

Research Article

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Physico-Chemical Sediment Properties of Mangroves of Odisha, India

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Abstract

The physico-chemical properties of sediments are most likely control the reforestation success as well as the nutrient recycling in mangrove sites. A study of physico-chemical parameters of mangrove sediments of Odisha from five different sampling sites such as Bhitarakanika, Dhamra, Mahanadi, Devi and Budhabalanga was carried out. Different physico-chemical characters such as pH, conductivity, salinity, Organic carbon, alkalinity and total phosphates were analysed. The pH was found to be alkaline i.e., 8.77 ± 0.10 at Budhabalanga whereas slightly acidic i.e., 4.32 ± 0.12 at Devi sampling site of Odisha. Salinity was maximum i.e., 4.63 ± 0.16 PSU at Bhitarakanika whereas minimum i.e., $0.39 \pm 0.0.05$ PSU at Budhabalanga sampling sites. Organic carbon content was maximum i.e., 51.86 ± 0.11 mg/g at Bhitarakanika site whereas minimum i.e., 6.7 ± 0.12 mg/g at Budhabalanga site. The present study would form a useful tool for further ecological assessment and monitoring of the coastal mangrove ecosystems of Odisha.

Keywords: Physicochemical properties; Mangrove sediments; Ecological assessment

Introduction

Mangrove forests occupy several million hectares of coastal area worldwide and support an ecosystem, comprised of plants, animals and microorganisms, having a dynamic environment. The total area covered by mangroves in India is estimated to be 6,740 km², which accounts for about 7% of the world's total mangrove vegetation. Mangrove ecosystem is known to be very rich due to high amount of dissolved and particulate organic matter which acts as a homeland for diverse microbes. Sediments are originated basically from soil erosion, decomposition of plants and animals within the estuary itself. A lot of previous reports are available over the last few decades on the biogeochemical role of estuaries and mangrove ecosystems [1,2], but there is little information which links the role of these ecosystems in enhancing production functions of the adjacent agro ecosystems through nutrient export. Many reports are available on the physico-chemical features of Indian estuaries [3-11]. Mangroves ecosystem of Odisha is a very less explored ecosystem. Odisha is located between 17°49' N and 22°34' N latitudes and between 81°27' E and 87°29' E longitudes. Out of 52,472 sq.km of forested area mangrove forests constitute 243 sq. km. Odisha consists of mangroves in five different areas such as Bhitarakanika, Dhamra, Mahanadi, Devi and Budhabalanga. In the present study, the physico-chemical parameters such as pH, conductivity, organic carbon, salinity, alkalinity and total phosphorus were analysed from sediments of five different sampling sites of Odisha.

Materials and Methods

Study area and description of sampling sites

Samples have been collected from five different mangrove areas of Odisha (Figure 1) and the sampling sites were described as follows.

Bhitarakanika (SITE-1): Bhitarkanika is the second largest mangrove ecosystem of India situated at Long. 20°30' N and Lat. 86°45' E. The mangroves cover an area of 650 sq. km. The sediment samples were collected from five different localities such as Kantaikhai (BKS-1), Khola (BKS-2), Dangamal (BKS-3), Mahisamunda (BKS-4) and Dangmal (BKS-5).

Dhamra (SITE-2): Dhamra mangrove ecosystem is present in the bank of river Dhamra situated at Long. 20°47' N and Lat. 86°56' E. A small patch of mangroves present in the port site has been identified for protection by the Dhamra port. Sediment samples were collected from Kalanali jora site (DHS-1), Chandinipal (DHS-2), Dhamra MAPOT (DHS-3), Jyotsnamayee (DHS-4), and Kalanali mangrove site (DHS-5).

Mahanadi (SITE-3): Mahanadi mangrove is located in the combined delta of the rivers Mahanadi and situated at Long. 20°17' N and Lat. 86°42' E. The Mahanadi delta occupied an area of 9,000 sq.km. Sediment samples were collected from Kansardi (MHS-1), MHS-2, MHS-3, Ghangholia jora site (MHS-4) and MHS-4.1.4. **Devi Mouth (SITE-4):** The Devi mouth mangrove is located in the district of Jagatsinghpur (9° km) situated at Long. 19° 58' N and Lat. 86° 22' E. Sediment samples were collected from the mangrove areas of Machamachikuda (DVS-1), Bandar (DVS-2), Nadiakhia (DVS-3), Nentai (DVS-4) and Kiakhala (DVS-5).

