Seasonal Variation of Textural Analysis with Organic Carbon of Sediment from Estuarine Ecosystems of South Odisha Coast, India

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Abstract
This study deals with the monthly distribution and seasonal variation of textural analysis with organic carbon of sediment from two transects like Rushikulya and Bahuda estuary of south Odisha coast during Feb' 2022 to Jan'2023. The textural analyses of air and oven dried sediment samples were made by dry sieving. The organic carbon of sediment performed the standard method of estimation. As a result of which high organic carbon values (6.89 mgC g^{-1}) were obtained at upstream stations of pre-monsoon, post monsoon and monsoon seasons for higher plankton production. The sediments of estuarine region have relatively higher levels of organic carbon found mouth of the estuary than the riverine region. During monsoon the sediment was mainly clayey sandy and in the post monsoon and pre monsoon, it was found to be sandy except in the mouth of the estuary. These studies possess important tool in interpreting the value of organic carbon and assessing the textural regeneration of estuarine sediment.

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Keywords: Coast, ecosystem, estuarine, Organic Carbon, sediment

1. Introduction

The texture of the sediments of estuary is an important attribute to substratum ecosystem. Estuaries are generally contributed effectively to the coastal zone's organic carbon budget (Liu *et al.*, 2020) [14] and function of sources of the grains, distance, medium of transportation with environmental conditions at the site of deposition. Texture is a basic characteristic of the sediments directly attributable to the depositional conditions which are dominated by forces acting on the sediment prior to their deposition. After deposition, the texture of sediment is dependent on different factors like bottom relief, shoreline configuration, currents, waves, tides and sea level fluctuations (Nichols, 2009; Dey *et al.*,2012) [19, 6]. Grain size distribution has been widely used for evaluation of environmental conditions of the depositional area. The major textural characteristics of sediments include their distribution and the concentration of organic carbon, which play an important role in determining the properties of both the sediment and the overlying water column. Some reports are available on the geochemical aspects of coastal shelf sediments along the Bay of Bengal (Zhao *et al.*, 2023) [26]. Increased human activities in coastal ecosystems has become rapid turnover of nutritional elements taken place between sediments and overlying water column of estuaries (Naik *et al.*,2023) [18]. The three most important basic elements favouring the aquatic productivity are carbon, nitrogen, phosphorus etc. Information pertaining to texture of sediments and concentration of organic carbon from the Rushikulya and Bahuda estuary of south Odisha coast adjoining the Bay of Bengal are very scanty. Further, the study of the textural analysis was also undertaken in order to understand the sediment with respect to organic carbon would predict the environmental effects of increased sediment load in both the estuarine ecosystems.

2. Materials and Methods

2.1. Study area description

The Peninsular region of India was endowed with an extensive tropical coastline of more than 6500 kms. of which Odisha coastline comprises of about 480 kms. covering an area of about 5133.71 km^2 Ganjam, the south Odisha coast includes a coastline of about 60 kms. forming 12.5% of the state. In present area under study the source of materials of sand derives mainly from the rocks of Eastern Ghats (Naik *et al*.,2023) [18]. In this region Rushikulya and Bahuda rivers originate from Rushi Mala and Kerandimala mountains of eastern ghats respectively. Two distinct transects were selected, one at the Rushikulya estuary (Transect-1) and Bahuda estuary (Transect-2) each with two stations, total four stations were chosen for study (Fig.1).

Rushikulya Estuary (Transect-1)

Rushikulya river flow through the Ganjam district in Odisha meet the Bay of Bengal at Ganjam district thus forming a typical tropical estuary. It is situated between 19^0 22' – 19^0 24' N longitude and 85^0 02' – 85^0 05' E latitude which is connected with the southern sector of the Chilika lake by Palur canal. The Rushikulya river is recipient of a variety and varying amounts of effluents discharging from a chloro-alkali industry and also from nearby small-scale industries thereby attracting environmental research (Das and Sahu,2002) [5]. This estuary is highly productive and forms a nursery ground for a variety of flora and fauna. The fishery activity of the estuary is influenced by domestic sewage in addition to industrial effluents (Mohanty *et al*.,2023) [16]. The seawater penetration occurs up to a distance of about 5 kms upstream from the mouth. Two stations selected each at this transects of the estuary are described as below:

Station I: This station was situated near to the bend of the estuary towards north direction of Bay of Bengal, which is about 2 kms away from the bar mouth. The depth of the water column was between 1.6 to 2.5 m during pre-monsoon.

