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Surface Water Quality Assessment in the Different Coastal Regions of Bangladesh

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ABSTRACT

The study evaluated the suitability of surface water for routine utilization in the coastal regions of Bangladesh during the period from February to May 2023. Water samples were collected at 11 sampling stations near the river in 7 distinct districts and analyzed at NGO Forun in Dhaka using Standard APHA methods. The results indicated that the pH, TSS, DO, nitrate, and BOD readings were within acceptable limits according to WHO'11 standards. The TDS, chloride, hardness, and EC values at all sites exceeded the allowable range. The TDS and EC values were 25,300 mg/L and 50,570 µs/cm at Kutubdia, while chloride and hardness were 5,984 mg/L and 9,810 mg/L at Bhatiary, which were the highest values among all stations. The minimum values recorded for TDS, chloride, hardness, and EC were 330 mg/L, below 60 mg/L, 90 mg/L, and 645 µs/cm, respectively. GIS was used to understand the scenario of acceptability of surface water in the coastal region. The correlation analysis revealed a high positive correlation between the EC value and the hardness, chloride, BOD, and TDS readings. Surface water EC values may increase due to saline intrusion caused by rising sea levels, decreased upstream flow, natural disasters, and increased groundwater exploitation.

INTRODUCTION

Safe and accessible water is essential for the existence of life on Earth. Potable water can enhance the environment, health status, economy, and food production (Jain, 2011). Approximately 36% of individuals residing in urban areas and 65% living in rural areas did not have access to potable water (Sharma & Mishra, 2022). One of the most significant challenges in contemporary global development is guaranteeing sustainable water security (Srivastava *et al.,* 2022). By 2021, the number of individuals residing in water-stressed nations has surpassed 2 billion. This predicament is projected to worsen in specific areas due to the combined effects of climate change and population expansion (Marzi *et al.,* 2021). The ecological and socio-economic significance of marine ecosystems is crucial for both wildlife and human populations, with their benefits being contingent upon maintaining high water quality (Suarez *et al.,* 2024). The Coastal zones of Bangladesh are characterized by their hydrological nature, since they are included by the Ganges, Brahmaputra, and Meghna (GBM) river system, as well as the Bay of Bengal. The coastline region encompasses 32% of the country's total land (Ahamed *et al.,* 2020). Most of Bangladesh's coastal towns are situated along the shores of low-lying tidal zones, with an average elevation of 1.0–1.5 meters above sea level (Rahman & Rahman, 2015). The coastal population of Bangladesh in these regions heavily depends on rivers, tube wells (groundwater), and ponds for the purposes of washing, bathing, and obtaining drinking water (Habiba *et al.,* 2013; Abedin *et al.,* 2018; Khan & Paul, 2023). The circular and aqueous environment of the southwestern coastal regions of Bangladesh, known as SWCRB, is highly vulnerable to the infiltration of saltwater caused by cyclones and storm surges (Raknuzzaman *et al.,* 2016; Ashrafuzzaman *et al.,* 2022). The overall saline area has expanded to around 1.056 million hectares, up from 0.833 million hectares during the past four decades (Hasan *et al.,* 2019). The salinity intrusion in the coastal zone of Bangladesh is caused by several factors, including the country's critical geographical location, reduced river flow due to a barrage in the upstream neighboring country, inadequate management of coastal polders, rising sea levels, cyclones and storm surges, backwater effects, precipitation, and shrimp culture (Ayers *et al.,* 2017; Islam *et al.,* 2017). Water quality is often categorized based on biological, physical, and chemical criteria, with multiple factors falling under each category (Akhtar *et al.,* 2020). The physicochemical and biological characteristics of the aquatic environment directly influence the organisms inhabiting these water bodies and the overall aquatic ecosystem (Ebuete *et al.,* 2023).