Budhabalanga (SITE-5): The Budhabalanga estuarine mangrove situated at Long. 21° 28' N to Lat. 87° °5' E. Sediment samples have been collected from Balaramgadi (BDS-1), Haldigudi (BDS-2), Nandachaha (BDS-3), Sanipala (BDS-4) and Budhabalanga River (BDS-5).

Collection and processing of sediment

Sediment samples were collected with an air dried Beckman's grab in the month of October from all the sampling areas. The sediment collected were aseptically transferred to the labeled polythene bags and kept in an ice-chest box before transferring to the laboratory.

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Samples were collected from five different locations of each sampling sites. The collected sediments were air dried at room temperature in the laboratory for 7-10 days for evaporation of moisture content. The dried samples were further crushed to fine texture in a ceramic mortar, re-packaged in labeled polythene bags and stored in the laboratory for sediment characterization study.

Physico-chemical characterization of sediment

Before analysis, the air-dried followed by oven-dried sediment samples were sieved using 2.0 mm mesh sized sieve and 0.5 mm sieve for other analyses. For all the tests, the sediment was dissolved in required amount of milliQ water and filtered. The filtrate was used for further tests. pH and conductivity of the sediment samples were measured by using a digital pH and conductivity meter. Salinity, alkalinity and total phosphorous were analyzed following the methodology of APHA [12]. The oven dried sediment samples were powdered with grinder (Tetsch, model, RM 100). Then required amount of grounded sample was taken for total organic carbon analysis following Walkely and Black method [13].

Results and Discussion

pН

A little variation in pH was found among different stations. It was found to be minimum i.e., 6.91 ± 0.042 and maximum i.e., 7.7 ± 0.06 at Bhitarakanika. In sediments of Dhamra, pH varied from 6.23 ± 0.13 to 7.75 ± 0.16 . In Mahanadi, it varied from 6.27 ± 0.04 to 8.3 ± 0.03 whereas in Devi and Budhabalanga it ranged from 4.32 ± 0.12 to 7.54 ± 0.21 and 8.22 ± 0.09 to 8.77 ± 0.10 (Figure 2).

Conductivity

There was a little variation in conductivity of sediments. The conductivity ranged from 2087 \pm 167 to 2199 \pm 189 μ S/cm at Bhitarakanika whereas it was 1782 \pm 167 to 2236 \pm 167 μ S/cm, 2095 \pm 235 to 2564 \pm 256 μ S/cm, 1327 \pm 113 and 1675 \pm 138 μ S/cm, 2312 \pm 266 and 2457 \pm 245 μ S/cm at Dhamra, Mahanadi, Devi and Budhabalanga mangrove sediments respectively (Figure 3).

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Salinity

The salinity varied a lot among all the sites. In Bhitarakanika, it ranged from 0.86 \pm 0.067 PSU to 4.63 \pm 0.16 PSU. It was maximum i.e., 3.73 ± 0.198 PSU and minimum i.e., 0.75 ± 0.084 PSU at Dhamra. In the sediments of Mahanadi delta, salinity varied from 0.78 ± 0.087 to 3.18 \pm 0.13 PSU whereas in mangrove sediments of Devi and Budhabalnga estuary, it was between 1.15 ± 0.12 PSU to 3.84 ± 0.21 PSU and 0.39 \pm 0.05 PSU to 0.67 \pm 0.072 PSU respectively. It was highest in Bhitarakanika and lowest at Budhabalnga (Figure 4).

Organic Carbon (OC)

The sediment organic carbon in different sampling sites varied greatly. It was between 51.86 \pm 0.11 to 36.42 \pm 0.14 mg/g; 13.88 \pm 0.05 to 24.68 \pm 0.21 mg/g; 14.1 \pm 0.09 mg/g to 44 \pm 0.14 mg/g; 10.98 \pm 0.055 to 48.48 \pm 0.05 mg/g and 6.7 \pm 0.12 to 21.3 \pm 0.24 mg/g in mangal sediments of Bhitarakanika, Dhamra, Mahanadi, Devi and Budhabalanga respectively (Figure 5).

