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IMPACT OF RAINFALL ON SPATIO-TEMPORAL DISTRIBUTION OF SEDIMENT ORGANIC MATTER ALONG THE CHITTAGONG COAST, BANGLADESH

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ABSTRACT

Sediment organic matter regulates the coastal biogeochemical cycle which is influenced by rainfall pattern and has potential relationship with organic carbon as well as mud characteristics. The objective of present research was to identify the impact of precipitation on the spatio-temporal variation inorganic features of intertidal mudflats. Three locations were selected in freshwater zone; two were in brackish water region and last three locations situated in marine waters from Halda to Salimpur coast. Two sites from each location were designated as the highest high tide level (onshore) and lowest low tide level (offshore) of the intertidal zone during winter (December to February) and monsoon (June to August) spanning between 2013 and 2014. Sediment organic matter and carbon were measured by combustion and Walkey-Black wet oxidation in turn. Average organic matter content in monsoon were found 4.5±0.03, 2.3±0.01 and 2.4 in freshwater, brackish and marine locations whereas 5.2±0.6, 3.9±0.14 and 5.4±0.04% investigated during winter. Precipitation pattern varies from different seasons and locations that have impact on land runoff, freshwater inflow, mixing and circulation. Mud dominated coastal intertidal zones represented high organic matter content than sand dominated coast. Furthermore, depositional pattern, transport, erosion-accretion processes, tidal action, wave characteristics and seasonal inconstancy control the organic matter characteristics in the coastal sediment. This research suggests the necessity of periodic observation of rainfall pattern and organic matter distribution to assess the intertidal deposits which support the stabilization of local geomorphology and biogeochemistry in Chittagong coastal region.

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INTRODUCTION

Sediments play an important role in organic matter degradation and nutrient recycling in aquatic ecosystems (Hopkison et al., 1999). The coastal zone is one of the major upwelling regions of the world ocean and exhibits high rates of primary productivity (Behrenfeld et al., 2005; Davenport et al., 2002), high export fluxes of particulate organic carbon (Schlitzer, 2000) that ultimately deposits in the sediment (Jahnke, 1996). Coastal region of the Bay of Bengal is the most dynamic one due to its wave, tide, current dominated processes and land sea interaction. It traps a significant amount of natural and anthropogenic organic matter that interacts with hydro-geological processes. Sources of organic matter and organic carbon are essential to understand the global biogeochemistry and associated processes. Mineralization of organic matter reduces organic carbon and nutrient concentration of intertidal coastal sediment. Important macro-nutrients are continuously being interchanged between sediment and over-lying water that assists to develop the organic contents (Aboweiand Sikoki, 2005). Sandy soils are poor store house of nutrients containing low organic matter and also accelerate high leaching of applied nutrients. Organic compound in intertidal surficial sediment is originated from terrestrial and oceanic sources (Tesi et al., 2007). The pH value also reduces the mineralization rate that helps to accumulate organic matter in the coastal environment. The intense and highly variable currents also lead to a re-suspension and re-distribution of the shallow shelf sediments and to a net offshore transport of particulate material. Total organic carbon of sediment has a major role in thriving the biological activity (Satheeshkumar and Khan, 2009). The oceanic biological pump sequesters approximately forty percent of the carbon on continental margins (Muller-Karger et al., 2005).

The seafloor is the place of accumulation of solid detrital material of inorganic or organic origin which is virtually covered with unconsolidated sediment. The importance of marine sediment study is obvious when it is realized that most of the rocks exposed at the surface of the earth are sedimentary deposits laid down under the sea. Sediment carbon cycle and circulation is influenced by deposits size classes and distribution pattern. Carbon-di-oxide and dissolved organic matter produce carbon in the water column that deposits in the continental shelf regions. Sedimentary organic matter is the most important indicator of erosion-accretion pattern and geomorphological change. Organic carbon buried in the world's ocean mainly followed in the continental shelf regions which comprises approximately 90% (Hu et al., 2006; Goni et al., 1997; Hedges, 1992; Emerson and Hedges, 1988). Organic particles are transported to the continental rise and open ocean from continental shelf and slope as dissolved and suspended forms (Bauer and Druffel, 1998). Besides, the margins serve as a source of organic matter to the intertidal beach regions and deep ocean. Seasonal variation in precipitation, organic matter characteristics are directly and indirectly influenced by primary productivity. Rainfall pattern is an important criterion for temperature, salinity distribution and water column density structure. Organic matter and other sedimentological particle characteristics are controlled by rainfall, freshwater runoff and heat flux variation. Moreover, organic matter decomposition is primarily influenced by temperature, local sedimentological conditions and moisture characteristics. Sediment organic matter also acts as sponge and holds approximately ninety percent water of its weight. Organic matter has less water holding capacity than clay but helpful to aquatic floral and faunal development. Approximately 20-30% erosion reduction occurs if sediment organic matter increases upto 1 to 3%. In addition, water filtration and sedimentation process are caused by the organic matter distribution (Plaster, 1996; Barber, 1984).