So, the assessment of these three categories, utilizing parameters obtained by on-site monitoring of water samples, offers crucial data for discerning patterns, expanding the scope of understanding for water resource authorities, and making recommendations for future planning (Sutadian *et al.,* 2016; Zainurin *et al.,* 2022; Amon *et al.,* 2022; Hassan *et al.,* 2020). Multiple research studies have tested the water quality of the coastal zone in Bangladesh. The investigations have concentrated on groundwater hydro geochemical characterization, suitability for irrigation and drinking purposes, and the effects of shrimp farming and toxic algal blooms. The findings imply that water quality in the coastal region of Bangladesh differs based on the location and

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characteristics examined. Some regions have groundwater that is potable and good for drinking and irrigation, while others are deemed unsuitable for human consumption. Shrimp farming operations have been identified as a possible source of water quality problems, including elevated ammonia and nitrogen levels. Harmful algal blooms have been seen in coastal waters, impacting aquatic ecosystems, fisheries, and public health. Additional study is required to enhance our comprehension and reduce the negative impacts of these blooms on the marine resources in the Bay of Bengal (Shaibur *et al.,* 2023; Khan *et al.,* 2022; Tajwar *et al.,* 2023; Uddin *et al.,* 2024; Hossain al., 2021; Akhter *et al.,* 2023; Hossain., 2022). This study evaluated the geochemical features of surface water (SW) in the coastal region. The primary objective of this study was to assess if the water quality at the research locations is suitable for routine purposes. To accomplish this, the study had the following objectives: generating maps of the region using GIS, examining surface water's parameters and co relation between them.

MATERIALS AND METHODS

Study Area

According to Adhikary *et al.* (2012), Bangladesh has a 711-kilometer coastline that includes a vast system of river canals. In ten districts, including Chattogram, Cox's Bazar, Khulna, Bagerhat, Satkhira, Barisal, Patuakhali, Laxmipur, and Bhola, the study was carried out in eleven villages and three upazilas (sub-districts) (Figure 01). Due to the restricted water supply, salinity, and other water quality criteria, certain coastal regions of the nation are having a very difficult time meeting their freshwater demands (Adhikary *et al.,* 2012M. R. Khan *et al.,* 2022). As shown in Table 1 below, samples are taken following the usual procedure for gathering water samples from a variety of districts and locations.

Sampling

Water sampling was conducted from February to May 2023, both during dry and pre-monsoonal months to control for temporal differences in water quality. Triplicate samples were collected at each of the 11 stations to reduce temporal sampling bias. Samples were collected using pre- cleaned 1000ml high-density polyethylene (HDPE) bottles, following standard APHA guidelines. The bottles were rinsed with sample water three times before collecting. Each sample was preserved immediately by storing it in a light-restricted icebox and transported to the laboratory within 12 hours to minimize degradation.

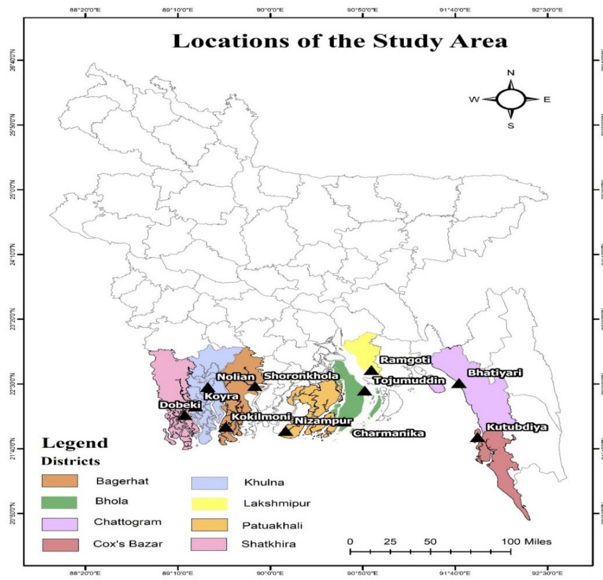


Figure 1: The overall scenario of the study area in Bangladesh

Table 1: Sampling collection points from different locations to the related rivers

Location	Surface Water	Collection Date	Lat-Long
Kokilmoni	Java River	20 Feb 2023	21.946128° - 89.597579°
Dobeki	Araibegi River	22 Feb 2023	22.098412° - 89.228009
Char Manika	Meghna River	2 April 2023	22.015178° - 90.664761°
Koyra	Sakbaria River	4 April 2023	22.210402° - 89.325218°
Kutubdia	Kutubdia Channel	22 Feb 2023	21.814728° - 91.869565°
Nizampur	Meghna River	2 April 2023	21.894699° - 90.137158°
Nolian	Shibdah River	11 April 2023	22.460082° - 89.436424°
Ramgoti	Meghna River	23 March 2023	22.678353° - 90.910816°

