Mar. Sci. Tech. Bull. (2023) 12(4): 530-539
e–ISSN: 2147–9666
info@masteb.com

dergipark.org.tr/en/pub/masteb
www.masteb.com
DOI: 10.33714/masteb.1367368

Marine Science and Technology Bulletin

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RESEARCH ARTICLE

Fluctuations of physicochemical parameters in the waters of the Chattogram coastal area, Bangladesh

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ARTICLE INFO

Article History:
Received: 27.09.2023
Received in revised form: 20.11.2023
Accepted: 27.11.2023
Available online: 25.12.2023

Keywords:
Seasonal feature
Ship-breaking activities
Physicochemical parameters

ABSTRACT

Fluctuations in seasonal features of physicochemical factors in the coastal zone are expressively related to the development of aquaculture. The research examined some common physicochemical characteristics of water such as temperature, salinity, light penetration, pH, biological oxygen demand (BOD), dissolved oxygen (DO), total dissolved solids (TDS), total suspended solids (TSS), and nutrients like nitrite and phosphate for the Chattogram coast of the Bay of Bengal, Bangladesh, for a period about one year (December 2020 to November 2021) during the pre-monsoon, monsoon, and post-monsoon seasons. The analyzed physic-chemical parameters' spatio-temporal variability was discovered to be as follows: average temperature 28.20±2.28°C, light penetration 9.95±1.75 cm, p^H 7.38±0.17, salinity 20.11±1.44 ppt, DO 7.41±0.91 mg/l, BOD_5 8.28±1.15 mg/l, TSS 2.61±0.43 g/l, and TDS 21.99±2.06 g/l. The concentration of nutrients indicates significant variations, and their levels in the water increased during the monsoon period. Total nitrate-nitrogen ranged between 0.867 µg/l and 1.472 µg/l and total phosphate-phosphorus ranged between 0.221 µg/l and 0.844 µg/l. Shipbreaking activities near the study area possess adverse impacts on native geomorphology, freshwater inputs, rainfall, and the aquatic ecosystem as well. This research proposes the value of regular supervision to assess the status of water quality and the next prospect of aquaculture in the Chattogram coastal area. Seasonally, without DO, all values showed a significant difference, whereas $p<0.05$.

Please cite this paper as follows:

Rahman, M. H., Pandit, D., Begum, N., Das, R., Sikder, M. N. A., Preety, Z. N., & Roy, T. K. (2023). Fluctuations of physicochemical parameters in the waters of the Chattogram coastal area, Bangladesh. *Marine Science and Technology Bulletin*, *12*(4), 530-539. https://doi.org/10.33714/masteb.1367368

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Introduction

Bangladesh is a sloping, riverine nation (Pramanik, 1988) endowed with immense natural water bodies in a variety of forms (Ali et al., 2017; Mia et al., 2017), the largest of which is a 710 km long coastline. The littoral and estuarine regions consist of extensive muddy areas, brackish water, saline water, and confined bays. These locations are home to a large quantity of valuable life forms that are suited for ocean farming (Kamal & Khan, 2009). Estuaries serve as an intermediate region between the ocean and the land because they are fragile habitats with distinctive chemical and physical features. Numerous physical and chemical reactions occur as riverbanks and oceans interact, and those events might affect the state of the water. Surface water quality is a particularly delicate subject (Prasanna & Ranjan, 2010) that refers to the present state of the water body, which depends on various parameters and directly or partially controls the aquatic ecosystem (Srinivasan et al., 2013). The existence of organic and inorganic substances that are either deferred or melted in water determines the physicochemical characteristics relevant for water quality assessment. Water quality characteristics in aquatic habitats are the result of several biological, physical, and chemical exchanges (Ugwu & Wakawa, 2012). The physicochemical makeup and biological variety of an aquatic habitat determine its health (Venkatesharaju et al., 2010). Especially in tropical countries, which are characterized by mostly shallow water bodies, the coastal ecosystems are inherently rich in biodiversity and productive (Srinivasan et al., 2013). The coastal zone is one of the most significant commercial sectors in any state in the world. Additionally, this zone serves as a crucial filtration system and buffer zone for the coastal ecology (Srinivasan et al., 2013). Furthermore, each of these components exists in an intricate balance that is maintained by biological and physical procedures and is easily disrupted by environmental or human intrusion (Viles & Spencer, 2014).