The effects of rainfall pattern and its impact on coastal sedimentological nature are essential for evaluating the coastal biogeochemical processes and its mechanisms. Differences in sediment particle size distribution pattern, also impacts organic matter levels; organic matter breaks down faster in sandy sediments than in fine-textured sediments. Many researchers have done their work on distribution, origin, effecting factors and controlling mechanisms of sediment organic compounds (Khodse and Bhosle, 2013; Omura et al., 2012; Xing et al., 2011; Silva et al., 2011; Burke et al., 1989; Parton et al., 1987). That's why the objective of this research was to observe the impact of rainfall trends on the seasonal and spatial characteristics of organic matter and organic carbon of intertidal sediment of Chittagong coastal belt along the Bay of Bengal.

MATERIALS AND METHODS

Study Area

Eight distinct locations were selected to conduct the research. Three freshwater locations Halda (22°25'59"N, 91°52'20"E), Karnafully (22°25'50"N, 91°53'13"E) and Chaktai (22°19'42"N, 91°51'11"E) were designated due to inland runoff and freshwater inflow. Besides, two brackish water locations Saderghat (22°19'32"N, 91°50'12"E) and 15 No. Ghat (22°14'31"N, 91°49'12"E) were selected having moderately saline zone, intertidal mudflat and marsh communities. Two brackish water locations were in the Karnafully river estuary and selected due to disposal characteristics of sediment along the river bank. Three marine locations Patenga (22°13'49"N, 91°47'40"E), Khejurthalighat (22°21'05"N, 91°45'18"E) and Salimpur (22°24'00"N, 91°44'24"E) were chosen. Patenga sea beach is characterized with more extended sand dominated beach without any prominent vegetation. Khejurthalighat characterized with salt marsh, mangrove plant communities was selected for mixed sediment type beach and long intertidal zone characteristics. In contrast, last location Salimpur was designed on account of extended thick sediment bed, creek networking, mangrove and salt marsh communities (Figure 1).

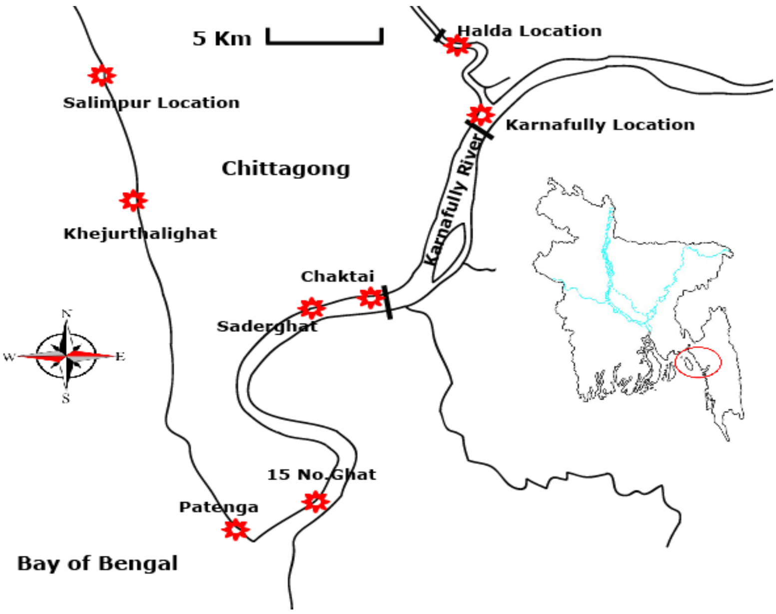

Figure 1. Geographical Locations of Research Area along the Chittagong Coast

Sampling and sample handling

Replication of sample was collected from two sites of each location during low tide of monsoon and winter season. Samples were taken at schedule basis during the new moon phase of hydrological year 2013 to 2014. Sediment corer used to collect sediment sample having the diameter of 10 cm and 20 cm in length. Collected sediment samples were kept into polythene container (500g). Later they were spread on sheet of trays and dried in air at laboratory. Larger aggregates were broke preferably in a wooden mortar and pestle and passed through a 0.5mm sieve. Processed sediment sample were preserved in low temperature (>25°C) in the plastic pack for further analysis.

Laboratory Analysis of Sample

Sediment organic matter was measured by combustion process and other sediment quality parameters also measured by standard methods (APHA, 2005). Organic carbon was determined by Walkey and Black wet oxidation method modified by Huq and Alam (2005). Precipitation data of the respective year along the Chittagong coast was recorded from Patenga station and collected from Bangladesh Meteorological Department.

Statistical Analysis

Data were analyzed by IBM SPSS 22.00 software for statistical analysis, such as seasonal variation, Two Way ANOVA, bivariate analysis; box and whisker plot. Analysis of variance test established relationship among precipitation trends with various seasons and locations; also showed impact of rainfall on sedimentological characteristics. Bivariate analysis demonstrated significant relationship among various sedimentological parameters. Box and whisker plot was used to demonstrate the variation in characteristics of sediment organic matter and organic carbon from mean value.