Shoronkhola	Panguchi River	30 March 2023	22.472419° - 89.860601°
Bhatiyari	Bay of Bengal	27 March 2023	22.511468° - 91.700591°
Tojumuddin	Meghna River	22 Feb 2023	22.414012° - 90.851517°

Parameters and Analytical Method

All tests were performed at NGO Forum, Lalmatia, Dhaka. Instruments for measuring physicochemical parameters (EC meters, DO meters, Spectrophotometers) were calibrated using standard solutions. The Table 2 shown below summarized the physicochemical parameters analyzed in this study, along with the respective analytical methods and standard protocols followed.

Table 2: Analytical Methods for Water Quality Parameters

Parameter	Analytical Method	Standard Protocol
pH	Digital pH Meter	APHA 4500-H^+
Total Dissolved Solids (TDS)	Digital Conductivity/TDS Meter	APHA 2540C
Dissolved Oxygen (DO)	Winkler Titration Method	APHA 4500-O
Nitrate (NO_3^-)	UV Spectrophotometry	APHA 4500-NO_3 E
Chloride (Cl^-)	Argentometric Titration	APHA 4500-Cl^- B
Total Suspended Solids (TSS)	Gravimetric Analysis	APHA 2540D
Biochemical Oxygen Demand (BOD_5)	5-Day Incubation at 20°C	APHA 5210B
Electrical Conductivity (EC)	Digital Conductivity Meter	APHA 2510
Hardness (as $CaCO_3$)	EDTA Titrimetric Method	APHA 2340C

RESULTS AND DISCUSSIONS

Water Parameters

The Surface water quality of the coastal regions of Bangladesh was evaluated by analyzing their physicochemical parameters and comparing them with established standards according to WHO (WHO'11). The pH values of surface water samples in the coastal region range from 7.1 to 7.9. According to WHO'11, these values were within the range of 6.5–8.5.

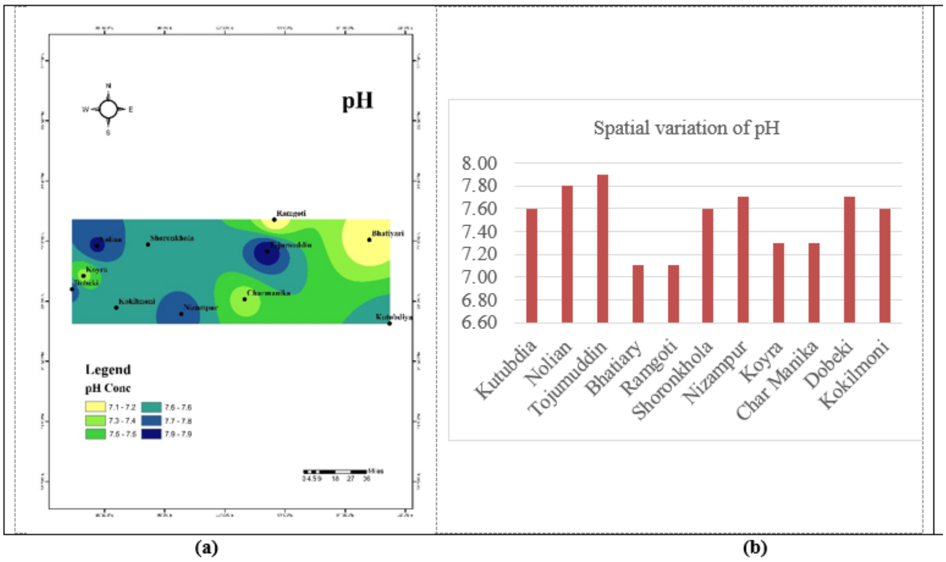


Figure 2: pH concentration: (a) Spatial Distribution using GIS, (b) pH vs Locations.