Water quality analyses are a core component of an ecological tracking system for recreational spots and provide crucial data for the administration of the coastal zone (Ariza et al., 2007). Coastal effluent, agricultural runways, urban waste, and industrial discharge in the neighboring river can alter water quality (Inyang & Daniels, 2009). The purity of water is influenced by both organic and human procedures such as precipitation, sedimentation, and the degradation of crystalline materials (Chakrapani et al., 1993). Physical, chemical, and biological characteristics can be used to define the quality of aquatic body (Trivedi et al., 2009). However, there might be some link between these variables, and the major one could be used to determine the water's quality (Manjare et al., 2010). The biochemistry of the water body is significantly influenced by physical factors. The water quality of the study system can be significantly impacted by small changes in the environment, which could then have an impact on how nutrients are distributed both spatially and temporally and/or on biological communities (Sreenivasulu et al., 2015). As a result, while designing a water quality management program, seasonal changes in surface water quality must be considered (Ouyang et al., 2006). A vast area of polluted aquatic or coastal water bodies plays an important role in fish and wildlife resources. The establishment of water quality variations over time and space requires regular monitoring procedures (Prasanna & Ranjan, 2010). In this regard, a study was conducted to examine the status of physicochemical parameters of water and to know the seasonal fluctuations of these parameters in the Chattogram coastal area, Bangladesh.

Material and Method

This research was carried out at four locations (Banshkhali, Anwara, Patenga, and Dakshin Kattali) towards the littoral of Bangladesh, primarily in the Chattogram district. The position and details of the sampling sites are depicted in Figure 1, respectively. From December 2020 to November 2021, water samples were collected throughout three distinct periods: pre-monsoon, monsoon, and post-monsoon seasons. To conduct the physicochemical analysis, 500 ml of water samples were taken at each of the designated locations. Some physicochemical variables were measured on-site, while others were conveyed to the laboratory in opaque polyethylene plastic flasks, and ice cases; thus, the duration through sampling and analysis was less than 3 hours.

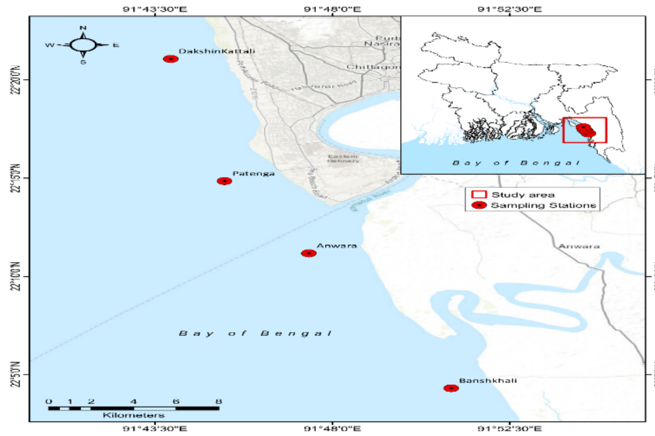

Figure 1. Study area map

Collection of Physicochemical Parameters

Within an extent of 3 meters, measurements of surface and subsurface water were taken at an offshore location that was 200 meters from the shoreline and in a low tide zone. A mercury thermometer was used to gauge the temperature of the water's outermost layer. Salinity was determined utilizing the Mohr-

Knudsen titration technique, and water pH was determined with a pen pH meter (Model: Phillips PW 8409) (Barnes, 1959; Eaton et al., 2005). Throughout the course of a 5-day time frame, the biological oxygen demand (BOD_5) of every water sample was determined through the OxiDirect BOD system (HACH). A handheld aquaculture kit (Model FF2, HACH, USA) was used to detect total hardness, dissolved oxygen (DO), and total alkalinity. A hydrophobic EC/TDS tester (Adwa AD31) was used to detect total dissolved solids (TDS) and electrical conductivity (EC). The Hach Kit (DR/2020, a direct-reading spectrophotometer) was used to quantify the amount of nitrate-nitrogen (NO_3-N) and phosphate-phosphorus (PO_4-P) using high-range chemicals (Nitra Ver. 5 nitrate reagent powder pillows for NO_3-N research and Phos. Ver. 3 phosphate reagent powder pillows for PO_4-P analysis).

Evaluation of Water Quality

The results were compared with the reference values (EQS, 1997; FAO, 2004; Santhosh et al., 2007; Hossain et al., 2009; Uddin et al., 2014; Talukder et. al., 2016; Saha et al., 2017; WHO, 2022) for water quality parameters, and followed by Uncumusaoğlu & Mutlu (2021).

