# Sediment texture and nutrients of Muttukadu, sand bar built backwaters, Tamilnadu, India

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## Abstract

**Muttukadu backwater form a complex system of shallow estuarine network spread over an area of 0.87 km$^2$ meant for fishing and boating activities. The study area is connected to the sea by a bar mouth, the width of which is variable from a few meters to 200 m in different months. Mouth closes due to sandbar formation from March to September. A combination of reduced river discharge, the build-up of an oceanic bar as a result of onshore sediment transport by long-period swell wave action during summer, cause the formation of sand bar. Sediments are the major sink for chemical components of water bodies and sediment chemical analyses afford methods for measurements of the quality of overlying water and the levels of potential pollutants. Station 1(0.5 km away from the mouth) and 9 which is in the sea is always sand dominated as they are influenced by the nearshore dynamics. The saline sea water, which enters the estuary, resuspends the flocculated sediments at the mouth and transports the fine floccules to the water column during the open condition. pH (7.7) of the sediment is high during monsoon season. The total nitrogen (4.7µg/L) of sediments is higher during summer season due to the oxidation of dead plant organic matter, which has settled on the top layer. Total Phosphate shows a positive correlation with silt. Phosphorus load is high in the stations 5, 6, 7 and 8 is 2.3, 2.1, 4 and 2.5 (µg/L) which is located in the upstream of the backwater and in Buckingham canal compared with the mouth region, indicating that the environment is substantially influenced by local sources of sewage, industrial effluent etc.**

## Introduction

Estuarine sediments and waters are characterized by specific and complex physical, chemical and microbiological properties. These properties depend and interact with each other and collectively constitute a unique environment to the organism. The study of sediments represents a useful tool for determining the actual state of environmental pollution of a water body. Textural characteristics of estuarine sediments are strongly influenced by several factors, including source area composition of adjacent lands, climate, length and energy of sediment transport, redox conditions in the depositional environments (Fralick and Kronberg, 1997). It is well recognized that the primary productivity in shallow marine environment depends on nutrients economy which is known to be governed by the sediment nutrient level. Knowledge on the role of sediments in this is useful in determining the sediment-water interactions eventually affect the productivity of the overlying

water body (Venkatasamy and Hariharan, 1986). According to Tennore, (1981) nitrogen is the major regulatory nutritional factor in most detrital based system. Sreenivasan (1976) reported that, the bottom sediment is the main source for different forms of nitrogen. The physicochemical character of sediments regulates the type of food, feeding and other life activities of benthic forms to a great extent (Ramachandra *et al.*, 1984). The variability of freshwater discharge at the upstream boundary is a major control on sediment concentration and transport (Schubel and Prichard, 1986; Sharp *et al.*, 1986; William, 1989; Rajasegar *et al.*, 2002). Soil acts as a reservoir of nutrients and several biogeo-cycling, exchange of nutrients takes at bottom water interface. Nutrients are also derived from the drainage water and mineralization of organic matter. Many studies have been carried out so far on sediment nutrients from various estuaries of India (Remani *et al.*, 1980; Murthy and Veerayya, 1981; Sivakumar *et al.*, 1983; Sesamal *et al.*, 1986; Nair *et al.*, 1987; Satyanarayana *et al.*, 1993; Seralathan *et al.*, 1993; Rajasegar *et al.*, 2002;

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Venkatraman *et al* 2010). The present study was carried out on the seasonal composition, texture and distribution of nitrogen and phosphorus of sediments in the Muttukadu Backwater. The present study will be useful tool for future ecological assessment and monitoring of this Backwater.

## Material and methods

Muttukadu (Kovalam) Backwater (latitude 12° 46'N and longitude 80° 18'E) is located at 36 km south of the Chennai, Southeast coast of India. The geology of the study area is represented by the basement Archean charnockite rocks which are overlain by a thick mantle of quaternary alluvium and these in turn overlain by the Holocene tidal flat deposit and coastal dunes (Achyuthan, 2006). The coastal beach area at Muttukadu is characterized by salt marsh and barrier dunes and forming paleoshorelines and a spit. The study area is connected to the sea by a bar mouth, the width of which is variable from a few meters to 200 m in different months. Backwater is normally cut off from the sea between March and September, when a sand bar is formed. During October-December due to inundation by the water from the upper reaches, sand bar gets eroded and the connection with the sea is restored. A spit of sand protects the low lying marshy land at Muttukadu (Achyuthan *et al.,* 2009). The site selection was based on their proximity to sand bar and the level of anthropogenic pressure.