The average TDS value was remarkable high in the Kutubdia Channel, which was 25300 mg/L. In addition, the TDS values for the Meghna River in Ramgoti, Tajumuddin, Char Manika, Nizampur were 6430 mg/L, 2557 mg/L, 330 mg/L, and 7120 mg/L, respectively. On the other hand, the TDS values for the Java River at Kokilmoni, the Araibegi River at Dobeki, the Sakbaria River at Koyra, the Shibdah River at Nolian, the Panguchi River at Shoronkhola, and the Bay of Bengal at Bhatiyari were 13,160 mg/L, 13260 mg/L, 23000 mg/L, 3250 mg/L, 5840 mg/L, and 24000 mg/L respectively. According to WHO'10. The TDS readings for all surface waters, except Char Manika, were higher than the standard. The TSS value for all locations was within permissible limits.

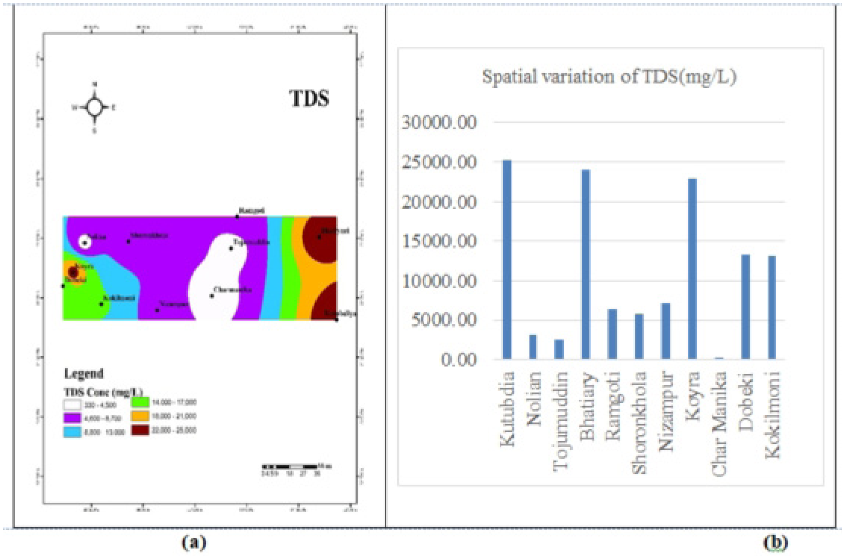


Figure 3: TDS concentration: (a) Spatial Distribution using GIS, (b) TDS vs Locations.

The dissolved oxygen for all samples was within standard limits. The average value was the minimum for Jamuna River at Ramgoti, which was 5.5 mg/L, and maximum was 6.1 mg/L at Char Manika. The nitrate value was maximum for the Meghna River at Char Manika which was 2.3 mg/l and maximum was 15.5 mg/L at Tojumuddin for the same river. All values for other river water were within the standard limit according to standards. The value of chloride in every river's surface water was higher than the recommended level, except for the Char Manika, which is less than 60 mg/l. The peak value was found at Bhatiary. At Bhatiary on the Bay of Bengal, the hardness and EC values are maximum, whereas at Char Manika, they are lowest. Others were found to be above the standard permissible limit. All BOD values, except for Tojumuddin and Nolian, were within the allowable range. These two stations had the same BOD result of 0.4 mg/L.

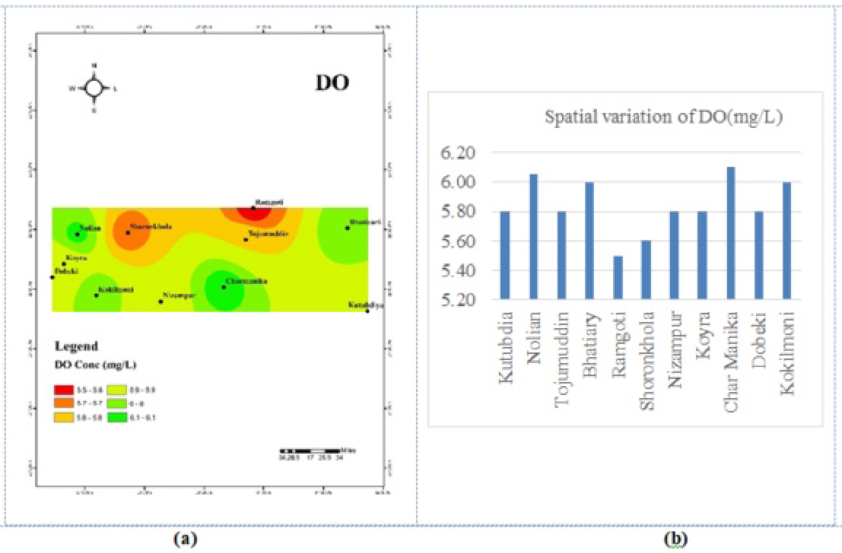


Figure 4: DO concentration: (a) Spatial Distribution using GIS, (b) DO vs Locations.