Station II: It was situated close to the estuarine bar mouth, which was characterized by extensive sand deposition, with the mouth having an approximate width of 200–300 m. In between the two stations the Palur canal joins to the estuary with the southern sector of Chilika Lake. The depth of the station was at 2 to 3 m during post monsoon.

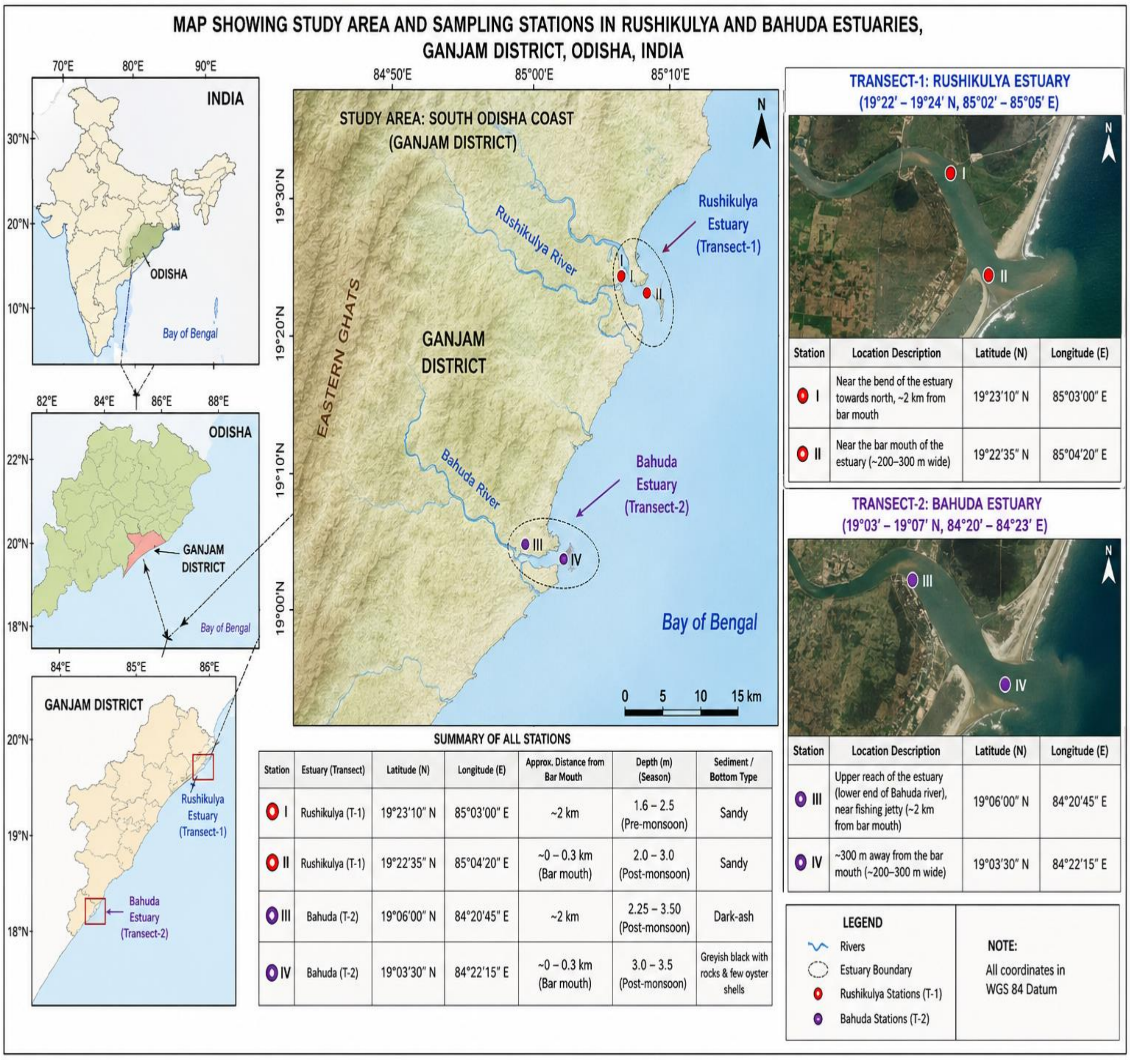

Fig 1: Map showing 4 different sampling stations of South Odisha coast

Bahuda Estuary (Transect-2)

The estuary is situated near Sonepur in the southern region of Ganjam district, Odisha, along the eastern coast of India, extending approximately between 19°03′–19°07′ N latitude and 84°20′–84°23′ E longitude. The southern direction from river discharges the freshwater into this estuary which is enduring one. The major pollutants in this station are coconut husk retting waste materials producing H_2S, fish waste, municipal sewage, agricultural seepage with fertilizer residue etc. (Guha *et al.*,2024) [8]. The estuary was shallow and remains well mixed for the most part of the year. Now a days the disposals of aquaculture are also responsible for polluting the estuarine environment. Stations III and IV were selected in the estuary, the detailed description was as follows.

Station III: It was fixed at the upper reach of the estuary which was lower end of the Bahuda river. During the post-monsoon season, the depth of the water column was observed to range from 2.25 to 3.50 m and the colour of the bottom soil was dark-ash type. The distance of the station from bar mouth was around 2 kms which was located near the fishing jetty.

Station IV: The location of this station was about 300 mts away from the bar mouth of the estuary. The estuarine bar mouth measured approximately 200–300 m in width, while the water column depth during the post-monsoon season ranged between 3.0 and 3.5 m.

The water was high turbidity all seasons due to the churning process by wave actions and the colour of the sediment was greyish black with rocks found with few oyster shells attached to it.