RESULTS

Spatial variation

Sediment organic matter content of eight intertidal locations was varied from location to location. Organic matter was found to vary from 0.99 to 7.28%. Peak concentration was investigated from Salimpur coast; then the level gradually decreases to 5.93% in Khajurthali. Karnafully and Halda found dominant in sediment organic matter after Salimpur and Khejurthali as 5.9±0.02% and 5.3±0.13% correspondingly. The lowest concentration of organic matter noted from Patenga (0.99%) intertidal sand dominated zone (Figure 2).

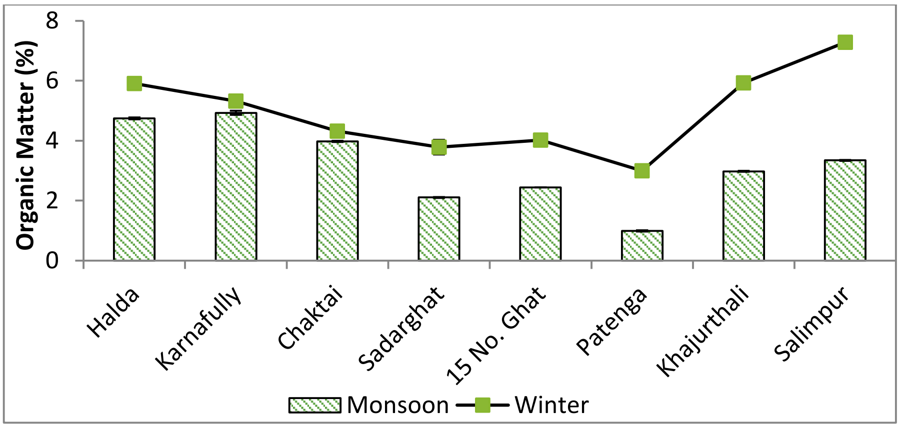

Figure 2. Spatial distribution pattern of sediment organic matter

Sediment organic carbon was closely related with organic matter and rainfall characteristics which fluctuated from 0.6 to 4.35%. The highest concentration was reported from the coastal belt of Salimpur whereas lowest concentration found in Patenga. In addition, organic carbon of other locations was recorded from 1 to 3% (Figure 3).

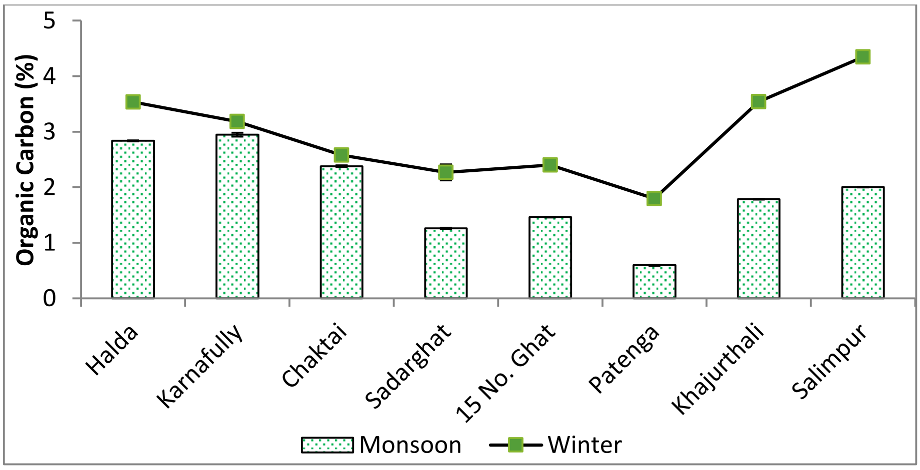

Figure 3. Spatial variation trends of Sediment organic carbon

The regularity in sediment temperature characteristics depends on various hydrogeological features as well as local condition. Range of intertidal surface sediment temperature varied moderately from 20.4 to 31.9°C. Maximum temperature was observed from Patenga coast while minimum at Karnafully location (Figure 4). In contrast, the pH of eight locations fluctuated in a narrow range (6.0 to 6.7). Peak level of pH was investigated from Karnafully to Saderghat location and lowest stated from the Saderghat location (Figure 4).

