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Seasonal Variations in Physico-Chemical Parameters of Water and Sediment Characteristics of Pondicherry Mangroves

P. Satheeshkumar and B. Anisa Khan

Department of Ecology and Environmental Sciences,
Pondicherry University, Puducherry, India-605014

Abstract: Seasonal variation of physico-chemical parameters were studied at four different stations in Pondicherry mangroves, southeast coast of India. Atmospheric and surface water temperatures (ºC) varied from 17.9-41.7 and 16.66-37.91 respectively. Annual rainfall and relative humidity ranges were 1.1-808 mm and 37-100% respectively. Seasonal variations of different parameters investigated were as follows: salinity (6.36-36.77ppt), dissolved oxygen (3.45-5.49 mg/l), pH (7.11-8.52), electrical conductivity (26.65-52 ms^{-1}), sulphide (2.76-47.16 mg/l), soil parameters sand (63.69-87.31%), silt (9.89-29.32 %), clay (3.06-17.98 %) and organic matter (0.94-3.94 %). pH, temperature, salinity, sand, silt, clay and organic matter indicated a correlation at $P<0.01$. Multivariate statistical technique was applied to evaluate the temporal/spatial variations in mangrove water quality of Pondicherry mangroves.

Key words: Seasonal variation · Physico-chemical characteristics · Mangrove · Water · Sediment · Pondicherry

INTRODUCTION

India with a coastline of over 8000 km long infringed with several rivers draining a total catchment of $3.02x10_6$ km_2 and their estuaries have a water-spread area of $2.7x10_4$ km_2, has 80% of mangrove recorded on the east coast and 20% on the west coast [1]. Mangrove forests one among the world's most productive tropical ecosystems. Mangrove ecosystem in Pondicherry is dynamic, fragile with the plant and environmental factors interconnect the process of energy fixation, accumulation of biomass, decomposition of dead organic matter and nutrient cycling. Mangrove ecosystem provides an ideal nursery and breeding ground to most of the marine and brachishwater fish and shell fish [2]. Environmental conditions such as salinity, oxygen, temperature and nutrients influence the composition, distribution and growth of its biota [3]. Mangrove areas are ecologically sensitive and play a major role in supporting tropical estuarine and coastal food webs [4]. Hydrogen sulphide is a major pollutant of the water bodies; the blackening of sediment in the polluted area was due to the local chemical reaction where sulphates get converted to sulphides [5]. Total organic carbon of sediment has a major role in keeping fertility of soil and thereby flourishing the biological activity [6]. Sediments are indicators of quality of overlying water and its study is a useful tool in the assessment of environmental pollution status [7]. Pondicherry coastal area is polluted due to the discharge of industrial, domestic and agricultural wastes through small tributaries and channels in to the Bay of Bengal. There are several major and small industries located in the vicinity of the study area, discharging their effluents continuously into these estuaries and coastal environments. In this present study we report on physico-chemical parameters of water and soil characteristic of Pondicherry mangroves on southeast coast of India.

MATERIALS AND METHODS

Study Area and Sample Collection: Pondicherry mangroves, the study area lies within the boundaries of latitudes 11°46'03" to 11°53'40" North and longitudes 79°49'45" to 79°48'00" East. Mangrove exists as fringing vegetation over 168ha distributed along the sides of Ariankuppam estuary, it is seasonally bar-built and semi diurnal type that flows eastwards emptying in to the Bay

Corresponding Author: P. Satheeshkumar, Department of Ecology and Environmental Sciences, Pondicherry University, Puducherry, India-605014 Tel: +91-04132654324