2.2. Analytical Parameters

a) Glassware, Chemicals and Sampling

All the glass wares used in the present experiment were cleaned by soaking in 1:1 HNO_3 and $KMnO_4$ for 24 hours and washed with copious amounts of deionized water. All chemicals used with analytical reagent grade and deionized water was used for organic carbon.

b) Methods of sampling

Generally, the months are classified with different seasons, which are pre monsoon (February-May), monsoon (June-September) and post monsoon (October-January) respectively. Sediment samples were collected monthly from all selected stations across three seasons covering the period from February' 2022 to January' 2023.

c) Sampling of Sediment

The bottom sediment samples in duplicate from each station were collected by help of a Van Veen grab sampler. The grab was hauled up once it penetrates the bottom, then the sediment sample was collected at random from inside the grab and stored in polyethylene bags as suggested by Panda and Mishra (2023) [20].

d) Preservation of Sediment

After collection of the sediment sample from different stations for organic carbon analysis were preserved with oven dried at 90°C to constant weight and grounded with agate and mortar to pass through a 100 µm screen (Hedges *et al.*, 2003) [9]. The finer sediment particles were kept with air tight plastic bottles in a desiccator for digestion and analysis.

2.2.1. Texture

The textural analyses of air and oven dried sediment samples were made by dry sieving from each station were subjected to mechanical sieving using a Ro-Tap shaker for 15 minutes and separated into different particle-size fractions, including 2 mm (stones and gravel), 0.5 mm (coarse sand), 0.25 mm (medium sand), 0.625 mm (fine sand), and 0.031 mm (coarse silt), following the standard procedure recommended by ASTM (2007)[1]. The final tray was used for the collection of medium fine silt and clay. The different fractions of sediments retained in different trays were weighed and expressed in percentage basis.