Monthly sediment samples were collected from nine stations (Fig. 1) in Muttukadu Backwater for a period of one year from January-December 2009.

- Station 1 – 0.5 km away from the mouth
- Station 2 – 1.5 km from the mouth near TTDC Boat house
- Station 3 – 2 km distance from the mouth
- Station 4 – 3 km from the mouth near crab culture
- Station 5 – 4 km from the mouth
- Station 6 – 6 km from the mouth near Industrial outlet
- Station 7 and 8 – 1.5 km and 2 km respectively from the mouth inside Buckingham Canal
- Station 9 – 0.5km distance opposite to Muttukadu mouth in Bay of Bengal

Sediments were collected using Vanveen grab and were taken to the laboratory in clean polythene bags. The percentage composition of sand, silt and clay were determined by combined sieving and pipette method as described by Krumbein and Pettijohn (1938). Soil pH was recorded by pH meter. The sediment temperature was recorded by inserting the thermometer just below the surface of the sediment.



Figure 1 Study Area with Sampling Stations

Total nitrogen in the sediment was estimated by Kjeldahl method as out lined by Barnes (1959) and total phosphorus was determined by the method described by Rochford (1951). The north east monsoon in Chennai brings intense rainfall from October to December months. The pattern of rainfall facilitates various season of the year into post monsoon (January – March), summer (April – June), Pre monsoon (July – September) and monsoon (October – December).

The seasonal variations of the environmental features in the estuarine system are chiefly controlled by the spectacular regime of the rainfall during monsoon. The data were subjected to statistical computations such as principal component analysis using statistica version 8 and microsoft excel stat and cluster analysis using PRIMER.Cluster analysis (CA) is to make objectives into groups based on the similarities inside of the group and dissimilarities of different groups.

The groups are divided by their unique characteristics, and often, it helps interpreting the data (Vega *et al*. 1998). Many studies have shown that CA reliably classifies surface water quality and can guide future sampling strategies (Wunderlin *et al*. 2001; Simeonov *et al*. 2003; Singh *et al*. 2004). In this study, hierarchical agglomerative CA wasperformed on the normalized data set by means of the wards method, using single Euclidean distances as a measure similarity (Simeonov *et al*. 2003; Shrestha and Kazama 2007).

**Table 1. Descriptive statistics of the data along the study sites of Muttukadu Backwater from January to December 2009**

|  | Mean | Median | Min | Max | Range | Std.Dev. | SD (+0.95) | SD (0.95) | Coef.Var. |
|---|---|---|---|---|---|---|---|---|---|
| **Sand** | 90.22 | 91.00 | 59.90 | 99.70 | 39.80 | 9.56 | 7.92 | 12.08 | 10.60 |
| **Silt** | 3.13 | 2.60 | 0.00 | 16.00 | 16.00 | 3.06 | 2.53 | 3.87 | 97.87 |
| **Clay** | 7.40 | 3.40 | 0.00 | 39.10 | 39.10 | 9.32 | 7.72 | 11.78 | 125.93 |
| **pH** | 7.08 | 7.00 | 6.50 | 7.50 | 1.00 | 0.20 | 0.17 | 0.25 | 2.83 |
| **Temp** | 29.35 | 31.20 | 18.90 | 34.00 | 15.10 | 4.61 | 3.82 | 5.83 | 15.71 |
| **TN** | 1.81 | 1.60 | 0.01 | 4.30 | 4.29 | 1.47 | 1.21 | 1.85 | 80.81 |
| **TP** | 1.30 | 1.40 | 0.20 | 2.40 | 2.20 | 0.67 | 0.55 | 0.84 | 51.37 |