Fig. 1: Map of the study area showing station location points

of Bengal at Veerampatinam on south east coast of India, carrying wastes from adjacent agriculture lands and industries in addition to domestic municipal and distillery effluents. The present investigation was carried out in four well formed stations: 1 Veerampattinam; 2 Thengaithittu; 3 Ariyankuppam; 4 Murungapakkam mangrove areas of Pondicherry. Annual rainfall, temperature and relative humidity data was obtained from Regional Meteorological department at Chennai. Water and sediment samples from the surface and bottom levels were collected from 4 stations in Pondoicherry mangrove region (Fig. 1). Samples were collected every month for one year from September 2008 - August 2009. Water samples were collected in a plastic container, sediments by the Vanveen grab. Water samples were tested for different physico-chemical parameters. A water characteristic of dissolved oxygen (DO) was estimated Winkler`s methods and Sulphide [8], Water temperature (º mercury thermometer), salinity by hand Refractometer (ERMA), water pH (hand held pH meter, pH scan-2), Electrical conductivity (EC) was measured using EC instruments. Sediment texture was determined by pipette analysis method [9]. Total organic matter of sediment was determined by wet oxidation method [10]. Different measures for the similarity with respect to distance between parameters and different algorithms for finding a cluster are applied [11] in the present study.

Statistical Analyses: Co-efficient of correlation (r) was worked out to understand the relationship between the various parameters and to test the significance of the models. It was considered to be not significant when the value of the probability of significance (p) was greater than 0.05. Means and standard deviations were calculated for each parameter. All these statistical analyses were performed using SPSS statistical (Version 7.5 for Windows XP, SPSS and Chicago, IL, USA). Bray-Curtis similarity was analysed using PAST (statistical Version 1.93 for Windows XP).

RESULTS

Physico-Chemical Parameters of Water: Total rainfall during Sep2008 - Aug-2009 was 1520.7mm with monthly ranges between 1.1-808mm (Fig. 2). Relative humidity of atmosphere varied from 37-100(%) with monsoon season (Oct-Dec) having high and summer season with lowest range. Atmospheric and surface water temperatures ranged between 17.9-41.7ºC and 16.66ºC-37.91ºC (Fig. 3 and 4) respectively with maximum during summer and minimum during monsoon. Salinity at four stations varied from 6.36-36.77 ppt. and maximum salinity (36.77 ppt) was recorded at station 1 (Fig. 5) throughout the year. Significant positive correlation obtained between salinity and air temperature ($r = 0.720$; $P<0.01$) indicates that the salinity is largely influenced by temperature at this mangrove environment.

Seasonal mean fluctuations recorded in water acidity (pH 7.11-8.52) (Fig. 6) between the four stations, however, with clear spatial and temporal variations. The trend of pH resembles that variation in salinity and dissolved oxygen concentrations. Physico-chemical and sediment composition revealed significant correlation with a strong affinity for each other (Table 2). Station 1 registered high pH values during summer and showed positive significance ($r = 0.833$; $P<0.01$) between pH and salinity. Seasonal variation of DO ranged in all stations between 3.45-5.49 mg/l (Fig. 7). Though relatively monsoon registered high DO throughout study period, relatively low DO concentration recorded during summer at all 4 stations can be attributed to high surface water temperatures recorded during this season.

EC at four stations varied from 26.65-52ms^{-1} (Fig.8) with maximum EC (52ms^{-1}) recorded at station 3. Seasonal mean fluctuations recorded in the sulphide concentration varied from 2.76-47.16 mg/l (Fig.9) respectively with maximum during pre and post monsoon. In the present investigation maximum content of sulphide (47.16mg/l) was recorded at station 4. Significant negative correlation between sulphide and DO ($r = -0.601$; $P<0.05$) at station 4 indicates that DO is largely influenced by sulphide at this station. Dendrograms indicates the Bray-Curtis similarity for physico-chemical parameters of water and sediment composition (Fig. 10).

Table 1: Seasonal variation of sediment composition and organic matter at stations 1-4