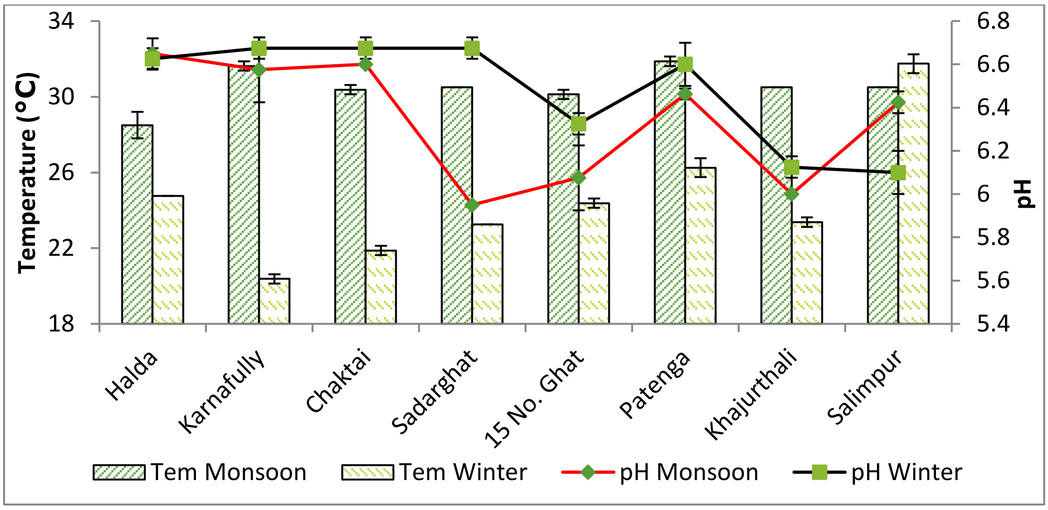

Figure 4. Spatial distribution pattern of Temperature (Tem) and H

Silt and clay percentage in sediment helps to trap detritus and accelerate the mechanisms of organic matter concentration. Mud that is the combination of silt and clay content varied in a wider range from 8.08 to 98.47%. The highest variation in mud content found in Salimpur mudflats whereas lowest noted from Patenga (Figure 5). Increased mud content denoted the aggregated concentration in organic matter along with other sedimentological properties.

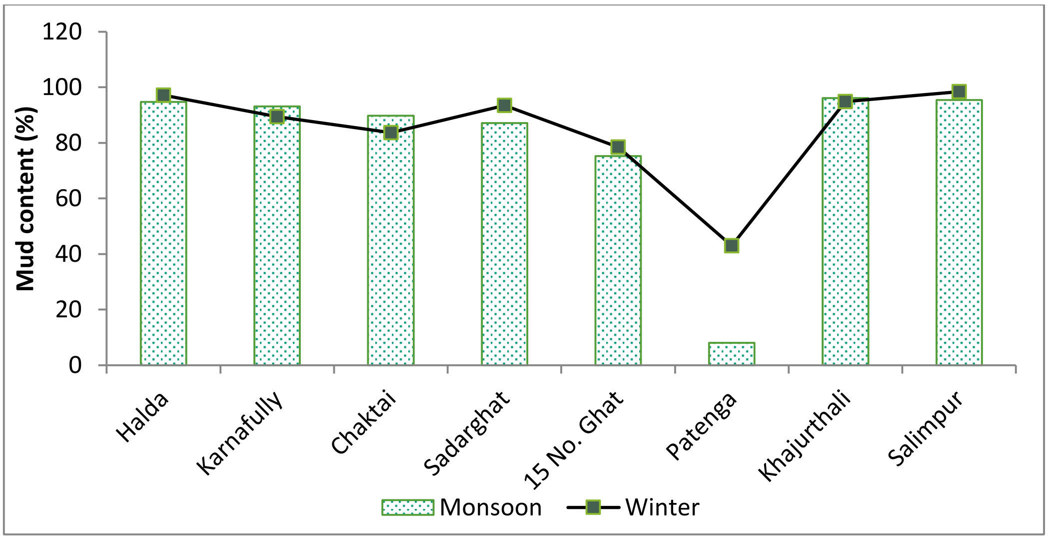

Figure 5. Spatial variation characteristics in mud content (%)

Seasonal variation

The range of organic matter observed from various locations showed anomalous seasonal distribution. During monsoon, the peak concentration in organic matter was recorded as 4.93±0.07% from Karnafully whereas 7.28±0.08% found at Salimpur coast in winter. In contrast, the lowest concentration 0.99±0.22% and 3.0±0.01% were noted from Patenga during monsoon and winter in turn (Figure 6). The concentration reached at its peak during winter and lowered in monsoon. Organic carbon content is closely related with the changing pattern and processes of organic matter. Sediment organic matter of winter season in every location was significantly higher than monsoon. Two Way ANOVA result showed significant variation in sediment organic matter between two seasons at the level of 5%.