**Table 2. Correlation between different physico-chemical parameters of sediment along the study sites of Muttukadu Backwater from January to December 2009**

|  | Temp | pH | TN | TP | Sand | Silt | Clay |
|---|---|---|---|---|---|---|---|
| **Temp** | 1.00 |  |  |  |  |  |  |
| **pH** | -0.11 | 1.00 |  |  |  |  |  |
| **TN** | -0.38 | 0.01 | 1.00 |  |  |  |  |
| **TP** | 0.08 | -0.18 | 0.54 | 1.00 |  |  |  |
| **Sand** | 0.15 | 0.10 | -0.57 | -0.43 | 1.00 |  |  |
| **Silt** | 0.24 | -0.38 | 0.13 | 0.46 | -0.23 | 1.00 |  |
| **Clay** | -0.25 | 0.02 | 0.53 | 0.25 | -0.94 | -0.08 | 1.00 |

**Results and Discussion**

The mean and standard deviation with standard error values of temperature, pH, sediment composition, total nitrogen and total phosphorus are given in Table 1.

The sand, silt and clay contents of the study area based on the opening and closing of sand bar are presented in Figure 2. The sediment distribution in estuaries and nearshore region to a large extent depends on the source and texture of sediments supplied and topographic features of the area. In the present study, the percentage composition of sand in sediment is higher during monsoon season or when the mouth is open. This may be attributed to the winnowing activity of the monsoonal flood and due to tidal activity. Higher clay content (24.6%) was observed during the post monsoon and summer

while lower level (2.9%) was found during monsoon. The higher value during summer may be attributed due to the fluctuations and settling of finer fractions and at high saline conditions, the clay and colloidal particles are neutralized and are drawn together into larger particles, which could settle faster than individual charged particle.The surface sediments in station 2 were found coarse in nature and the estimated sand content varies from 88 to 90%. The transport of beach sand due to the tidal activity is the main reason for sand domination. When the mouth is fully open and closed, the clay is present in negligible amount but during the intermittently open condition, percentage of clay increases which may be due to riverine sediments or sludge from stations 7 and 8. Sand dominance in stations 3 and 4 is due to tidal activity. Further during the open and closed conditions, an increase in silt content noticed due to flocculation of fine particles in the water column, sediment mixing and resuspension by organisms. Human activities i.e., boating also play a major role in concentrating the fine particles in the stations 3 and 4 of the Backwater.
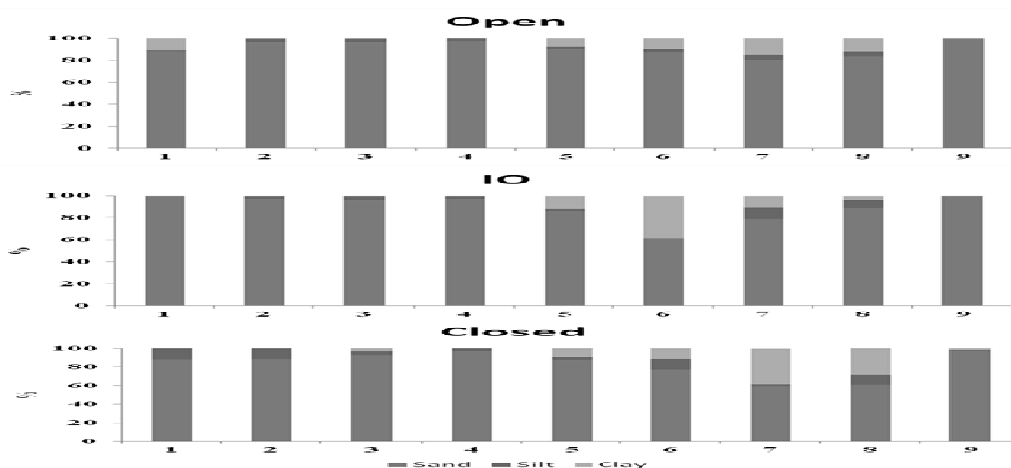