Monsoon	Sand (%)	Silt (%)	Clay (%)	OM (%)
Station 1	83.38±3.64	19.12±11.81	4.14±1.59	0.94±0.31
Station 2	69.90±11.18	23.61±6.48	6.47±4.98	1.94±0.89
Station 3	73.24±17.20	21.60±12.94	5.81±3.18	3.21±0.88
Station 4	75.78±4.02	22.53±2.85	3.49±0.44	3.3±0.79
Post monsoon				
Station 1	72.40±16.31	16.66±14.41	10.01±0.84	1.58±0.31
Station 2	74.55±21.19	17.39±20.67	8.22±4.47	2.07±1.27
Station 3	67.60±22.37	26.06±24.07	6.23±1.91	3.13±0.86
Station 4	39.54±22.62	29.35±8.03	31.20±22.35	3.53±0.71
Summer				
Station 1	87.31±9.74	9.89±11.46	3.06±1.59	1.74±0.51
Station 2	83.42±11.46	12.23±9.36	4.99±3.021	2.18±0.39
Station 3	75±11.48	15.31±8.64	10.49±10.23	3.64±0.45
Station 4	67.88±29.44	14.72±19.25	17.98±11.24	3.76±0.44
Pre monsoon				
Station 1	71.83±21.02	24.21±20.75	4.04±0.42	1.12±0.30
Station 2	63.69±22.63	25.66±9.06	11.76±12.51	1.20±0.36
Station 3	77.87±10.06	18.02±8.69	4.07±2.05	3.82±0.74
Station 4	68.13±12.28	26.41±12.84	5.54±0.74	3.94±0.68

OM=Organic matter

Soil Texture Analyses: Composition of sediment particles varied between the four mangrove areas (Table 1). Sediment substratum was mainly composed of sand with an admixture of silt and clay. Sand fraction ranged between 63.69-87.31 % followed by silt (9.89-29.32 %) and clay (3.06-17.98 %). Seasonally station 1 recorded higher

Table 2: Correlation matrix between Physico-chemical and soil parameters in different seasons

	Salinity	pH	T	DO	EC	Sulphide	Sand	Silt	Clay	OM
Salinity	1.000									
pH	0.789	1.000								
T	0.890	0.671	1.000							
DO	-0.346	-0.021	-0.348	1.000						
EC	0.586	0.337	0.3347	-0.110	1.000					
Sulphide	-0.036	-0.406	-0.093	-0.600	-0.001	1.000				
Sand	0.347	0.3368	0.409	0.4786	0.0894	-0.404	1.000			
Silt	-0.554	-0.567	-0.668	-0.11	-0.19	0.389	-0.73	1.000		
Clay	-0.177	-0.150	-0.135	-0.536	-0.060	0.253	-0.85	0.307	1.000	
OM	-0.065	-0.420	-0.037	-0.659	0.026	0.840	-0.31	0.128	0.293	1.000

T = Temperature; DO= Dissolved oxygen meter; EC= Electrical conductivity; OM= Organic matter