Alkalinity

In mangrove sediments, the alkalinity varied a lot. In Bhitarakanika it varied from 4.7 \pm 0.18 to 7.64 \pm 0.16, whereas in other sites such as Dhamra, Mahanadi, Devi and Budhabalanga it varied from 6.78 ± 0.13 to 7.85 \pm 0.11; 5.85 \pm 0.12 to 7.74 \pm 0.12; 4.7 \pm 0.18 to 7.64 \pm 0.16; 7.75 \pm 0.09 to 8.75 ± 0.25 respectively. The Budhabalanga sediments are more alkaline than other mangrove sediments (Figure 6).

Total Phosphorus (TP)

sediments. It was minimum i.e., 58.94 ± 0.63 mg/ml at BKS-3 whereas least 42.52 ± 1.13 mg/ml at BKS-4 was observed in Bhitarakanika. In Dhamra, it was 18.9 ± 0.652 to 44.88 ± 0.91 mg/ml at DHS-1 and DHS-5. Total phosphorus content was from 22.12 ± 0.78 to 32.96 ± 1.98 mg/ ml in MHS-2 and MHS-5; 14.23 ± 0.61 to 25.5 ± 1.11 mg/ml at DVS-1 and DVS-5 and 6.68 \pm 1.56 to 14.34 \pm 1.57 mg/ml at BDS-5 and BDS-4 (Figure 7).

TP was found to be maximum at Budhabalanga mangrove

In sediment analysis, six parameters such as pH, conductivity, and salinity, OC (Organic carbon), Alkalinity and TP (Total Phosphorus) were studied. A significant variation was observed between all the data's between the groups and within the groups by ANOVA tests. From the F-test, all the parameters were found to have significant differences (p<0.05) among each other in all the five sampling sites. The F-values were 8.781, 36.586, 3.327, 6.986, 6.296, 1.264 for pH, conductivity, salinity, OC, alkalinity and TP respectively where p<0.05 (Table 1). While studying the correlation study between all the parameters taken in the present study in Bhitarakanika, pH was positively related to conductivity (r=0.336), salinity (r=0.970, p<0.01), alkalinity (r=0.653, p<0.01) and conductivity (r=0.447, p<0.05) whereas negatively related to OC and TP. Conductivity was positively correlated with maximum parameters studied while a positive significant correlation was observed with salinity (r=0.447, p<0.05) and alkalinity (r=0.588, p<0.01). Salinity







was found to possess negative relation with maximum parameters studied (Table 2). The statistical analysis for correlation study between all the physico-chemical parameters of Dhamra indicates that pH has positive relation with most of the parameters while significantly related

to salinity (r=0.772, p<0.01) (Table 3). The results for correlation analysis among all the physico-chemical parameters of Mahanadi mangrove sediments, showed that pH has positive significant relation (p<0.05) with conductivity and alkalinity (r=0.479, 0.454) whereas positively

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		SS	Df	MS	F	
рН	Between Groups	18.413	4	4.603	0.704*	
	Within Groups	10.484	20	0.524	0.701	
Conductivity	Between Groups	27777235	4	694308.660	26 596*	
Conductivity	Within Groups	379550.4	20	18977.520	30.300	
Colinity	Between Groups	15.116	4	3.779	2 207*	
Saimity	Within Groups	22.714	20	1.136	3.327	
00	Between Groups	2508.388	4	627.097	0.000*	
00	Within Groups	1795.171	20	89.759	0.900	
Alkalinitu	Between Groups	18.597	4	4.649	6 206*	
Alkalinity	Within Groups	14.768	20	0.738	0.290	
ТР	Between Groups	522.334	4	130.584	1.064*	
	Within Groups	2065.702	20	103.285	1.204	

*Significant at 5% level (p<0.05); Foot Notes: SS: Sum of the Squares; df: Degrees of Freedom; MS: Mean Sum of the Squares; F: Variance Factor; OC: Organic Carbon; TP: Total Phosphorus

Table 1: Analysis of Variance (ANOVA) between the physico-chemical parameters and microbial diversity (actinobacterial and fungal) recorded in mangrove sampling sites of Odisha.

	рН	Conductivity	Salinity	OC	Alkalinity	ТР
рН	1	-	-	-	-	-
Conductivity	0.336	1	-	-	-	-
Salinity	0.970**	0.447*	1	-	-	-
OC	-0.059	0.048	0.011	1	-	-
Alkalinity	0.653**	0.588**	-0.718**	0.221	1	-
TP	-0.355	0.043	-0.425*	0.747**	-0.121	1

*Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed)

Table 2: Correlation coefficient between physico-chemical parameters in sampling sites of Bhitarakanika.