**Figure 2 Sediment composition based on sand bar formation**

Stations 5 and 6 in the upper reaches of the estuary is generally occupied by clayey silt. This confirms that the marine end is characterized by sand and the riverine end is characterized by silt and clay. Stations 7 and 8 in the Buckingham canal shows an increase in silt content due to large amounts of sludge deposition and microbial decomposition. Stations 1 and 9 was observed always sand dominated as they were influenced by the nearshore dynamics. The saline sea water, which enters the estuary, resuspends the flocculated sediments at the mouth and transports the fine floccules to the water column during the open condition.The tidal currents also plays a major role in removing the fine particles from the estuarine mouth and it can be seen clearly. pH of the sediment was high (7.5) during monsoon season. Low pH (6.5) was recorded during premonsoon. Higher value during summer could be due to a course of the redox changes in the sediment and water column apart from the influence of fresh water (Rajasegar *et al.*, 2002). In the present study, sediment temperature was high (33.9$^{\circ}$C) during summer when the mouth is closed. Low temperature (18$^{\circ}$C) was recorded during monsoon season this could be due to fresh water inflow. High temperature during summer season is caused by ocean's large thermal inertia, which causes a lag between absorption and subsequent release of solar energy to the atmosphere. otal Nitrogen concentration varies from 0.01 to 4.7 µg/g (Figure 3).

The total nitrogen of sediments was higher (4.7 µg/g ) during summer season due to the oxidation of dead plant organic matter, which has settled on the top layer.
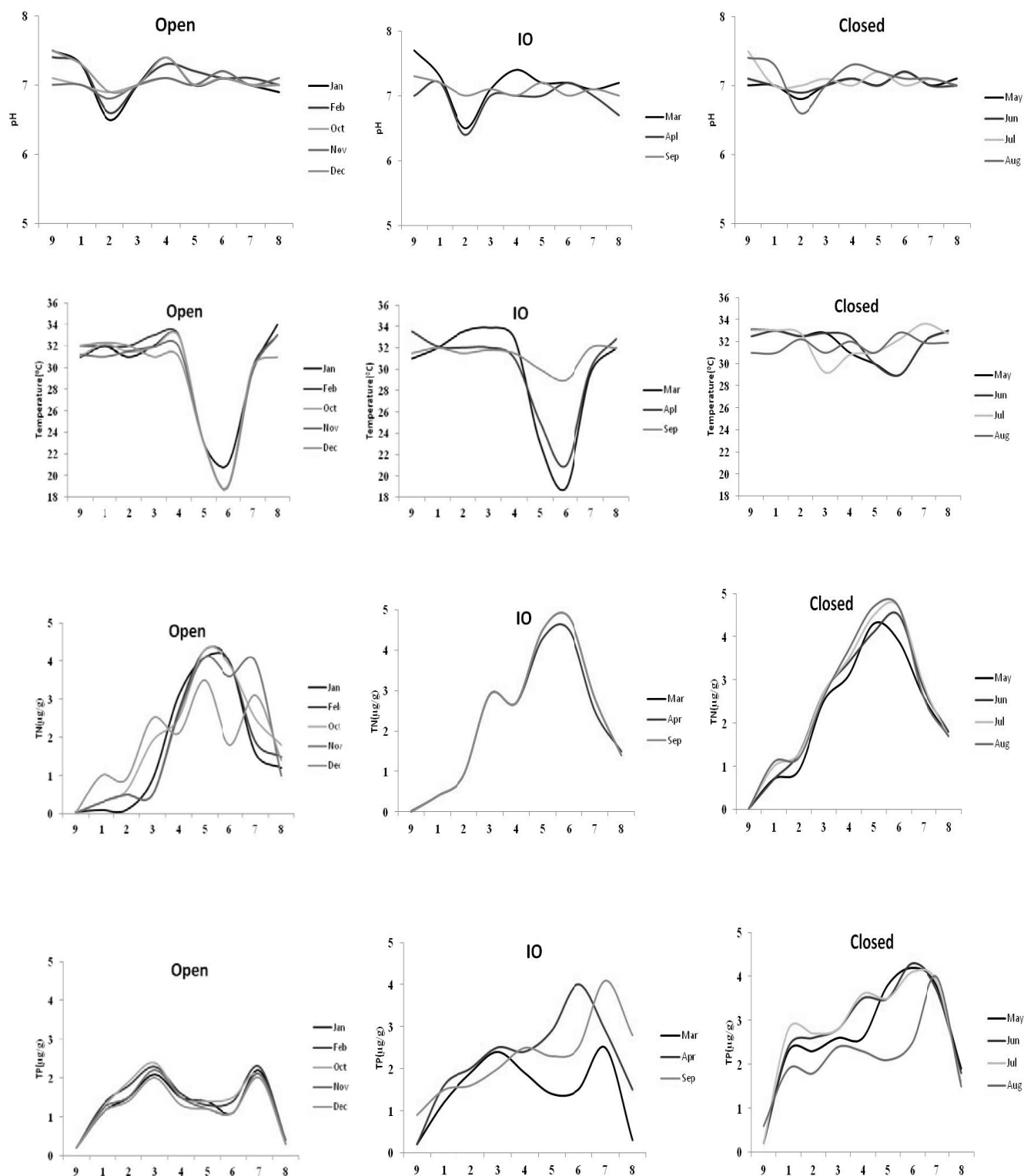
**Figure 3 Variation in physico-chemical parameters based on sand bar formation**