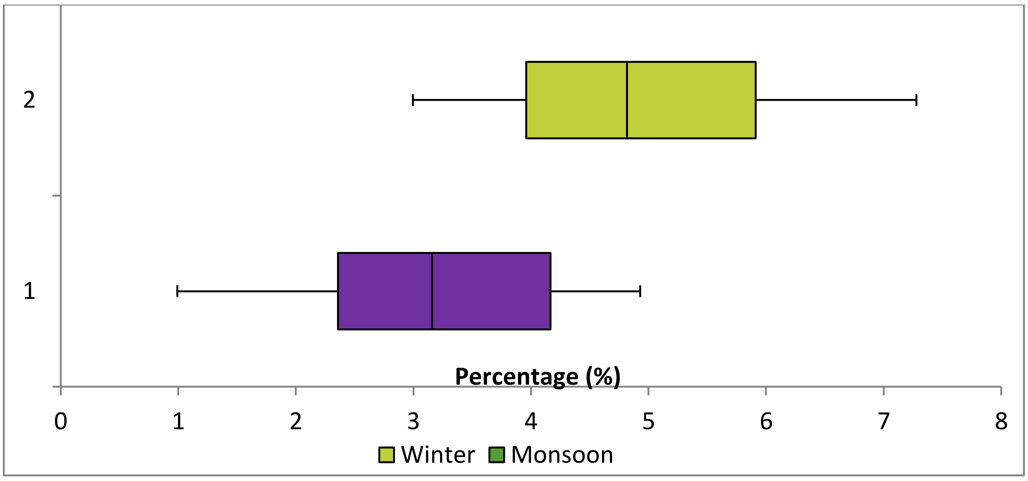

Figure 6. Seasonal distribution pattern of sediment organic matter

Organic carbon (0.6-4.4%) varied from season to season as well as from location to location. Maximum organic carbon was reported 2.94±0.04% at Karnafully in monsoon while 4.35±0.02% was investigated from Salimpur coast during winter. On the other hand, organic carbon decreased as 0.6±0.01% in monsoon and 2.4±0.03% at winter from the Patenga coast (Figure 7). The distribution trends of organic matter also prevailed in organic carbon characteristics. Sediment organic carbon in all locations was significantly correlated with sediment organic matter ($p<0.01$) (Table 1). Significant variation was found ($p<0.05$) in organic carbon concentration between two seasons.

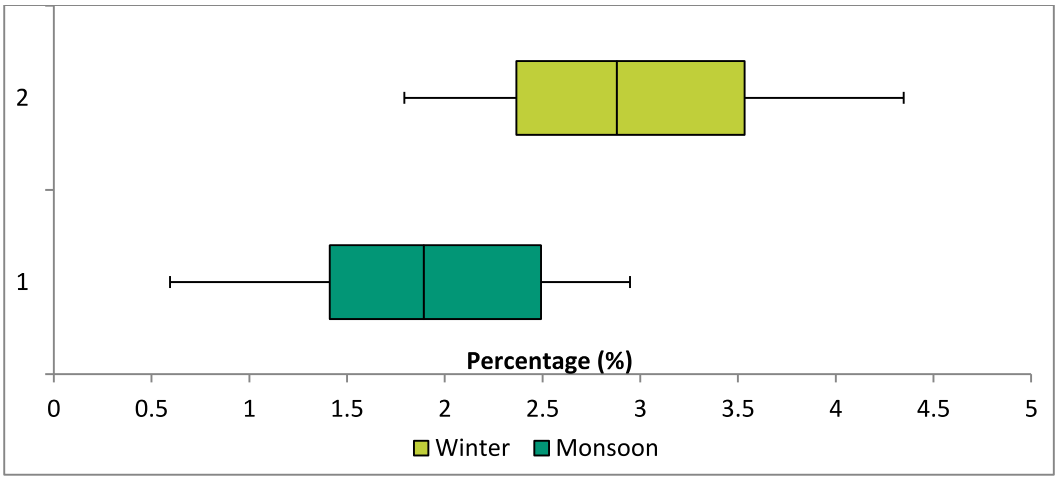

Figure 7. Seasonal variation trends in sediment organic carbon content

Table 1. Correlation among various sedimentological parameters (SOM= Sediment Organic Matter, SOC= Sediment Organic Compound, STem= Sediment Temperature, SpH= Sediment pH and MC= Mud Content)

Parameters	SOM	SOC	STem	SpH	MC	Rainfall
SOM	1					
SOC	1.00**	1				
STem	-0.28*	-0.28*	1			
SpH	0.26	0.26	-0.35**	1		
MC	0.63**	0.63**	-0.15	-0.11	1	
Rainfall	-0.46**	-0.46**	0.78	-0.22	-0.10	1

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

Sediment temperature was influenced by water movement, temperature and other frictional forces of bed characteristics. Temperature of surface sediment ranged from 20.4 to 31.9°C. In monsoon, the maximum sediment temperature was observed as 31.9±0.25°C in Patenga whereas lowest noted 28.5±0.7°C from Halda. Again, the peak temperature was investigated in Salimpur (31.8±0.5°C) while the temperature downed as 20.4±0.25°C during winter (Figure 8). The highest temperature in intertidal surface sediment was examined during monsoon at Patenga coast which is sand dominated coastal region whereas lowest was recorded at winter season at Karnafully river location. Surficial sediment temperature was found negatively related with organic matter and organic carbon ($p<0.05$) (Table 1).