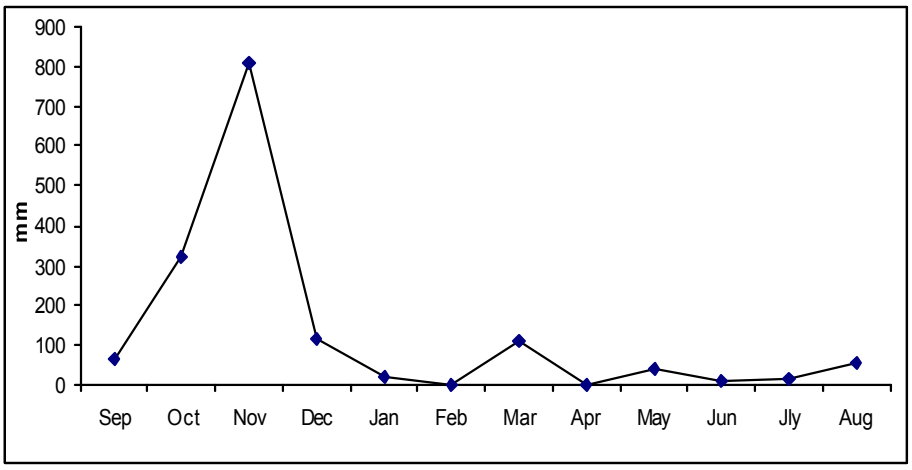


Fig. 2: Rainfall in Puducherry regions
Source: Regional meteorological center

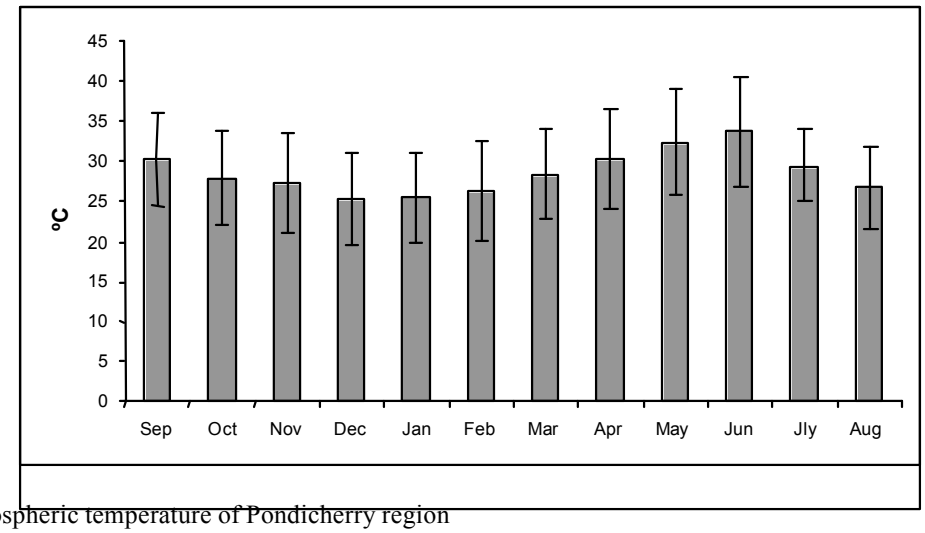


Fig. 3: Atmospheric temperature of Pondicherry region
Source: Regional meteorological center