The low values (0.3 µg/g) of total nitrogen observed during monsoon season may be ascribed to the low level of organic matter during monsoon season associated with higher sand. During pre and post monsoon periods, the fresh water flow is low but the nitrogenous effluents discharged from industries located in the upstream (Stations 5 and 6) would settle at the stations 3 and 4. This might be the reason for the nitrogen increase in these regions. In the estuarine region (Stations 1, 2 and 3), total nitrogen shows a seasonal variation with the highest and lowest during post monsoon and monsoon respectively. The highest concentration of nitrogen during postmonsoon might be due to the contribution from organic detritus, the resulting from the planktonic bloom in these months and the decay of vegetation which reaches the bottom sediments by the relatively higher accumulation of organic materials in the sediments from overlying waters. Low TN during the monsoon observed in the stations 1 and 9 could be attributed coarse sandy texture. Clay and TN is positively correlated, from the main components of organic matter and are mostly associated with fine soil particles particularly clay (Table 2).Total Phosphate concentrations vary from 0.2 to 5 µg/g (Figure 3). The capacity of sediment to retain or release phosphorus is one of the important factors, which influence the concentration of inorganic/organic phosphorus in the overlying waters. Total phosphorus in the sediment was high and low (2.8 and 0.2 µg/g) during summer and monsoon season Station 6 and 9 representing the upstream region and coastal water. The stations are clustered to different groups based on the distance from the mouth. Station 9 and 6 influence the transport of sediment. It is seen that clay from land discharge during the monsoon and sand from the sea forms a distinctive limiting factor in the distribution of nutrients when the mouth is open (Murthy and Veerayya 1981). The stations receiving maximum nutrient load due tourism and effluents from the industries group together. TN and TP form the first group when the mouth is closed. The stations which receive maximum urban sewage through Buckingham canal (e.g. 7 and 8) is grouped together in the CA analysis and they also form a part of a larger group. Biplot of sites identifies three clusters as i) mouth, ii) Buckingham canal stations

respectively. The higher values are attributed to the dead organic matter settling from top and are related to the permeability of the sediments and the lower values may be due to the removal of top layer of sediments by heavy flood and deposition of sand. Stations 7 and 8 record the highest TP throughout the study period due to the accumulation of sludge from the domestic sewage during the summer season and also due to adsorptive tendency of phosphate is high with higher silt percentage. Further the transport of sludge by the movement of flow of water towards the mouth from station 8 could have also contributed to the adsorption of phosphorus compounds in the sediments of stations 1 and 2. The sandy texture of the sediment in stations 1 and 9 limits the seasonal variation of the sediment phosphate to considerably low levels compared to the upstream region of the backwater. Total Phosphate shows a positive correlation with silt (Table 2). Phosphorus load is high in the stations 5, 6, 7 and 8 compared with the mouth region, indicating that the environment is substantially influenced by local sources of sewage, industrial effluent etc.

**Cluster Analysis**

Dendrogram plot (fig4)based on the hydrographical condition provided a fairly convincing grouping of stations. Stations 1, 2, 3, 4 and 5 represent the conditions of estuarine mouth and the backwaters. Stations7 and 8 form another group, exhibiting the similarity of the Buckingham canal. 7 and 8 stations are highly influenced by anthropogenic activities as compared to other stations and iii) station 6 which form the dominant cluster indicating the influence of the upper reaches on backwaters.

