reef complex characterized by high primary productivity and weak currents, leading to OM accumulation. The low SOC contents in Stations 4 and 6 are due to a combination of low primary productivity and high water energy since the terrigenous sand bottoms are characterized by relatively strong currents (Hulings and Ismail, 1978). Furthermore, the dilution of these sediments by the input of terrigenous materials may play a further role in reducing the SOC content of the sediment (Vaugelas and Naim, 1982).

The association between OM and SOC, TN are positive

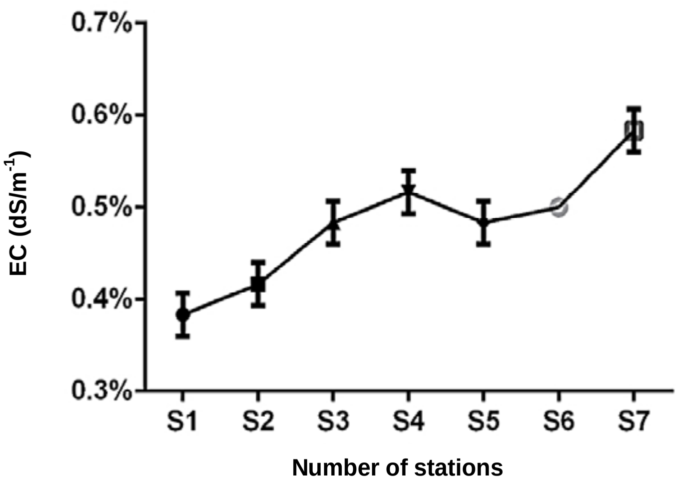

Figure 6. Electrical conductivity analysis of collecting marine sediments.

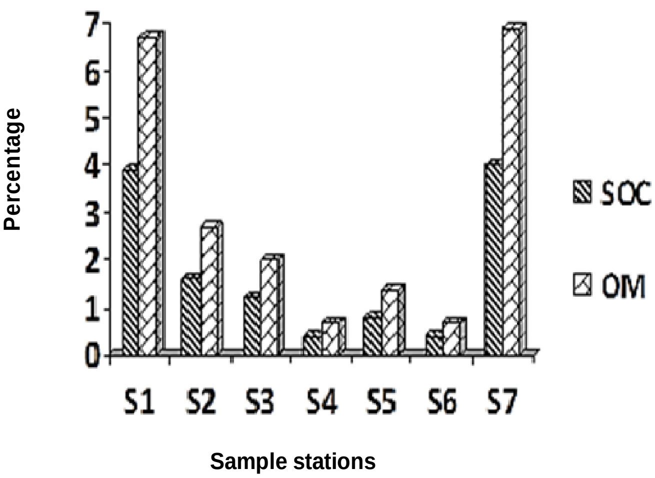

Figure 7. SOC and OM concentration of marine sediment sample.

and significant (r = 0.161, $p < 0.01$; Table 3 and Figure 7), the moderate the OM, the adequate the OC, and TN contents. These result shows moderate SOC values found at Station 3 are due to suitable biological activity and coral reef cover, which is considered as the main source of OM in the surface sediments (Wollast, 1991; Rasheed et al., 2003), however these concentrations were diluted at the IC site (group C) by the input of terrigenous sediments reaching these areas of land. These results are similar to those presented by Hulings and Ismail (1978), who found that, SOC is directly related to $CaCO_3$ contents and the highest content of SOC was in the seagrass beds, followed by coralline sands and terrigenous sand bottoms.

The high, significant correlations between OC and TN indicate that, these parameters are very tightly coupled (r = 0.154, $p < 0.01$; Table 3 and Figure 8) because of their occurrence in a common phase (OM). The TN concentrations in sediment most likely result from deposition and sinking of microorganisms from the water column. The anthropogenic sources of organic N are from seagrass bed in Thondi coastal moderate. Values for OC and TN in this study were similar to those reported in earlier studies along the Jordanian coast of the Gulf of Aqaba (Abu-Hilal, 1986; Rasheed et al., 2003).