	рН	Conductivity	Salinity	ос	Alkalinity	ТР
рН	1	-	-	-	-	-
Conductivity	0.267	1	-	-	-	-
Salinity	0.772**	0.329	1	-	-	-
OC	0.266	0.445*	-0.358	1	-	-
Alkalinity	0.112	0.816**	-0.567**	0.578**	1	-
ТР	0.154	0.119	-0.303	-0.037	0.474*	1

*Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed)

Table 3: Correlation coefficient between physico-chemical parameters in sampling sites of Dhamra.

related to all the parameters studied. OC has negative correlation with alkalinity and TP (Table 4). While studying the correlation in Devi mangrove sediments, pH was positively significantly related to most of the parameters such as conductivity (r=0.482, p<0.05), OC (r=0.774, p<0.01) and alkalinity (r=0.670, p<0.01). Conductivity was negatively related to maximum parameters studied (Table 5). In Budhabalanga mangrove sediments, pH has negative relation with alkalinity and TP (r=-0.128, -0.387) whereas positively related to all. Conductivity has positive relation with all parameters except OC and TP (r=-0.042, -0.535). Salinity has negative relation with OC whereas positive relation was found with other parameters studied (Table 6).

Discussion

Different physico-chemical parameters were investigated such as pH, conductivity, salinity, OC, alkalinity and TP of the sediments. Soil texture of the different locations of the mangroves of Odisha was also studied. Analysis of Variance (ANOVA) worked out for different physico-chemical parameters are given in Table 1. Results of correlation coefficient for different parameters recorded at five different sites are given in Tables 2-6. Sediment composition studies have indicated the predominance of clay as the major component followed by sand and silt in all the stations.

pH is controlled by both biogenic and abiogenic reactions. In the present study, the sediment was acidic or near neutral or slightly alkaline in all the stations. The acidic pH may have resulted from Humic Acid (HA) formed from decaying organic matter (leaves), which is consistent with the report of the Niger Delta swamp environment [14] where observed pH values in the acidic domain were attributed to

the presence of humic acid. In the present study, among the five sites studied, pH of Budhabalanga was maximum (8.45 ± 0.09) is alkaline in comparison to Devi having minimum (5.79 ± 0.14) is acidic in nature which is consistent with the range (4.5 to 9) specified by Costerton et al. [15] for microbial activity to take place whereas in contrast more uptake of CO₂ by the photosynthetic organisms could have increased the pH level. Similar range of pH has also been reported by earlier workers [16-18]. A significant correlation obtained between for pH with salinity, alkalinity and conductivity (Tables 2-6) has revealed the influence of salinity over pH. Alkalinity was more i.e., 8.17 ± 0.156 at Budhabalanga and less i.e., 5.95 ± 0.21 at Devi, which indicates that alkalinity is directly related to pH. Alkalinity changes in salinity might affect microorganisms in two different ways. They adapt to the changed salinity or they are replaced by microorganisms that are adapted to the changed conditions [19]. The salinity is the chloride content of sediments, which are known to be controlled largely by the frequency and duration of tidal submersion, subaerial evaporation and leaching. The salinity was maximum i.e., 4.63 ± 0.16 PSU and minimum i.e., 0.39 ± 0.05 PSU at Bhitarakanika and Budhabalnaga respectively (Figure 3). The characteristics of sediments further revealed that the chloride conc. of sediment depends on the salinity of overlying water. Similar observations were made by Sanders et al. [20], Reddy [21]. The conductivity is directly related to salinity, i.e., where the salt conc. is more, the conductivity will be more. Organic carbon represents the organic matter in the sediments and this is of potential significance for mangrove productivity. In the present study, maximum conc. of OC i.e., 51.86 ± 0.11 mg/g was recorded at Bhitarakanika whereas minimum amount i.e., 6.7 ± 0.12 mg/g was recorded at Budhabalanga sediments of Odisha. The wide range of fluctuations was attributed to

	рН	Conductivity	Salinity	OC	Alkalinity	TP
рН	1	-	-	-	-	-
Conductivity	0.479*	1	-	-	-	-
Salinity	0.575**	0.075	1	-	-	-
oc	0.304	0.396	0.220	1	-	-
Alkalinity	0.454*	-0.310	-0.520**	-0.295	1	-
ТР	-0.268	-0.284	0.167	-0.582**	0.593**	1

*Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed)

Table 4: Correlation coefficient between physico-chemical parameters in sampling sites of Mahanadi.