Statistical Analysis

Before using Microsoft Excel to compute the numerical information derived from this study, the necessary adjustments and modifications were performed on the data. To assess whether or not there are any variations in the water quality measures that are statistically significant ($p<0.05$), a one-way analysis of variance (ANOVA) that was executed in Microsoft Excel was implemented. Using the IBM SPSS v27 program, the degree of significance of the findings was analyzed by Duncan's and Tukey's methodologies.

Results and Discussion

Spatial Variations of Physicochemical Parameters

Table 1 displays the physicochemical characteristics of study locations that were recorded throughout the time frame of this study. All the physicochemical characteristics, except pH, fluctuate significantly ($p<0.05$) depending on the time and season of year. The air temperature and water temperature both rise throughout the summer months, which is a typical occurrence. Among the stations, the measured water temperature revealed significant ($p>0.05$) seasonal change where the highest was in Pre-monsoon (30.69 ± 0.24^{a}) °C and the lowest was in post-monsoon (25.43 ± 0.23^{c}) °C (Table 1 and 2). Our study indicates clear seasonality. The present finding of water temperature was more or less similar to the findings of Haque et al. (2015) who found clear seasonality and the temperature range was 20-28.5°C and 21.2-29°C in Tidal Sangu River. Among the stations, the measured water temperature revealed no significant ($p>0.05$) spatial change, being lower (28.07±1.76°C) and higher (28.45±1.6°C). Boyle & Fraleigh (2003) and Ezzat et al. (2012) also eminent the expulsion of contaminants may raise the temperature of water, declining water levels, and rising concentrations of particulate pollutants throughout the summer cause the water to become hotter. St. 1 was shown to have been mostly contaminated throughout the research interval by the dumping of residential and urban rubbish. Industrial and municipal garbage has been shown by Bhouyan (1979) to have a considerable impact on the pH of the water at the disposal position. The pH ranged from 7.2-7.45, in sites and 7.25-7.53 among seasons without any significant difference ($p<0.05$) (Tables 1 and 2; Figure 3). pH was found to be oppositely related to both air and water temperatures and to have significantly risen over pre-monsoon to post-monsoon. The pH difference between the research and control sites fluctuates from the pre-monsoon to the post-monsoon seasons ($p>0.05$ seasonally) (Tables 1 and 2). This finding is consistent with the findings of Ferdousy et al. (2017). The ideal water pH range, according to WHO (2022), is between 6.5 and 8.5 (Uncumusaoğlu & Mutlu, 2021). Considering energy expenditure and environmental damage, our reported station's pH is in the standard range. The maritime salinity in Chattogram's coastal region was found to fluctuate between 19.37 ppt and 20.73 ppt at the surface, with Dakshin Kattali recording the lowest value throughout the monsoon and Banshkhali recording the highest average while on the post-monsoon (Tables 1 and 2; Figure 4). Temporally the value was highest (21.59±0.36) in post-monsoon season and lowest in monsoon season. In every season, the salinity of surface waters is lower than that that exists in the deeper layers. Haque et al. (2015) recorded water salinity varied from 13 to 33 ppt in the tidal Sangu River and Ferdousy et al. (2017) discovered that water salinity ranged from 0.0 to 13.5 ppt year-round in Mongla River. Our results were lower than Haque et al. (2015) but higher than those of Ferdousy et al. (2017). The monsoon impact, rainfall, land drainage, and heavy rains, which were found to rise during the post-monsoon with the start of the dry season, may be to blame for the progressive drop in salinity after the month of June and its fall to zero ppt from September to December. Due to circulation in the Bay, river flow, dissolution, and runoff into the sea from rainfall, salinity varied during the research duration. The main characteristic of coastal water is salinity, and according to AHI (Saha et al., 2017), the ideal salinity level is about 25 ppt.