2.2.2. Organic Carbon (OC)

One gram of sediment sample involves the analysis of organic carbon of the composite sediment samples using weight digestion (chromic acid) and the analysis was completed by back-titrating the sample with ferrous ammonium sulphate solution using 1,10-phenanthroline as the indicator, and the resulting values were expressed as mg C g^{-1} of sediment following the method described by Heggem (2000) [10].

3. Results and Discussion

3.1. Textural Composition of The Sediment

The monthly percentage data on textural composition and Organic Carbon of sediment of Rushikulya and Bahuda estuary at stations I, II and III, IV represented at Table 1 and Table 2 during 2022-2023.The percentage of sand ranged between 7.29- 49.60 % on Feb'22 and Oct'23, clay from 21.30-58.40 % on month of Aug.'22 and Dec.'22 and silt from 8.58- 36.21 % on Jul'22 and Feb'23 at station I. The textural composition at station II was of similar magnitude as it was for station I with a little alteration. Though clay material dominated throughout the year, other fractions showed well marked fluctuations. In Bahuda estuary the sediment textural composition at station III sand varied between 8.38 - 47.54 % on the month of Aug'22 to Jan'23 dominating the textural characteristics may be the fresh water inflow during monsoon season. During the pre-monsoon season, the highest proportions of clay and silt were recorded at 63.30% and 29.50%, respectively, whereas at station IV, the sand content varied considerably, ranging from a maximum of 45.40% in July 2022 to a minimum of 12.15% in January 2023.The percentage of clay varied between 19.10 to 58.10 % on Oct'22 and Dec'22 and silt ranges from 16.76 - 37.00 % on Jun'22 to Oct'22 respectively. The order of clay content was recorded high during pre-monsoon >post monsoon>monsoon. The elevated values recorded during the post-monsoon season may be attributed to increased settling of fine sediment fractions under higher salinity conditions, where the neutralization of clay and

Table 1: Monthly percentage data with seasonal mean on Textural composition and Organic Carbon of sediment of Rushikulya estuary at stations I and II during 2022-2023

Month/ Season	Station I					Station II				
	Sand (%)	Clay (%)	Silt (%)	Texture	Organic Carbon	Sand (%)	Clay (%)	Silt (%)	Texture	Organic Carbon
Mar2022	16.50	57.80	25.70	Clay-silt	4.29	15.30	56.60	28.10	Clay-silt	3.82
Apr.	21.40	46.60	32.00	Clay-silt	5.44	22.10	38.40	39.50	Silt-clay	5.08
May.	14.50	52.70	32.80	Clay-silt	4.48	10.20	49.30	40.50	Clay-silt	4.26
June	18.30	55.80	25.90	Clay-silt	6.26	20.80	51.20	28.00	Clay-silt	5.56
Premonsoon (Mean)	17.67	53.22	29.01	Clay-silt	5.11	17.10	48.87	34.02	Clay-silt	4.70
Jul.	46.20	45.22	8.58	Sand-Clay	2.72	40.16	42.11	17.73	Clay-sand	2.04
Aug.	46.40	21.30	32.30	Sand -silt	2.36	41.40	38.40	20.20	Sand- clay	1.64
Sep.	32.60	36.10	31.30	Clay-sand	2.09	28.60	44.20	27.20	Clay-sand	1.34
Oct.	49.60	33.20	17.20	Sand-clay	3.17	48.30	36.30	15.40	Sand- clay	1.95
Monsoon (Mean)	43.70	33.97	22.34	Sand-clay	2.58	39.61	40.25	20.14	Clay-sand	1.74
Nov.	26.30	54.50	19.20	Clay-sand	3.56	17.50	52.50	30.00	Clay- silt	2.16
Dec.	17.60	58.60	23.80	Clay-silt	3.86	20.50	57.50	22.00	Clay-silt	2.42
Jan2023	16.60	57.30	26.09	Clay-silt	3.15	18.30	54.30	27.40	Clay-silt	2.55
Feb.	7.39	56.40	36.21	Clay-silt	2.67	14.40	51.70	33.90	Clay-silt	1.80
Postmonsoon(Mean)	16.97	56.70	26.32	Clay-silt	3.31	14.07	54.00	28.32	Clay-silt	2.23