	рН	Conductivity	Salinity	OC	Alkalinity	TP
рН	1	-	-	-	-	-
Conductivity	0.482*	1	-	-	-	-
Salinity	0.180	0.465*	1	-	-	-
OC	0.774**	-0.583**	0.140	1	-	-
Alkalinity	0.670**	-0.566**	0.089	0.232	1	-
TP	0.132	0.584**	-0.745**	0.171	-0.439*	1

*Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed)

 Table 5: Correlation coefficient between physico-chemical parameters in sampling sites of Devi.

	рН	Conductivity	Salinity	OC	Alkalinity	ТР
рН	1	-	-	-	-	-
Conductivity	0.222	1	-	-	-	-
Salinity	0.380	0.384	1	-	-	-
OC	0.342	-0.042	-0.715**	1	-	-
Alkalinity	-0.128	0.628**	0.646**	-0.385	1	-
ТР	-0.387	-0.535**	0.297	-0.224	0.221	1

*Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed)

Table 6: Correlation coefficient between physico-chemical parameters in sampling sites of Budhabalanga.

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S. No.	рН	Alkalinity	Salinity	Organic carbon	Inorganic Phosphorus	Sediment texture
Bhitarakanika	7.26 ± 0.03	6.07 ± 0.18	2.81 ± 0.10	4.36 ± 0.15	33.36 ± 1.99	Mostly clayey loam
Dhamra	6.9 ± 0.12	7.43 ± 0.10	2.01 ± 0.14	1.73 ± 0.09	27.2 ± 1.104	Mostly Silty clay
Mahanadi	7.5 ± 0.06	6.73 ± 0.11	2.35 ± 0.11	2.64 ± 0.11	25.38 ± 1.28	Silty clay and sandy clay
Devi	5.79 ± 0.14	5.95 ± 0.21	2.41 ± 0.17	1.97 ± 0.14	17.53 ± 0.84	Clayey
Budhabalanga	8.45 ± 0.09	8.17 ± 0.16	0.55 ± 0.05	2.22 ± 0.18	27.61 ± 0.86	Sandy clay

Table 7: Variation of some physicochemical parameters (mean ± S.E.) at different stations in mangrove sediment of Odisha.

the variation of temp. In the sediment, nature of vegetation, rate of accumulation of dead and decayed foliage's, topography, soil texture and depth of water. Similar observation was made by Kumar [22,23] in mangrove biotope of Cochin estuary [24]. Phosphorus is efficiently adsorbed by the fine sediments of muddy areas rather than the coarse grained sediments. This is probably the reason for mangroves growing luxuriantly in muddy environments. Whatever Phosphorus may be present gets bound with calcium, and is effectively held within the sediments [25]. Many organisms utilize both organic and inorganic forms of Phosphorus; however inorganic phosphorus seems to be more appreciated by plants than organic phosphorus [26]. There is a little detectable mobilization rate of TP from the mangrove sediment to the overlaying water through the mineralization process by microbial activity or due to degradation of organic matter [27-29]. Higher conc. of phosphate i.e., 50.7 \pm 0.05 mg/L was noticed and it was less 10.62 \pm 0.61 mg/ml at Budhabalanga (Table 7) [30].

Conclusion

Conclusively, in this study the sediment physico-chemical parameters such as pH, conductivity, Organic Carbon content, salinity, alkalinity and total Phosphorus content from the mangrove sediments of Odisha were assessed. Out of the five mangrove study areas of Odisha, the mangrove sediments of Bhitarakanika is highly nutrient rich ecosystem due to the amount of organic carbon content whereas the Budhabalanga sediments has less organic carbon content. The sediments of Bhitarakanika were having slightly neutral pH which indicates that the better growth and survival of highly diverse organisms. However, free exchange of mangrove water (along with nutrient) with the adjacent coastal area must be related to the hydrodynamic nature of the mangrove-fringed tidal channel. Such characteristics, export eutrophic and nutrient rich mangrove water seaward, thus enhances coastal productivity. The present study will highlight on the physicochemical constituents of sediments from mangrove environment which will highlight on the nutrient recycling in this particular area and the present baseline information in sediments would form a useful tool for further ecological assessment and monitoring of the coastal ecosystems of Odisha.

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