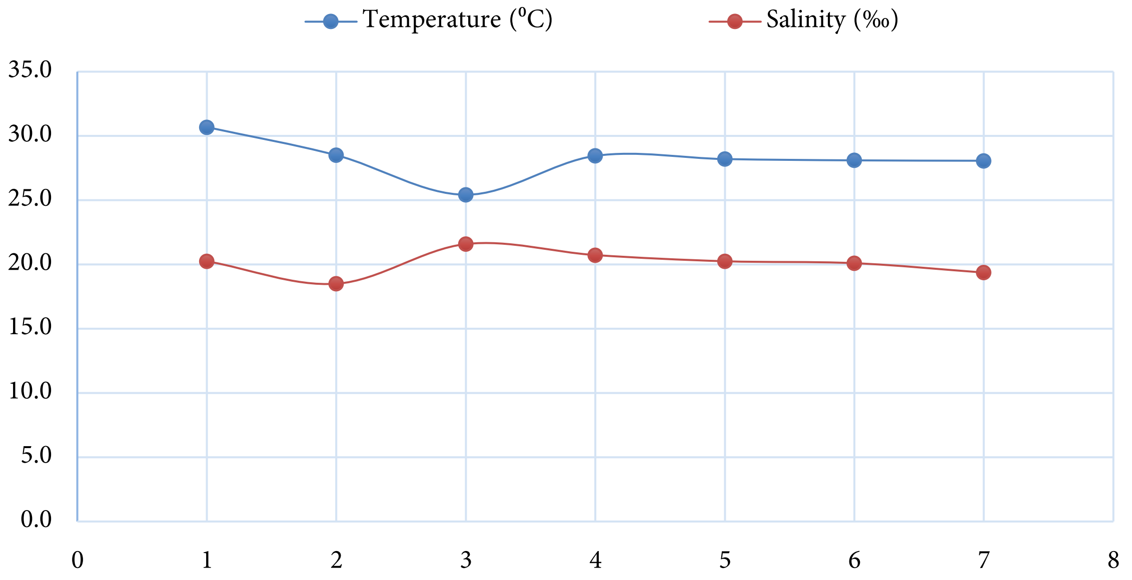

Figure 2. 1= Pre-monsoon, 2= Monsoon, 3= post-monsoon (seasonal variation); 4=st-1, 5=st-2, 6=st-3, 7=st-4 (spatial variation)

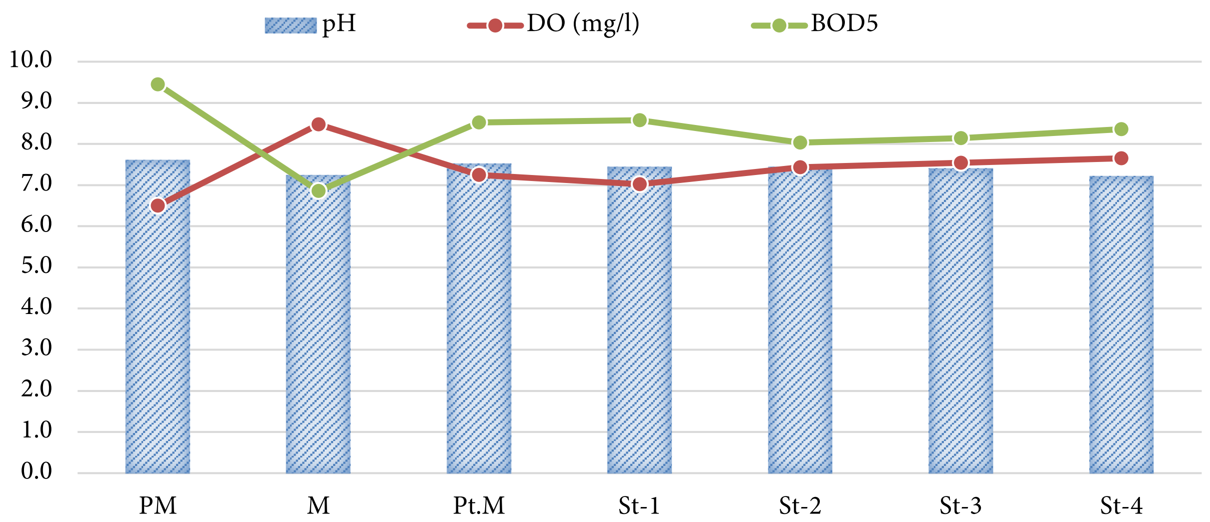

Figure 3. Effect of DO (mg/l) and BOD_5 (mg/l) basis on pH variation (seasonal & spatial variation)