Colloidal particles promote their aggregation into larger particles that settle more rapidly than individual charged particles (Rajasegar *et al.*, 2002) [21]. The present study shows that the stations II and IV are located at the northern most part of the respective estuary which are at the mouth of the estuary. Station I was located in the vicinity of a chlor-alkali factory nearby the estuarine head point, while station III also estuarine in nature. At these stations the major constituent fraction in the sediment was either clay-silt or clay-sand. The contention is well agreed with the earlier observation by (Ramaswamy,2008) [22]. These data indicate that the percentage of sand was relatively higher at stations I and II in Rushikulya and was lowered in Bahuda estuary at stations III and IV for all the seasons studied. This also indicates the impact of river on the estuarine stations where the sediments were relatively fine (Syvitski *et al.*, 2012) [25]. In contrast, stations I and II were characterized by relatively coarse sediments, whereas the low-energy conditions prevailing in the estuary promoted the deposition and accumulation of finer sediment particles at stations III and IV, which is consistent with the observations reported by Leithold *et al.* (2006) [13].

3.2. Organic Carbon (OC)

The OC of Rushikulya estuary fluctuated month from September to June'22 was from 2.09 to 6.26 mgC g^{-1} and from 1.34 to 5.56 mgC g^{-1} in stations I and II with seasonal average values varied from 2.58 to 5.11 mgC g^{-1}. The OC exhibited wide variations in four stations and it was found minimum 1.34 mgC g^{-1}at station II and maximum 6.89 mgC g^{-1} at station III during monsoon and pre monsoon season found higher OC in clay than in sand particles (Lalonde *et al.*,2012) [12]. The sediment OC values of Bahuda estuary at stations III and IV ranged from 2.12 to 6.89 mgC g^{-1} and from 1.45 to 5.79 mgC g^{-1} during monsoon and pre monsoon season with mean values from 1.91 to 5.78 mgC g^{-1}. The sediment OC values of Rushikulya estuary at both stations I and II, ranged from 3.82 to 6.26 mgC g^{-1},1.34 to 3.17 mgC $g^{-1}$and 1.80 to 3.86 mgC g^{-1}, while in Bahuda estuary at stations III and IV ranged from 3.92 to 6.84 mgC g^{-1},1.45 to 3.35 mgC g^{-1} and 2.07 to 4.25 mgC g^{-1} during pre-monsoon, monsoon and post monsoon season respectively. High OC values obtained during pre-monsoon period most probably that the estuary is subjected to a wide range of hydrographic conditions with large freshwater runoff during monsoon season generally months from July to October (Bianchi, 2011) [3]. During pre-monsoon showed high organic carbon value at stations I and III, while lower organic carbon values were observed at stations II and IV. Occasionally the high content in OC during post-monsoon and monsoon seasons in the region coincided with higher plant production (Naidu *et al.*, 2024) [17]. Seasonal variations in primary production, with higher values during the pre-monsoon period and lower values during the monsoon, influence the organic matter content of estuarine sediments through the input of terrestrial plant and animal debris carried by runoff and materials originating from adjacent ecosystems (Słowik, 2022) [24]. Associated with the freshwater runoff, the silt in colloidal suspension containing large quantities of soil humic substances, precipitate and settle in this region (Rui *et al.*, 2023)[23]. Relatively lower organic carbon (OC) concentrations were recorded at stations II and IV throughout all seasons, which may be attributed to the predominantly sandy nature of the sediments at these locations. The high value was noticed at the other stations especially at station III, where the sediment was clay dominated. This may be due to heavy rain followed by fresh water runoff and complete devastation of upper layer of bottom sediments and deposition of sand particles (Blair and Aller, 2012) [4]. In the present study, maximum OC value recorded was 6.89 mgC g^{-1} at station III during pre-monsoon season. The size of the sediment is one of the major factors affecting OC concentrations (Mayer, 2004) [15]. It was reported that the smallest sediment size fraction had more organic carbon than the largest size (Keil *et al*., 2004) [11] also pointed out that very fine sand had highest concentration of OC among different sediments. The accumulation and seasonal variation of organic matter in coastal sediments are further influenced by environmental conditions such as temperature, salinity, hydrodynamic activity, and anthropogenic disturbances, which collectively regulate the preservation and

