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Seasonal Variations of Water Quality Parameters off Togolese coast in Gulf of Guinea

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Abstract

Coastal water quality monitoring is crucial for understanding environmental impacts on marine life and its pollution. In this study, we monitored four (04) environmental water quality variables namely, temperature, salinity, dissolved oxygen and pH in the surface waters of Togolese coast around the port of fishing zone to examine the seasonal variations of water quality parameters. The fieldwork was conducted from January 2022 to September 2023 during low tide. Obtained results over this period shows that all water quality parameters have a seasonal variation in average, 27.9 ± 1.29 °C and 28.1 ± 1.96 °C for temperature; 35.2 ± 0.26 and 34.7 ± 0.5 for salinity; 5.77 ± 2.08 mg/l and 5.74 ± 2.37 mg/l for dissolved oxygen; and 7.94 ± 0.12 and 7.84 ± 0.15 for pH from dry season to rainy season, respectively. The Kruskal-Wallis test revealed that the season had no significant effect or there were no differences in water quality between seasons. This confirms that there are no variations in water quality in the Togolese coastal water around the fishing zone.

Key words: seasonal variation, water quality, surface coastal waters, port of fishing zone, Togolese coast.

Introduction

The Gulf of Guinea (GG) is a region located in the eastern Atlantic Ocean, which is bounded by the countries of Gabon, Cameroon, Equatorial Guinea, Sao Tome and Principe, Nigeria, Ghana and Togo. The GG is a critical marine ecosystem with high biodiversity and productivity, providing livelihoods for millions of people in West Africa[22,23,39]. The climate in this area is within the Guinean tropical climate. It is dominated by two dry seasons, August and November-March, and two rainy seasons, April-July and September-October[6]. The GG atmospheric conditions are governed by a regime of "trade winds" whose seasonal variation conditions the ocean[4,18,19,24,25]. During the boreal summer (June – September), in the eastern part of the basin a dominant trade winds (wind intensity 28 to 38 km/h) vary from south to southeast in the southern part of the Equator and become southwest along the GG coasts generating the West African monsoon[4,14]. Increased winds stress in the GG in boreal summer, leads to intense upwelling phenomenon characterized by the rise of deep higher nutrients, cold and high saline waters along the Equator and coasts[3,15,21,24,25,26]. Increase seasonal upwelling's activities mostly occurs in the equatorial and northern coasts and have a significantly impacts on surface water masses distribution of this region, that is strongly dependent on temperature and salinity variations[27,28]. The latter have a significant impact on marine life, climatic conditions and water quality parameters[5,20,27]. Also, a seasonal occurring of upwelling's in the GG during boreal summer significantly impact primary and fisheries productivity[16,17,21,22,38,40], with a positive effect on socio-economic of the bordering countries of this region[23].

The Togolese coast is an essential part of the GG ecosystem, supporting various marine species and human activities such as fishing, aquaculture, port activity and tourism. However, like many other coastal regions of the GG[1,2,8,9,10], the Togolese coast is subjected to various anthropogenic and natural stressors, which can significantly affect water quality parameters in this zone. Some of the essential water quality parameters that can be monitored in this coastal area include temperature, salinity, dissolved oxygen, pH, turbidity, and nutrient concentrations (nitrogen and phosphorus). These parameters can be affected by various factors, such as rainfall, rivers runoff, tidal movements, upwelling's, and human activities such as fishing, aquaculture, and marine pollution. The main source of marine pollution in this area is mainly caused by the steady increase of toxic heavy metals, hydrocarbons and radioactive pollutants, micro plastics pollutants, persistent organic compounds (agriculture pesticides and industrial chemicals), mining activities (case of Phosphate industry at Kpeme, Togo) mostly from terrestrial sources through groundwater intrusion and surface waters[30,31,32,33,34,35,36,42]. This consequently affects marine ecosystem and human life in this zone[29,37]. While we do have significant studies on water quality parameters estimate in soils, coastal sediments and lagoon systems in coastal environment[30,31,32,33,34,35,36,43], we are strongly missing the evaluation of water quality state in marine environment this due to lack of a continuous water quality monitoring.

The objective of this study is to investigate the seasonal variation of water quality parameters, temperature, salinity, dissolved oxygen and pH concentrations in the surface waters of Togolese coast around the port of fishing zone. Understanding the seasonal variation of water quality parameters off the Togolese coast is essential for effective management and conservation of the marine environment in the region.