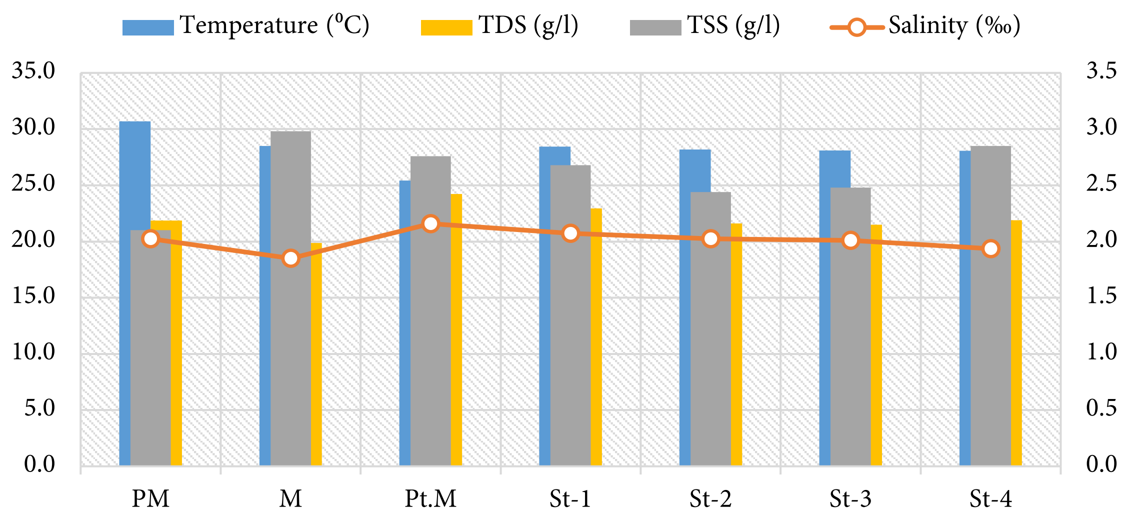

Figure 4. Salinity, variation with associated key features

Table 1. Physico-chemical parameters recorded from different study areas

Parameters	Banshkhali	Anwara	Patenga	Dakshin Kattali	Reference value
Temperature (°C)	28.45±1.6	28.2±1.34	28.1±1.31	28.07±1.76	20-30 (EQS,1997; Saha et al., 2017)
pH	7.45±0.13	7.45±0.13	7.41±0.06	7.22±0.04	6.5-8.5 (FAO, 2004; WHO, 2022)
Salinity (‰)	20.73±0.82	20.25±1.09	20.1±0.95	19.37±0.75	Saha et al. (2017)
DO (mg/l)	7.02±0.59	7.43±0.52	7.54 ±0.51	7.65 ±0.72	4-6 (Uddin et al., 2014)
Light Penetration (cm)	9.33±1.09	10.63±1.07	10.73±1.21	9.1±0.84	30-40 (Santhosh et al., 2007)
BOD_5	8.58±0.77	8.03±0.70	8.14±0.81	8.36±0.77	Saha et al. (2017)
TSS (mg/l)	2.68±0.28	2.44±0.25	2.48±0.26	2.85±0.33	Hossain et al. (2009)
TDS (mg/l)	22.95±1.38	21.61±1.17	21.49±1.25	21.9±1.49	<600 (WHO, 2022)
Nitrite-N_2 (µg/l)	1.17±0.149	1.32±0.13	1.28±0.11	1.08±0.04	Talukder et. al. (2016)
Phosphate-P (µg/l)	0.487±0.13	0.64±0.13	0.56±0.08	0.41±0.13	Hossain et al. (2009)

At St. 1, a substantial quantity of organic waste was subjected to elevated microbial breakdown, which resulted in a substantial decrease in DO. During the research time, noteworthy seasonal and geographic variations in DO content were also noticed. The monsoon season's greatest DO content in St. 4 (7.65±0.72 mg/l) suggests that while the lowest value (7.02±0.59 mg/l) was discovered in the highly polluted St. 1. One of the most important elements in any body of water is the amount of light that penetrates. In 2016, Talukder et al. (2016) also found that DO was high in the monsoon. DO varied from 7.02 to 6.65 mg/l in the experimental area, whereas the optimum value of DO is 5-8 mg/l. Using the effective influence of temperature on light penetration, pH, salinity, and other parameters seasonally, we found the average DO to be 7.41±0.91 mg/l ($p<0.05$) (Tables 1 and 2; Figure 2). The rate of photosynthesis is related to how much light gets into the plant. At different sites and times of year, the amount of light that got into the Chattogram coastal zone ranged from 9.1 to 10.73 cm during monsoon and post-monsoon, respectively, and the average amount of light that got in was 9.55±1.75 cm ($p<0.05$, annually) (Tables 1 and 2; Figure 4). The AHI of India (Saha et al., 2017) says that 30 cm is the best distance for light to get through.