**Conclusion**

From the present study it is concluded that the differences in nutrient concentrations and silt composition would have favoured the higher diversity and density of phytoplankton The sediment characteristics of Muttukadu are prone to changes which could arise from human activities such as domestic sewage, boating and industrial effluents. This call for management strategies geared towards the conservation and protection of environment.
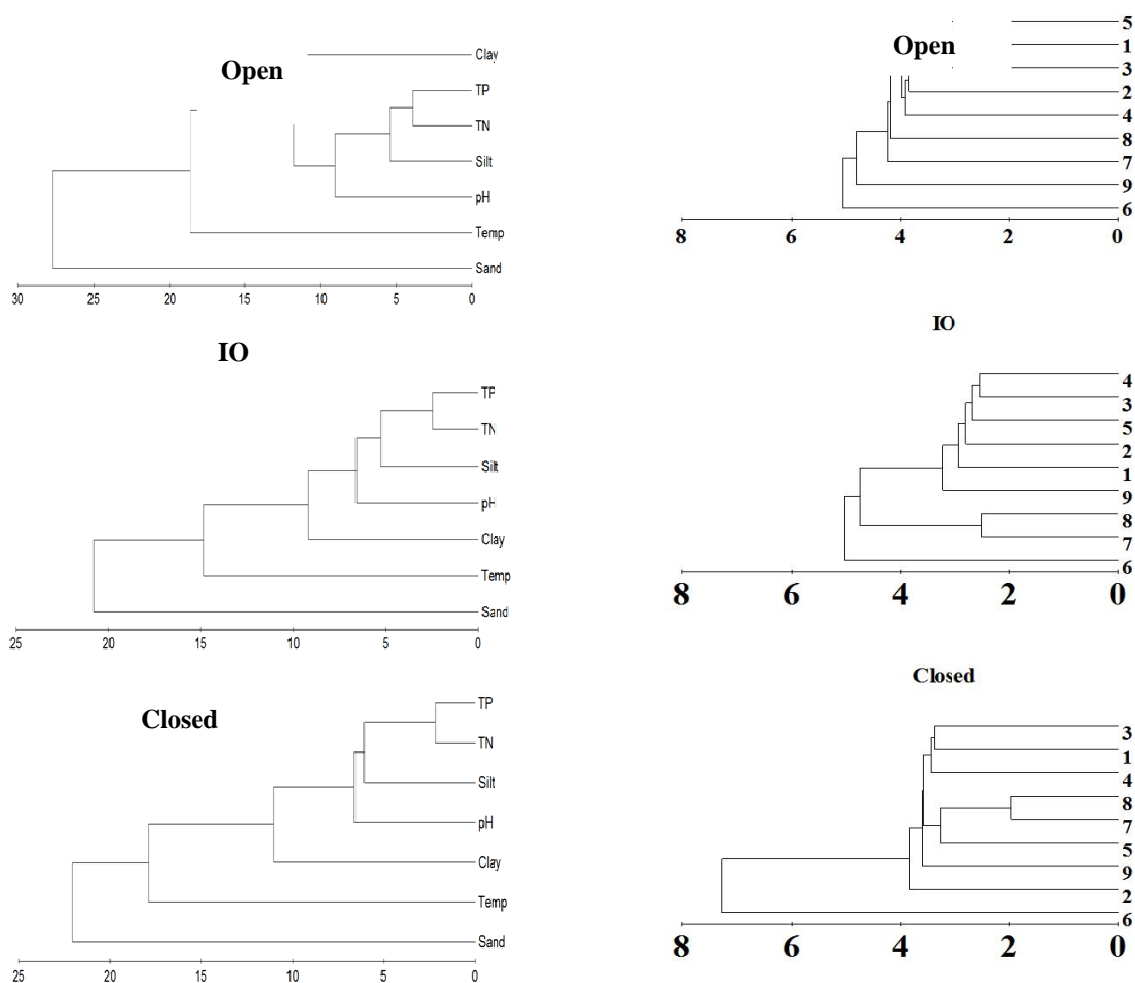
**Figure 4      Station wise and parameter wise clusters based on sand bar formation for sediment**

## Acknowledgment

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