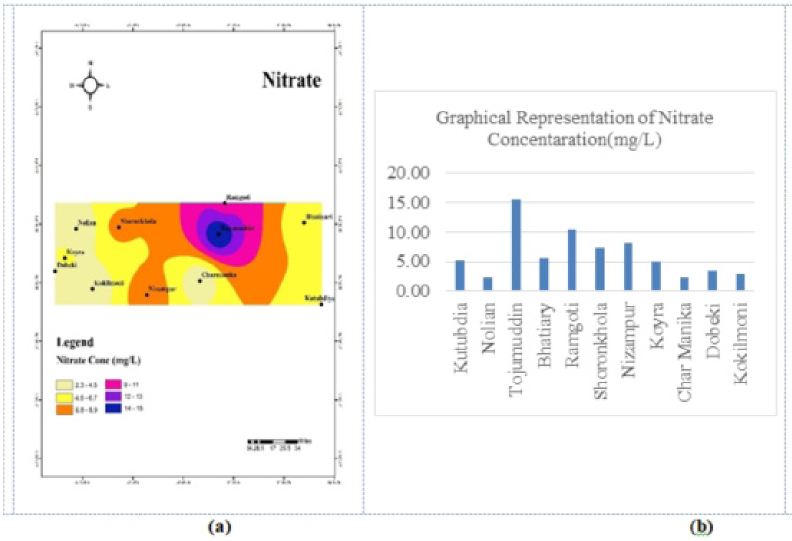


Figure 5: Nitrate concentration: (a) Spatial Distribution using GIS, (b) Nitrate vs Locations.

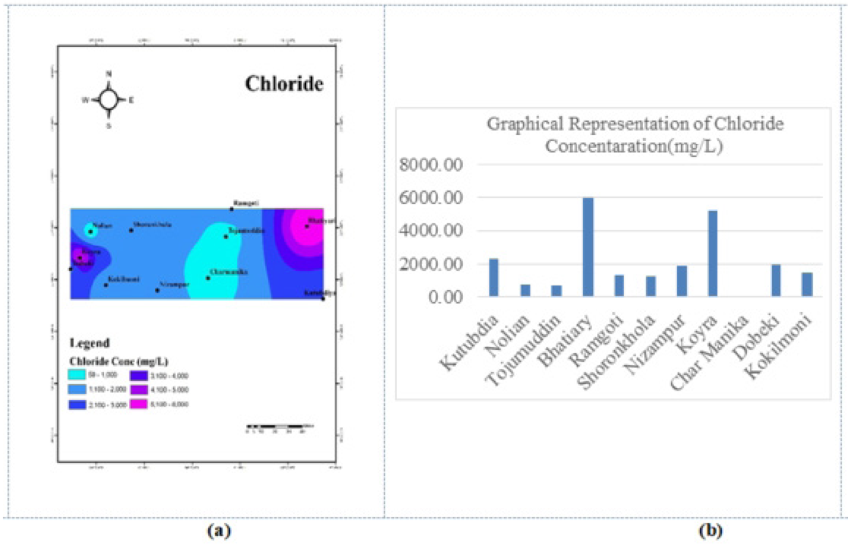


Figure 6: Chloride concentration: (a) Spatial Distribution using GIS, (b) Chloride vs Locations.