At the experimental locations, the biochemical oxygen demand (BOD_5) of the coastal water ranged from 8.03±0.70 to 8.58±0.77 mg/l in research stations where the highest was in St. 1 and lowest in St. 2. BOD_5 levels were significantly higher during the pre-monsoon at onshore sites and lower throughout the monsoon at experimental offshore sites (Tables 1 and 2; Figure 3).

The TSS of Chattogram coastal water was measured there between 2.44±0.25 and 2.85±0.33 mg/l throughout the area while the highest was in Dasknin Kattali and the lowest was in Anwara, respectively. The TSS value was lowest during the pre-monsoon and highest during the monsoon at the study location. TSS has a positive correlation with TDS, salinity, transparency, and air temperature. The average value of TSS at Chattogram coastal water of various seasons was significantly different $p<0.05$ (Tables 1 and 2; Figure 4), which is higher than the optimum value of TSS of 2-3.2 g/l (Hossain et al., 2009). Our findings are more than the reference value in all stations. The maximum total dissolved solids (TDS) of 22.95±1.38 µg/l was recorded at St-1during post-monsoon, and the minimum value of TDS was 21.49±1.25 µg/l at St-3 during monsoon. All the seasons were significantly different ($p<0.05$). Hossain et al. (2009) showed that the optimum TDS value should be 12.8 to 29.1µg/l, whereas the average value of TDS was 21.99±2.06 µg/l (Figure 4). According to the reference, our recoded values are in the range.

At the experimental location's offshore site, the nitrite-nitrogen concentration level peaked during the monsoon (1.34±0.07 µg/l), but it thereafter declined to the lowest level (1.00±0.05 µg/l) seen onshore during post-monsoon. NO_2-N values fluctuate from pre-monsoon to monsoon at the experimental location. The peak level of nitrite-nitrogen concentration was observed in St. 1 (1.32±0.13) where the lowest was in Dakshin Kattali (1.08±0.04) (Tables 1 and 2; Figure 5) No significant difference was found between pre-monsoon and monsoon. Talukder et al. (2016) showed a 1.94-2.58 µg/l level of NO_2-N from the coastal waters of Salimpur and Chattogram along the Bay of Bengal. Haque et al. (2015) recorded Nitrate nitrogen concentrations varying from 0.9 µg/l to 2.2 µg/l in tidal Sangu River. Our result is more or less similar to other findings.

From coastal water, the maximum phosphate phosphorus content was determined in St. 2 (0.64±0.13) and minimum in the St. 4 (0.41±0.13) to be 0.32±0.05 µg/l during the pre-monsoon was the minimum value, and the maximum value was 0.66±0.00 µg/l in post-monsoon (Figure 5). Raju (2017) examined the range of PO_4-P levels from the southeast Indian coast, from 0.29 to 2.15 µg/l. Haque et al. (2015) observed that PO_4-P concentration ranged from 1.5 to 2.9 mg/l with maxima and minima recorded in August and December, respectively, which is near the present study.

Seasonal Variation of Physicochemical Parameters

Temperature is one of the most important factors in increasing salinity. Despite the lower post-monsoon temperature, salinity rises due to low precipitation, a lack of fresh water, and other factors. According to Govindasamy et al. (2000), the amount of sunlight emitted, evaporation, insolation, freshwater intake, cooling, and rise and fall from nearby neritic seas all have a role in controlling surface water temperature. However, we have found a direct correlation between salinity, pH, light permeability, and water temperature. The association between water temperature and salinity was demonstrated by Özdemir et al. (2022). One of the most important chemical parameters in water quality fluctuations is dissolved oxygen, which influences both physical and biological processes in the water. The value of dissolved oxygen is a crucial issue in evaluating an aquatic ecosystem's water quality requirements. Seasonal observations of dissolved oxygen revealed an inverse relationship between temperature and salinity.