Study area

This research was conducted in the coastal surface waters of the fishing zone of the port of Lomé (Togo) from January 2022 to September 2023. In-situ direct measured water quality parameters, temperature, salinity, dissolved oxygen and pH concentrations, were collected monthly/bimonthly at a selected sampling sites located at 6°5'49.90" degree Latitude and 1°18'47.79" degree longitude (Figure 1).

Data and Methods

Sampling was done only during low tide periods. This was to eliminate the influence of tide not a sampling time on measured parameters. Water samples collected were preserved at 4 degrees Celsius and analysed in the dedicate laboratory. The sampling chronogram of field measurements and data retrieved are presented in the Table 1.

Temperature and the dissolved oxygen concentration were measured by using oximeter probe (WTW Portable Dissolved Oxygen Meter ProfiLine Oxi 3310). The oximeter used works according to the polarographic principle of measuring dissolved oxygen (DO) which involves the use of an electrode. Oxygen diffuses through a thin Teflon membrane and depolarizes the platinum electrode (the cathode) brought to a negative potential. Oxygen is reduced at the cathode, the current produced being directly proportional to the concentration of dissolved oxygen. The current is then measured and converted by the oximeter, which directly gives the dissolved oxygen concentration value in mg/L. Temperature Range/Accuracy/ Resolution are from -5 to 105 °C / ± 0.1 °C / 0.1. DO Range/Accuracy/ Resolution are: 0 to 90 mg/L / ± 0.5 % of value / 0.01, 0.1 mg/L. The measurement of the water sample pH was carried out in a conventional manner with a field pH meter (Fisherbrand™ accumet™ Portable AP110 pH Meter) allowing reading to 1/100 of a unit. The method is based on the use of commercial electrodes and NIST buffers. The seawater conductivity and salinity were measured by using the Portable conductivity meter (WTW Cond 3110 SET 1) with an accuracy of ± 0.5 % v.m and the range is 0.0 to 70.0.

We used monthly surface gridded sea surface temperature (SST), salinity (SSS), dissolved oxygen and pH fields from Copernicus Global Ocean Biogeochemistry Analysis and Forecast data. This data set has a spatial resolution of 1/4 degree and is providing 10 days of 3D global ocean forecasts updated weekly. This product includes daily and monthly mean files available https://data.marine.copernicus.eu/product/GLOBAL_ANALYSIS_FORECAST_BIO_001_028/description. We used World Ocean Atlas (WOA18) data for comparison with our observed data. This dataset is a collection of objectively analyzed, quality controlled temperature, salinity, oxygen, phosphate, silicate, and nitrate means based on profile data from the World Ocean Database (WOA18) available at https://www.ncei.noaa.gov/access/world-ocean-atlas-2018 /

Statistical analysis

The seasonal variations of water quality parameters in our study area was assessed through boxplot analysis. As the number of the water quality data points measured are less than two in some seasons we grouped water quality parameters into a large rainy season (April-July and September-October) and large dry season (August and November-March). Since the data collected were abnormally distributed, the nonparametric Kruskal-Wallis Hypothesis test was applied to investigate the effect of the seasons and sampling times on water quality parameters following[1]. The Kruskal-Wallis is a nonparametric version of the classical one-way ANOVA. It is often used to compare samples from two or more groups. The Kruskal-Wallis test was used to compare medians of the sample and returned the p -values for the null hypothesis showing that all samples are drawn from the same population or equivalently from different populations with the same distribution. The statistical significance test level was fixed at 0.05 corresponding to 95% confidence interval. The Pearson correlation matrix was performed to figure out the relationship between water quality parameters.

Results

The temporal variation of water quality parameters of Togolese coast is represented in Figure2. Figure 2a shows that the temporal mean of water temperature was 28 ± 1.54 ˚C. The water temperature measured values ranged from 25.7 °C to 30.5 °C. The temporal mean of water salinity was 34.96 ± 0.41 and ranged from 34.2 to 35.4 (Figure 2b). Dissolved oxygen (DO) ranged from 2.63 mg/l to 7.84 mg/l with a temporal mean of 5.76 ± 2.07 mg/l. (Figure 2c). Surface water pH values ranged from 7.63 to 8.06. The temporal mean of measured pH values was 7.89 ± 0.13 (Figure 2d). In general, we observed that the temporal variations of the measured temperature and salinity values compare relatively well with WOA18 climatological and Copernicus forecast data in comparison to DO and pH measured values.