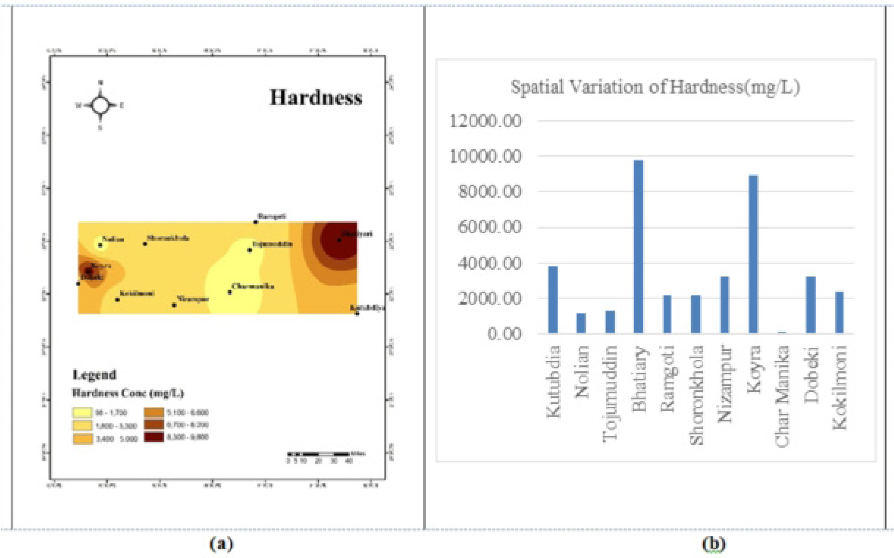
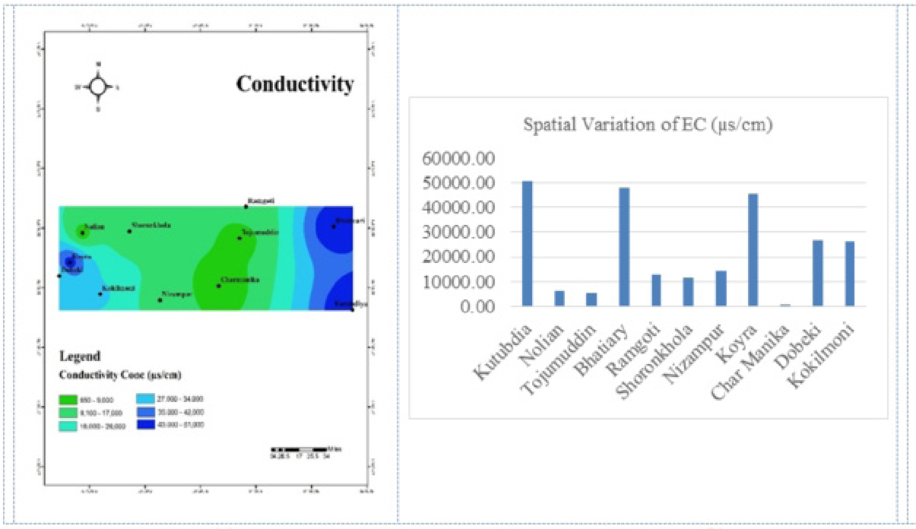
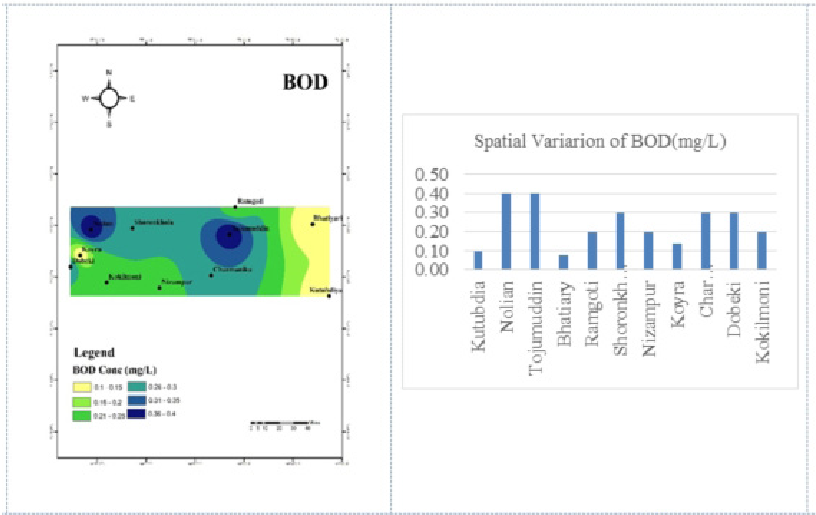


Figure 7: Hardness concentration: (a) Spatial Distribution using GIS, (b) Hardness vs Locations.