Among the key elements that improve chemical and biological properties is pH. Changes similar to these were also seen in Salimpur Coast, Chattogram, according to Talukder et al. (2016). He also demonstrated how pH, DO, and BOD_5 are related. Three locations in the research region are close to the estuary, where there is continual dissolution of saltwater by freshwater intrusion, and a single site is close to the Chattogram shipbreaking area. Numerous enterprises that demand oil disposal have an impact on coastal environments. pH remained slightly alkaline throughout the study period at all the stations. We noticed that the DO level gently increases from pre-monsoon to monsoon and decreases again from monsoon to post-monsoon. As high DO values showed in monsoons, BOD_5 was proportionally low. During monsoon season higher dissolved oxygen might be due to the effect of higher wind energy, air-sea interface combined heavy rainfall, and because of freshwater mixing. The water temperature during the post-monsoon was low because of strong land-sea breezes and precipitation, and the recorded high value during the pre-monsoon could be attributed to high solar radiation (Das et al., 1997). Seasonal variations in pH levels are caused by a variety of variables, including CO_2 removal by photosynthesis through bicarbonate depletion, mixing of saltwater by freshwater intrusion, poor primary production, decreases in salinity and temperature, and microbial disintegration (Karuppasamy & Perumal, 2000; Rajasegar, 2003).

Seasonal and spatial fluctuations among salinity and associated features:

The elevated salinity concentration is attributed to the rapid pace of vaporization, limited rainfall, the lack of river flow, tidal blending, and the predominance of neritic water from the open sea, as reported by Saravanakumar et al. (2008). The physicochemical parameters of the current research area's coastal water body demonstrated considerable seasonal fluctuations, which may be attributed to local climate circumstances. All the sites displayed the same trend with similar seasonal shifts. Salinity is a warning factor in the distribution of existing species, and its change owing to dilution from mixing and evaporation from temperature is most likely to stimulus the fauna in the intertidal region (Gibson, 1982). Salinity varies in response to changes in global temperature.

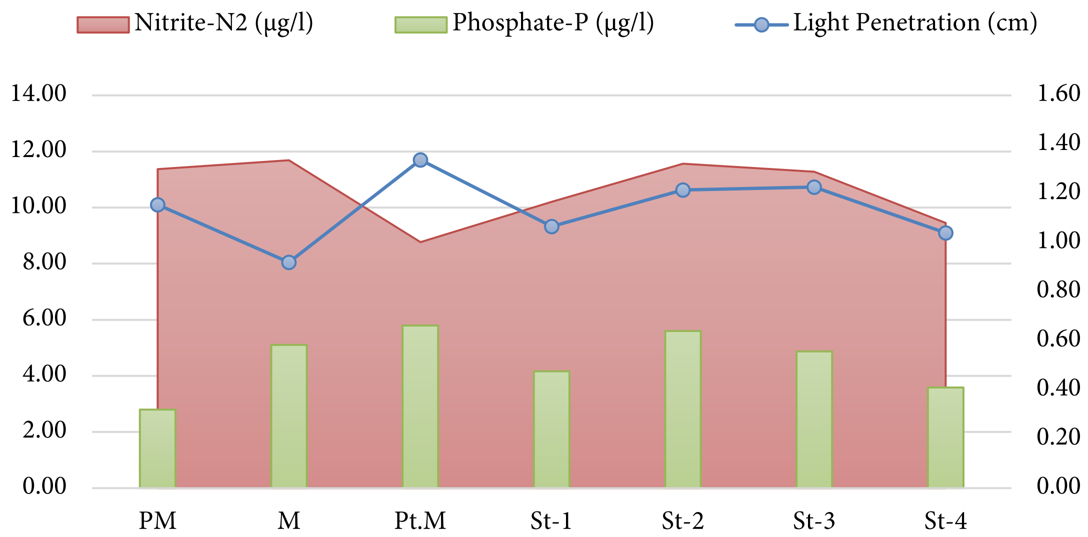

Figure 5. Nutrient variation and changes in LP

Table 2. Physico-chemical parameters recorded in different seasons.

Parameters	Pre-monsoon	Monsoon	Post-monsoon
Temperature (°C)	30.69±0.24[a]	28.5±0.074[b]	25.43±0.23[c]
Light Penetration (cm)	10.1±0.47[a]	8.05±0.32[b]	11.7±0.51[a]
pH	7.37±0.08	7.25±0.029	7.53±0.09
Salinity (‰)	20.25±0.33[b]	18.5±0.26[c]	21.59±0.36[a]
DO (mg/l)	6.5±0.22[c]	8.48±0.19[a]	7.25±0.12[b]
BOD_5	9.45±0.19[a]	6.86±0.15[c]	8.53±0.07[b]
TSS (mg/l)	2.1±0.06[b]	2.98±0.15[a]	2.76±0.08[a]
TDS (mg/l)	21.87±0.81[b]	19.86±0.11[c]	24.22±0.21[a]
Nitrite-N_2 (µg/l)	1.30±0.077[a]	1.3358±0.07[a]	1.00±0.05[b]
Phosphate-P (µg/l)	0.32±0.05[b]	0.58±0.10[a]	0.66±0.00[a]