Despite the co-occurrence of OC and phosphate in OM, these two elements are negatively correlated (r = -0.171, $p < 0.01$; Table 3). Furthermore, the TP concentrations were accompanied by low OM (r = -0.166, $p < 0.01$; Table 3 and Figure 7) and TN contents (r = 0.161, $p < 0.01$; Table 3). Abu-Hilal (1987), were reported to sediment cores from the coast of the Gulf of Aqaba, who found that all forms of P, except the non-apatite inorganic P, are poor or negatively correlated with OC and calcium carbonate which indicates an anthropogenic origin of P.

Different results were obtained by deKanel and Morse (1978), Barrie et al. (1983), Balzer et al. (1985) and Rittenberg et al. (1992), who found that, phosphate has a strong affinity for adsorption on reef carbonate sediments and can be trapped within the crystal lattice of carbonate granules. However, Entsch et al. (1983) and Szmant and Forrester (1996) found significantly higher P levels (double) in sea floor sediments outside the influence of a coral reef.

The higher TP concentrations from this study were found at Station 3, followed by station 6 (Table 2; Figure 8). This may be partly attributed to the fact that, Station 3 is host to seagrass beds (*Halophila stipulcea*). According to McRoy and Barsdate (1970), seagrass has the ability to absorb P from sea water since, most of the industries are receiving uncontrolled discharges of wastewater and elevate the phosphate contents in the sediments (Bonanni et al., 1992; Badran and Foster, 1998). High phosphate overload has been recorded as the main nutrient increase in industrialized and densely populated areas (Barabas, 1981). However, the Station 3 is located within the marine reserved (protected) area, which may explain their low anthropogenic TP sources.

Conclusion

Station 3 of sediment from the Thondi coastal regions in southeast coast of Tamilnadu, India, was recognized in this study. Moderate solid organic carbonate sediments (1.2%), which characterized the pelagic sediments and are composed mainly of materials derived from calcareous skeletal structures; low SOC sediments (<1%), which are composed of terrigenous materials

Table 3. Chemical sediments correlations.

Parameter	pH	EC (dS/m^{-1})	SOC (%)	OM (%)	N (%)	P (%)	K (%)
pH	1						
EC (dS/m^{-1})	0.223	1					
SOC (%)	-0.308	0.040	1				
OM (%)	-0.299	0.046	1.000	1			
N (%)	-0.841	-0.650	0.161	0.154	1		
P (%)	0.717	0.339	-0.171	-0.166	-0.705	1	
K (%)	-0.794	0.201	-0.025	-0.030	0.510	-0.511	1

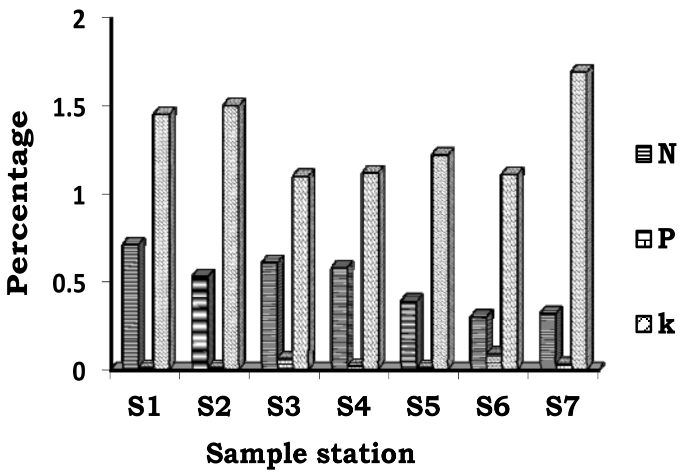

Figure 8. N, P, and K concentration of marine sediment samples.

transported from shore and near shore area by winds, floods, and waves; and a third type with intermediate SOC content (1 to 3%). Chemically, the results show a strong correlation between SOC and TN contents indicating the biological origin of these compounds. The association between SOC and TN indicates the occurrence of these components from the same phase (OM). Total phosphate moderate was found in stations closer to the phosphate loading berth and industrialized sites, indicating the importance of anthropogenic sources. It was also found that, the coarser, suitable sorted sediments contain moderate concentrations of SOC and TN than finer and well sorted sediments. Variations in textural properties and mud contents were due to differences in sediment sources, topography, and their response during currents and waves.

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