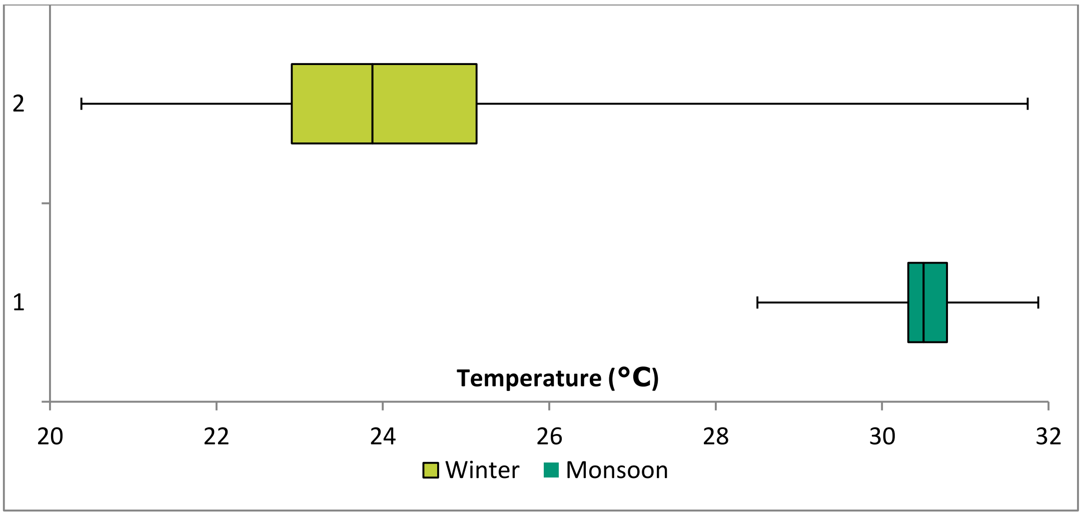

Figure 8. Seasonal variation trends in sediment temperature

The level of sediment pH was in regular trends at every location except Sadergaht. The pH level reached its peak (6.7±0.07) in Halda and downed to the lowest level (6.0) at Saderghat location during monsoon. Conversely, highest pH reported as 6.7±0.05 from Karnafully, Chaktai and Saderghat locations whereas lowest (6.1±0.1) observed at Salimpur during winter (Figure 9). The pH level closely related with rainfall pattern, freshwater inflow and coastal geomorphological processes. Sediment pH positively related with sediment organic matter and carbon content; also negatively correlated with sediment temperature (Table 1).

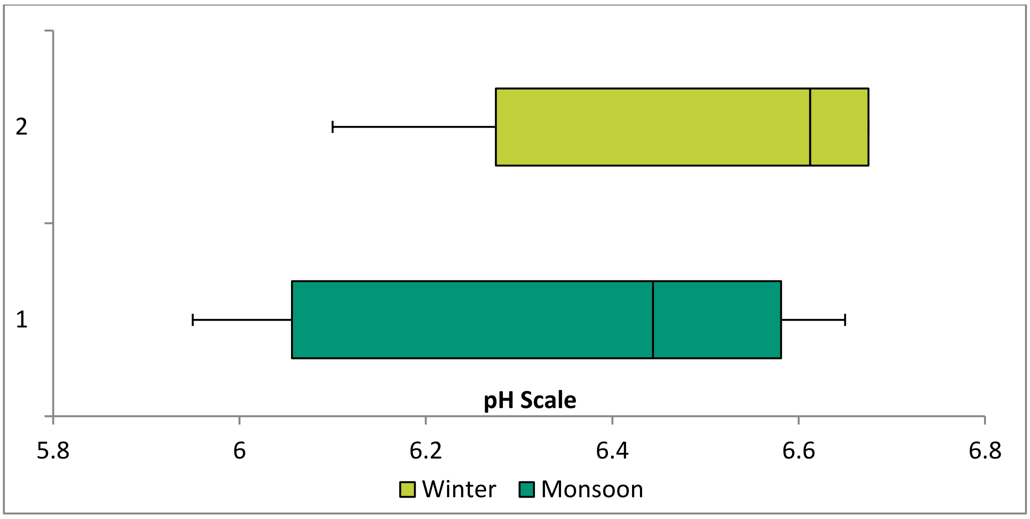

Figure 9. Seasonal distribution pattern of sediment pH level

Silt and clay particles help to accumulate organic content in sediment. Higher mud content indicate huge amount of organic matter in coastal sediment. Minimum concentration of mud content investigated as 8.08% and 42.98% from Patenga coast during monsoon and winter in turn. On the other hand, Khejurthalighat (96.15%) and Salimpur (98.47%) coast were exhibited maximum mud content in monsoon and winter respectively (Figure 10). The mud characteristics were positively related with the increase and decrease of sediment organic matter and organic carbon. Presences of dense saltmarsh vegetation and planted mangrove have vital contribution to increase the sediment organic matter and organic carbon in Salimpur coast. In contrast, Patenga coast is sand dominated bare zone (without saltmarsh, mangrove or other vegetation) where a little amount of mud indistinctly scattered over the sand bed during winter. Mud content of coastal deposits positively correlated with organic matter, organic carbon ($p<0.01$). Mud characteristics also have negative correlation with sediment temperature and pH level (Table 1).