A crucial characteristic of coastal water components is salinity, which additionally improves TSS and TDS. Srilatha et al. (2012) also observed a wide range of salinity (15-35 ppt). The seasonal variation of TSS varied, and that also influenced water quality largely. TSS indicates the river runoff, industrial effluents, agricultural effluents, and municipal sewage that are contaminated in the estuary or coastal water body. Saha et al. (2017) described that the Water Quality Index (WQI) assessment is a maneuver to appreciate the fitness of the aquatic system by considering all the parameters relevant for determining the ecologically sensitive zone in the coastal stretch. Waters with high TDS are indigestible and potentially unwholesome (Patel & Parikh, 2013). In the present study, TDS values also varied from 19.86 to 24.22 g/l at the experimental seasons. In aquatic ecosystems, total dissolved solids are composed mainly of phosphates, carbonates, bicarbonates, chlorides, and nitrates of sodium, magnesium, manganese, potassium, organic matter, salt, and other particles (Mahananda et al., 2010).

Seasonal Variation in Nutrient Characteristics

Light penetration is a crucial nutritional component in all aquatic systems. The nutrient profile of coastal water always varies faster than that of fresh water. Light penetration of the Chattogram coastal zone varied from 8.05 to 11.70 cm throughout different seasons, and from 9.10 to 10.73 cm at four sampling locations. Photosynthesis requires light penetration. According to the graphical presentation, the light presentation in St. 4 should be greater than 10.63 cm. This coast site's dominant particle is mud rather than sand, silt, or others, which are composed of muddy shore and always mix up water and mud. That's why light penetration is low, similar to St. 4. Light penetration varies seasonally, depending on temperature, weather conditions, coast profile coastal composition, sediments, etc. Variations in phytoplankton, transparency, oxidation, and nitrate reduction may all contribute to variations in nitrite nitrogen ions (Talukder et al., 2016). Less freshwater intake, increased salinity, and a higher pH during the post-monsoon were the causes of the low nitrite content of 0.87µg/l. The amount of phosphorus in phosphate also varied significantly from the pre-monsoon to the post-monsoon, whereas $p<0.05$. High concentrations are visible during the monsoon as a result of increased salinity, regeneration, and phosphate release from the bottom into the aquatic pole due to turbulence and mixing processes (Kumar et al., 2015). In the Chattogram coastal area, the concentration of phosphate phosphorus varied between 0.221 µg/l and 0.844µg/l. The above graphical statistic shows that both the fluctuation of NO_2-N and PO_4 depend on light penetration.

Conclusion

Assets along the coast and in estuaries are essential to ecology and financial stability. Water quality governs the whole ecosystem, directly or indirectly. Presently, factories and several mills have been set up on the banks of the Chattogram coastal area. They discharge their effluent through the poor drainage system, which falls into the Karnafully River and adjacent coastal areas. Chattogram shipbreaking yard is in Foujdarhat, Bangladesh, along the 18-kilometer (11-mile) Sitakunda coastal strip. They also discharge the ship's trash into the sea, resulting in continuous crude oil spill, which is happening illegally. Physicochemical parameters fluctuate seasonally, which is remarkable for our coastal region. As a result, the health of the coastal waterways is gradually deteriorating. Since prehistoric times, Bangladesh's coastline region has played a vital role in the country's financial development by providing a variety of aquatic resources. Proper actions should be taken to protect this critical region from the deterioration of water quality for the sake of future generations.

Acknowledgements

The authors would like to thank to all the lab members of the Institute of Marine Sciences, University of Chittagong, Bangladesh.

Compliance With Ethical Standards

Authors' Contributions

MR: Designed the study, Data acquisition, Data analysis, Drafting primary manuscript, Final approval, and Accountability
DP: Data analysis and drew table
NB: Data analysis and drew table
RM: Replying reviewer comments and drawing map
MS: Partial draft writing and reviewing
ZP: Data analysis and drew figure
TR: Data analysis and drew figure
All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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