(a) (b)

Figure 8: EC concentration: (a) Spatial Distribution using GIS, (b) EC vs Locations.



(a) (b)

Figure 9: BOD concentration: (a) Spatial Distribution using GIS, (b) BOD vs Locations

Correlation with All Parameters

The co-relation matrix (Table 4) shows that conductivity is significantly linked with hardness, TDS, and chloride, negatively with BOD, moderately with pH, and poorly with nitrate and TSS. TDS, chloride, and hardness negatively affect pH. In addition to conductivity, Hardness is negatively correlated with pH and BOD and strongly positively correlated with link with TDS and chloride. Nitrate correlates negatively with DO and positively with TSS. Chloride has a negative correlation with BOD and pH and a positive correlation with conductivity, hardness, and TDS. DO is negatively impacted by concentration of nitrate.

Table 3: Correlation among different parameters

	Conductivity	pH	BOD	Hardness	Nitrate	TSS	Chloride	TDS	DO
Conductivity	1.000	-0.341	-0.845	0.830	-0.246	0.067	0.836	1.000	0.011
pH	-0.341	1.000	0.626	-0.505	0.150	-0.048	-0.515	-0.342	0.092
BOD	-0.845	0.626	1.000	-0.749	0.182	-0.059	-0.756	-0.845	0.114
Hardness	0.830	-0.505	-0.749	1.000	-0.100	0.307	0.999	0.831	0.018
Nitrate	-0.246	0.150	0.182	-0.100	1.000	0.655	-0.115	-0.247	-0.598
TSS	0.067	-0.048	-0.059	0.307	0.655	1.000	0.305	0.066	-0.215

Chloride	0.836	-0.515	-0.756	0.999	-0.115	0.305	1.000	0.837	0.028
TDS	1.000	-0.342	-0.845	0.831	-0.247	0.066	0.837	1.000	0.010
DO	0.011	0.092	0.114	0.018	-0.598	-0.215	0.028	0.010	1.000

CONCLUSIONS

From the experimental Data, the pH, DO, and Nitrate were within the acceptable limits according to WHO'11, except for the CharManika, all tested parameters such as TDS, chloride, EC, and Hardness values were high for the surface water. The graph generated by ArcGIS 10.5 presented above displayed fluctuations in the various parameters that were assessed during the study. It helped with the simplification and explanation of all evaluated factors by illustrating the intensity of different parameters within the study area. The high EC value indicated that the water at the chosen sites was saline, posing a greater risk of human indigestion. High Total Dissolved Solids (TDS) levels might lead to odor issues and be aesthetically unsatisfactory. The high value of Hardness might be caused by problems associated with scale formation. From the correlation, it was found that the correlation coefficient values between conductivity and TDS, conductivity and Hardness, and conductivity and chloride ions were positive, showing that TDS, Hardness, and chloride rise as conductivity increased. The increase in conductivity was positively associated with the presence of chloride ions in water. This principle also applied to the relationship between conductivity and Hardness. In conclusion, the surface water in most studied regions is not suitable for routine domestic use without treatment, especially due to high salinity and mineral content. The study also emphasized generally the need of efficient water management techniques to solve salt intrusion, nutrient loading, and other water quality problems in coastal Bangladesh.

While the study reiterated the need for legislative measures and integrated management of water resources to counteract salinity impacts, there is a need to understand predominant methodological shortcomings. These included limited seasonal coverage, absence of microbial or heavy metal data, and restricted longitudinal sampling. In addition, while spatial variability was traced well with GIS, hydrodynamic modeling and pollutant source tracing were not conducted. Future studies must incorporate with year-round surveys to assess seasonal dynamics; inclusion of toxicological parameters; hydrological modeling combined with remote sensing; surveys of community perceptions and uses of water. Relevant policy and stakeholder- specific recommendations are:

- Setting up coastal buffer zones to reduce saline ingress.
- Enforcing wastewater discharge regulations in upstream areas.
- Investment in decentralized water treatment to remove saline for high salinity areas.
- Regular monitoring for frameworks assisted by the government as well as local institutions.

By addressing these areas, future studies can not only build upon the findings of this research but also improve water security and resilience in vulnerable coastal zones of Bangladesh.

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