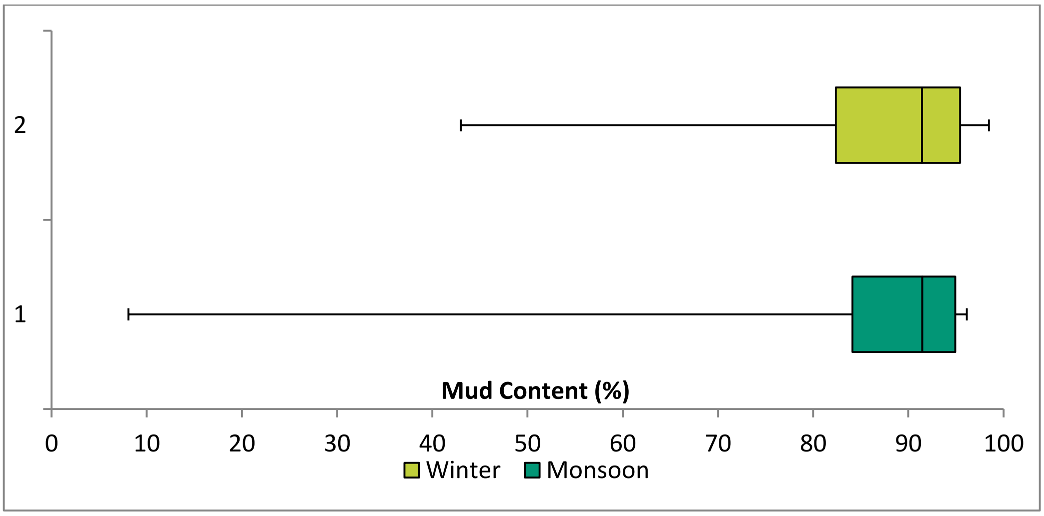

Figure 10. Seasonal distribution characteristics of mud content (%)

Chittagong coastal belt along the Bay of Bengal is characterized by humid and subtropical climatic features. The total annual rainfall from June 2013 to May 2014 hydrological year was about 2129 mm that was recorded from the Patenga station, Chittagong. About 55.7% precipitation was noted in the monsoon (June to August) whereas 25.5% and 17.1% rainfall noted during post-monsoon (September to November) and premonsoon (March to May) season in turn. Less rainfall was reported during the winter season (December to February) approximately 37 mm (1.7% of annual rainfall) accelerating the concentration of mud due to calm weather condition (Figure 11). Trends of precipitation negatively correlated with sediment organic matter and organic carbon ($p<0.05$) and positively correlated with sediment temperature ($p<0.01$). In addition, rainfall rate has negative correlation with sediment pH and mud content.

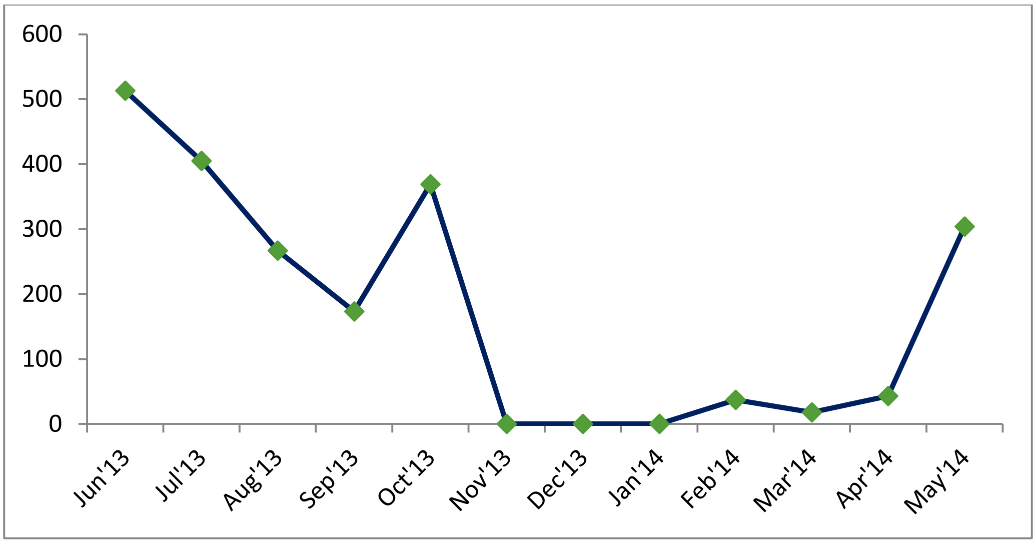

Figure 11. Temporal variations of rainfall pattern in Chittagong Coast
(Source: Bangladesh Meteorological Department)

DISCUSSION

Impact of Rainfall in Spatio-temporalvariability

The concentration of organic matter and carbon decrease seaward side along the intertidal zone from all the studied location. Mean organic matter content of three freshwater locations was observed as 4.9±0.69% whereas 3.09±0.95% and 3.92±2.28 found in brackish and marine sites, respectively. In experimental locations approximately 3.18% organic matter was observed during monsoon whereas 4.94% investigated during winter. Anthropogenic waste input through land runoff into the intertidal area act as a key source of organic matter and carbon. The most complex and least understood component of sediments is the organic matter and organic carbon (Magdoff and Weil, 2004). Higher value of organic matter was found in winter comparison to monsoon due to large amount of humus mainly leaves of mangrove, salt marsh and benthos associated particles transported by the creek networks and terrestrial land drainages especially in Salimpur and Khejurthalighat location. Particle size distribution pattern also assists to accumulate organic matter in the coastal sediment processes.