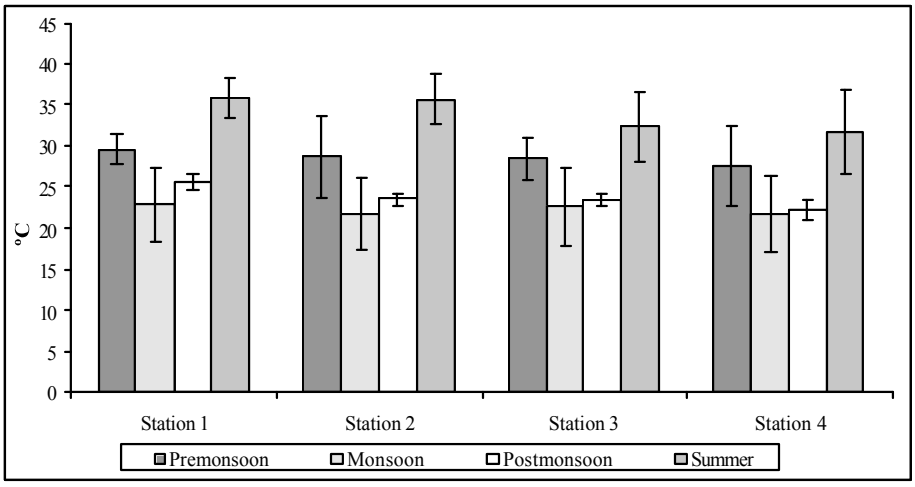


Fig. 4: Seasonal variations of temperature at stations 1-4

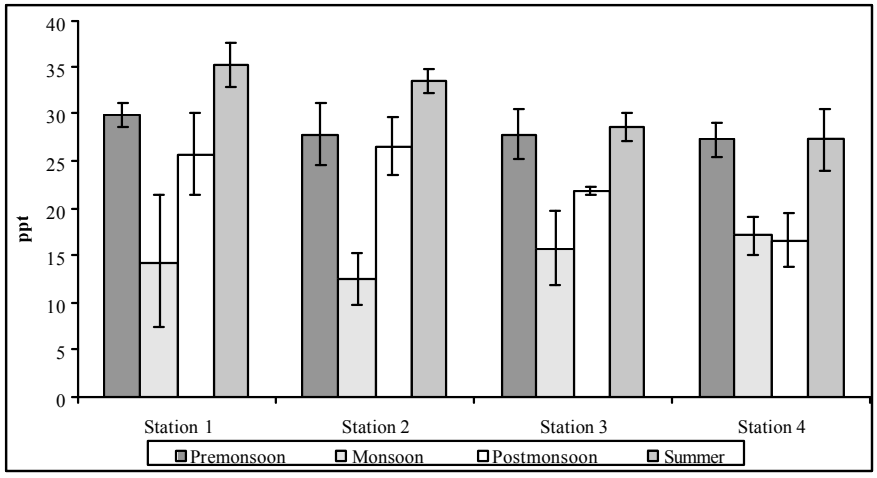


Fig. 5: Seasonal variations of salinity recorded at stations 1-4

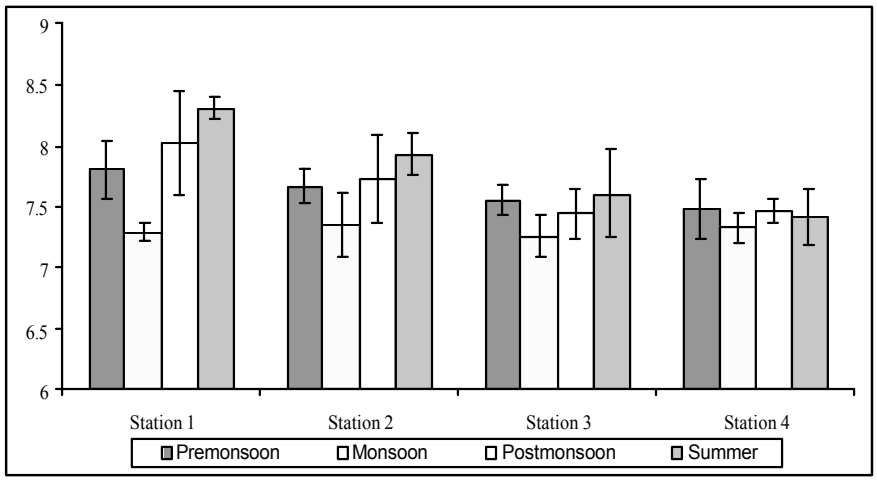


Fig. 6: Seasonal variations of pH recorded at stations 1-4

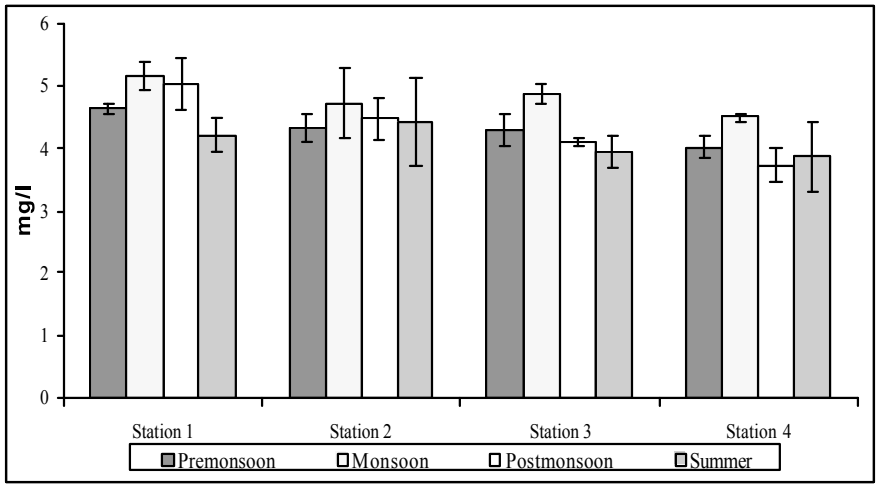


Fig. 7: Seasonal variations of Dissolved oxygen recorded at stations 1-4

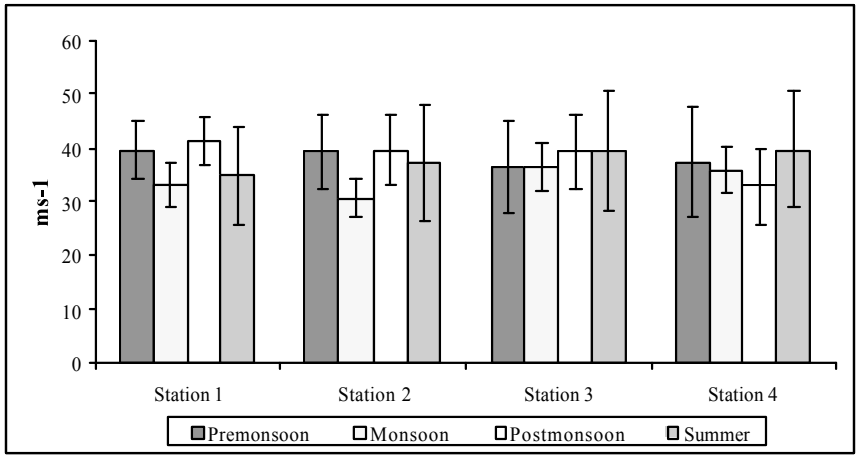


Fig. 8: Seasonal variations of electrical conductivity recorded at stations 1-4

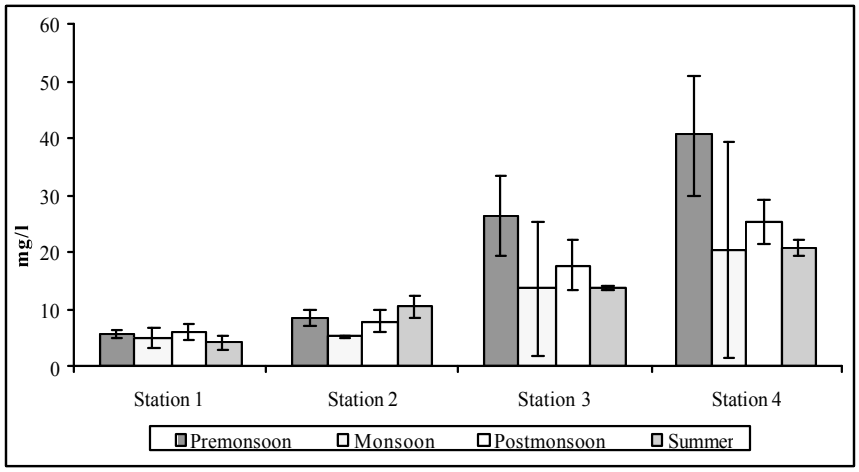
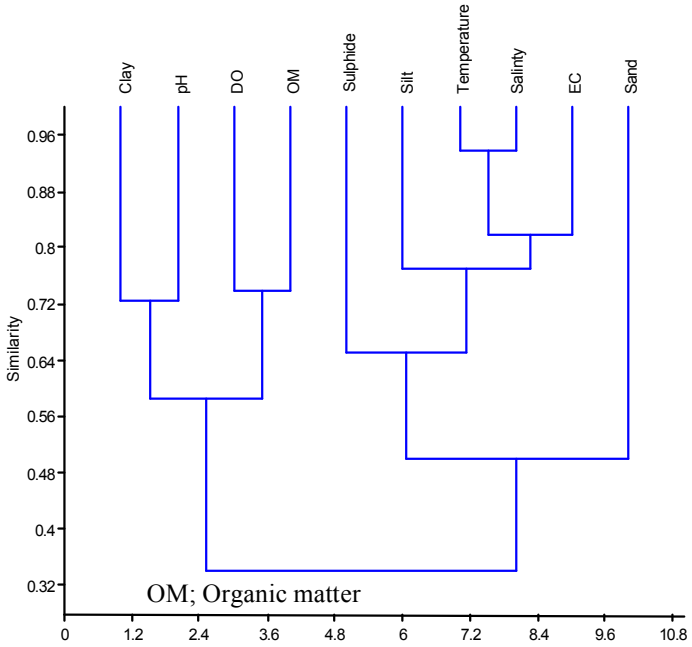


Fig. 9: Seasonal variations of Sulphide recorded at stations 1-4



DO; Dissolved oxygen meter
EC; Electrical conductivity

Fig. 10: Dendrogram of Physico-chemical parameters of water and Soil characteristics at Pondicherry mangroves

fractions of sand during monsoon and summer, silt content during post monsoon and pre monsoon period and clay during summer. Such differed combinations of sediment observed are mainly due to the transport of sediments from one place to another and back associated with tidal currents. Soil texture sand, silt and clay indicated high significant correlation at $P<0.01$.