Table 2: Monthly percentage data on Textural composition and Organic Carbon of sediment of Bahuda estuary at stations III and IV during 2022-2023

Month/ Season	Station III					Station IV				
	Sand (%)	Clay (%)	Silt (%)	Texture	Organic Carbon	Sand (%)	Clay (%)	Silt (%)	Texture	Organic Carbon
Mar. 2022	10.30	63.30	26.40	Clay-silt	4.69	20.60	55.30	24.10	Clay-silt	3.92
Apr.	18.60	51.90	29.50	Clay-silt	5.88	24.50	49.50	26.00	Clay-silt	5.07
May.	22.50	53.60	23.90	Clay-silt	5.66	28.60	51.50	19.90	Clay-sand	4.87
Jun.	19.70	56.30	14.00	Clay-silt	6.89	26.34	56.90	16.76	Clay-sand	5.79
Pre monsoon (Mean)	17.77	56.27	23.45	Clay-silt	5.78	25.01	53.30	21.69	Clay-sand	4.91
Jul.	44.70	40.70	14.60	Sand-clay	2.76	45.40	37.70	16.90	Sand- clay	2.27
Aug.	47.54	32.18	20.28	Sand- silt	2.42	42.30	32.60	25.10	Sand- clay	1.92
Sep.	36.30	36.10	27.60	Clay-sand	2.12	30.70	48.20	21.00	Clay-sand	1.45
Oct.	44.10	27.40	28.50	Sand- silt	3.35	43.80	19.10	37.00	Sand - silt	2.02
Monsoon (Mean)	43.16	34.09	22.74	Sand-Clay	2.69	40.55	34.40	25.00	Sand-Clay	1.91
Nov.	21.50	58.60	19.90	Clay-sand	3.80	28.50	51.60	19.90	Clay-sand	2.72
Dec.	12.60	62.40	25.00	Clay-silt	4.25	14.10	58.10	27.80	Clay-silt	3.26
Jan.2023	8.38	62.53	29.09	Clay-silt	3.79	12.15	51.35	36.50	Clay-silt	3.19
Feb.	17.00	55.00	28.00	Clay-silt	3.25	17.30	52.20	30.50	Clay-silt	2.07
Postmonsoon (Mean)	14.87	59.63	25.49	Clay-silt	3.75	18.01	53.31	37.80	Clay-silt	2.81

mineralization of organic matter in coastal sediments (Gerhard and Reinthaler, 2013) [7]. During monsoon season, the sediment was mainly composed of sand brought out by incessant flow of waters (Angusamy and Rajamanickam,2006) [2]. The organic carbon distribution has an effect on the mode of sediment transportation which are related to depositional setting may control the organic carbon content of an estuarine region.

4. Conclusion

These strategic location of Rushikulya and Bahuda estuary along Bay of Bengal, exhibits some exclusive features during southwest monsoon seasons, where heavy wind causes the estuarine waters choppy and turbid. When water enters it brings lot of dissolved and particulate matters like silt and sediment, which highly influences the water quality of the study area. In addition, during monsoon the silt derived from land run-off and resuspension of bottom sediment in the study regions together contributes to enrichment of nutrients and organic carbon. During substratum ecological investigation the textural study showed the impact of river on the estuarine stations (II and IV) suggesting that the sediments were clay–silt or silt–clay attesting relatively fine may probably be due to the prevailing low energy condition in the estuarine ecosystem that favored accumulation of fine sediments. The upstream sediments of stations I and III were found to be relatively coarser than the estuarine one’s. Stations comprising of sediments of clay–silt or silt–clay found organic carbon content high and low content was observed at the stations where the sediment was without clay composition. It was postulated the possibility of greater accumulation of organic carbon in clay sediments represents important tools for determining the exact status of environmental pollution of a water column.

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