Average range of organic carbon 2.91±0.41%, 1.85±0.57 and 2.34±1.36 were recorded from freshwater, brackish and marine water locations correspondingly. In contrast, sediment organic carbon investigated as 1.9% and 2.95% during the monsoon and winter season in turn. Organic carbon greatly influenced by the precipitation rate. Higher organic carbon concentration found during the winter season with less precipitation trends. During winter, thick mud bed formed and benthos communities of intertidal mudflat help to accumulate organic matter into the sediment. On the other hand, during monsoon huge rainfall washed out the sediment bed partially and creates less concentration of organic carbon accumulation. Sediment organic carbon plays a vital role in cation exchange capacity, nutrient retention and release, sediment structure and bulk density, water holding capacity and biological activity. Sediment organic carbon levels of all mineral sediments were commonly ranging from 4 to 7% of the total sediment mass (Hargrove and Luxmore, 1988). Distribution of organic carbon was closely related with the mud properties. Low mud content sediment has little organic carbon and when mud content increased, the total organic carbon also improved (Burone et al., 2003).

In winter, intertidal region of mentioned study area were significantly covered by thicker roofing of finer deposits which accelerate the increasing rate of organic particles (Burone et al., 2003). Increase of organic matter with the decrease of grain size is well recognized and several studies conducted and ascribed to co-sedimentation of organic matter with clay and mineral particles (Venkatramanan et al., 2010). Very fine grained deposits in coastal sediment are a very worthy sign of minimum values for carbon content. In winter dominant finer sediment accelerate the growth rate of salt marsh as well macro benthic faunal diversity. Higher amount of organic materials can be derived by decaying of intertidal and benthic macro flora and fauna which finally contribute to increase the total organic carbon. An abundant supply of organic matter and relatively rapid rate of accumulation of fine grained inorganic matter and low O_2 content of the water immediately above the bottom sediment help in high organic characteristics.

Surface sediment temperature varies from place to place as well as from season to season. Temperature of eight experimental locations ranged 26.3 °C, 27.1 °C and 29.0 °C in freshwater, brackish water and marine water locations correspondingly. 30.5 °C and 24.5 °C were recorded as average temperature during monsoon and winter correspondingly. Talukder et al., 2016 investigated the same trends of temperature from the coastal belt of Salimpur along the Chittagong coast. The pH range in the coastal zone of the Bay of Bengal reported as 6.39±0.14. Range of pH varied as 6.3 at monsoon and 6.5 in winter season of Chittagong coastal belt. Fluctuation of pH depends on hydro-chemical parameters like CO_2 removal by photochemical reaction, seawater and other biological activities (Rajuet al. 2015; Kamalkanthet al., 2012; Reddi et al., 1993). The pH varies with local geomorphological characteristics and the ranges of pH in experimental locations were slightly acidic. Talukder et al., 2016 and Raj et al., 2013 also investigated the similar trends.

Mud characteristics of intertidal zone depend on freshwater inflow, geomorphological condition and related physical properties like wave, tide and current processes. The percentages of mud content were 91.33%, 83.57% and 72.66% that observed from freshwater, brackish and marine water in turn. The mud content of marine locations was remained higher in all season excluding Patenga. The Patenga coast is dominated by sand particles with low amount of silt and clay which contribute less in organic matter concentration. Rainfall rate, trends and characteristics hampers to stabilize mud in the intertidal mudflat. During the monsoon approximately two-third of annual precipitation occurred. Therefore, freshwater runoff contributes less amount of organic content in the coastal surficial sediment in rainy season. On the contrary, organic matter and other associated parameters remain in positive trends during winter and calm intertidal zone help to trap sediment which enhance the contribution to organic content.

CONCLUSION

In this research, impact of rainfall on spatio-temporal distribution of organic matter and other sedimentological properties were observed from intertidal mudflats. The findings indicate that the variability of organic matter occur due to anomalous characteristics of rainfall pattern except the Patenga. Patenga sea beach was highly fine sand dominated with ignorable fraction of clay and silt. Contrariwise, fine grained dominated locations revealed more organic matter and carbon content than other locations. In the 15 No.Ghat, the concentration were in moderate level due to less clay and silt dominancy than Salimpur and Khejurthali location. The results of this study imply that, coastal sediment trapped in continental shelf margin during low energy season and washed away partially at high energy season. Surface sediment from all locations washed away due to land drainage and heavy precipitation rate which decreased the rate of organic matter and carbon during monsoon. Huge amount of sediment accumulate during winter season which is crucial for organic matter and carbon accumulation processes. Therefore, much attention should be paid to the intertidal surficial sediment for monitoring biogeochemical processes of the Bay of Bengal.

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