DISCUSSION

Rainfall being the important cyclic phenomenon in tropical countries brings vital changes in the hydrological characteristics of coastal marine environments. In the present investigation, peak values of rainfall were recorded during monsoon in Nov. Temperatures variations recorded at four stations exhibited nearly similar pattern, with minimum during monsoon and maximum during summer. Monsoonal clouds prevalent during October-December months would reduce air temperature. Water temperature during November was low because of strong land breeze and precipitation but the high temperatures during summer could be attributed to high solar radiation [12]. There was no relationship between the air and surface water temperatures, which could be due to different environmental situations.

Salinity varies in different ecosystems according to the topography, tides (high and low tide) and freshwater inflow. In the present study, salinity at all four stations was high in summer and low in monsoon season indicating that during summer it could be attributed to faster evaporation. Though perennial rivers are absent, the runoff due to rains during monsoon could reduce salinity [13]. pH was alkaline throughout study period at all 4 stations, which is a characteristic feature of the marine environments [14]. Higher pH during summer in the present study could be due to the removal of CO_2 by photosynthetic organisms and lower pH observed during monsoon in all 4 stations could be attributed to the dilution of saline mangrove waters by freshwater inflow.

In the present investigation, DO indicate higher value during monsoon which could be due to the cumulative effect of higher wind velocity coupled with heavy rainfall and the resultant mixing freshwater. Seasonal variation of dissolved oxygen is mainly due to freshwater flow and terrigenous impact of sediments [15]. In the present study high EC was recorded during post monsoon (52 ms^{-1}) at station 3. Relatively low values were at all stations during monsoon, with the lowest of 26.65 ms^{-1} at station 4. Electrical conductivity (EC of the saturation extract) was considerably higher at disturbed sites in Andaman mangroves (33.8 - 41.5 dS m^{-1}), indicating accumulation of salts [16]. In the present study higher sulphide levels occur in station 3 and 4 because there are several major and small industries discharging their effluents continuously into these stations. More over the piercing smell of H_2S from deeper sediments was precisely observed during field study. Hydrogen sulphide level was high (47.16 mg/l) during pre monsoon at station 4 and relatively low values were in summer (2.76 mg/l) at station 1. The sulphide biome in the retting zone is quite extensive from the surface waters down to the bottom and deeper into the sediment layers. Although the surface water becomes enriched with oxygen during monsoon, the deeper layers continue to be of anoxic sulphide biome. In Kayamkulam estuary, Cochin a peak value of 0.92 µg H_2S g^{-1} in soil was reported at the presence of large quantities of hydrogen sulphide [17]. A perusal of data on the texture of sediment in the present study revealed that most predominant fractions are sand followed by silt and clay at all four stations. These spatial and temporal variations are directly related to the variations of sediment texture brought about by variations in a circulation pattern during different environmental conditions of location at study. Among the sediment layers sand and silt content was more at upper and middle layers in comparison to lower layer of sediment at all four stations. However stations 2 and 4 had higher clay content at middle and lower layers. This observation on sediment layers is corroborating with that observed at estuarine mangrove biotope of Cochin [18]. Bray-Curtis similarity with respect to differences between physicochemical parameters of water and sediment characteristics is applied in the present study. The dendrogram (Fig. 10) shows the cluster being combined and the values of the coefficient at each step. Results clearly show that four groupings could be distinguished that apparently reflected differences in water parameters /sediment types with in Pondicherry mangroves.

CONCLUSION

Hydrological parameters exhibited distinct variations in the four categorized study zones. The present water quality of Pondicherry mangrove ecosystem reveals that salinity plays a dominant role in water quality. In addition, H_2S pollution from both agricultural and industrial inputs deteriorates the water quality of mangrove ecosystem at station 3 and 4.

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