Seasonal variation of water quality variables is represented in Figure 3; and summarized in Table 2. The seasonal average of water temperature off Togolese coast was 27.9 ± 1.29 °C and 28,1 ± 1.96 °C, respectively during the dry season and rainy season. The maximum temperature of 30.5 ˚C was observed during the rainy season whereas the minimum of 25.7 ˚C was obtained during the rainy season (Figure 3.a). During the dry season and rainy season, temperature varied between 26 – 28.8 °C, and between 25.7 – 30.5 °C, respectively. The Kruskal-Wallis test, pvalue= 0.66 showed that temperature do not varied significantly from one season to another. The seasonal average of water salinity was 35.2 ± 0,26 and 34.7 ± 0,5 respectively during the dry season and rainy season. The maximum salinity of 35.4 was observed during the dry season whereas the minimum of 34.2 was obtained during the rainy season (Figure 3.b). During the dry season and rainy season, salinity varied between 34.9 – 35.4 PSU, and between 34.2 – 35.2, respectively. The Kruskal-Wallis test, p-value = 0.15 showed that salinity have not varied significantly from one season to another. The seasonal average of water DO was 5,77±2,08 mg/l and 5.74 ± 2,37 mg/l respectively during the dry season and rainy season (Figure 3c). The maximum DO of 7.84 mg/l was observed during the rainy season, whereas the minimum DO of 3.9 mg/l was measured during the dry season. During the dry season and rainy season, dissolved oxygen varied between 3.9 – 7.64 mg/l, and between 2.63 – 7.84 mg/l, respectively. The Kruskal-Wallis test, p-value =1 showed that DO didn’t varied significantly from one season to another. The seasonal average of water pH was 7.94 ± 0.12 and 7.84 ± 0.15, respectively during the dry season, and rainy season (Figure 3d). The maximum pH of 8.06 was observed during the dry season, whereas the minimum pH of 7.63 was measured during rainy season.

During the dry season and rainy season, pH varied between 7.83 – 8.06, and between 7.63 – 7.97, respectively. The Kruskal-Wallis test, p-value = .0.56 showed that pH also didn't varied significantly from one season to another over our period of study.

Table 3 provides the correlation matrix of water quality parameters. Analysis of the matrix of correlations of variables reveals a weak positive correlation $r = 0.02$, pvalue > 0.05 between salinity and pH, salinity and DO reveal a moderate positive correlation $r = 0.56$, pvalue > 0.05. A weak positive correlation $r=0.13$, pvalue> 0.05 is reveal between temperature and pH. In contrast, a strong negative correlation was found between temperature and salinity $r=-0.77$, pvalue > 0.05; temperature and DO, $r=-0.73$, pvalue> 0.05; DO and pH, $r=-0.58$, pvalue > 0.05.

Discussion

The seasonal variations in water quality parameters off the Togolese coast can be attributed to changes in weather patterns, tidal movements, and anthropogenic activities. Temperature temporal variations observed in the present study are mainly controlled by climate. The temperature values observed fits well within the range of the observed Gulf of Guinea climatological temperature[5,11,12,13]. We found a higher water temperature during the dry season and lower water temperature during the rainy season. This is in line with previous studies[1,41]. In fact, increase light intensity and wind influence on surface water masses distribution during the dry season lead to an increase in heat absorption as consequence the rise of sea surface temperature. This explain the higher observed temperature. In contrast, during the rainy season mostly during June - September (west Africa monsoon) the presence of clouds reduced considerably the surface waters masses gain in heat due to sunlight intensity. This explained the decreased of the temperature during the rainy season. Also, the observed minimum temperature during the rainy season is explained by the fact that during boreal summer (June – September), a strong thermal contrast is observed between the cold ocean and the warm continent, inducing the intensification of the trade winds from the ocean towards the continent with significant effect on coastal precipitations meaning cloudier environment[14]. Increased south west trade winds intensity during boreal summer lead to intense upwelling's characterized by a rise of deep cold waters along the West African countries coasts[21,24,25,26]. This significantly reduced temperature[5]. The relatively cooler measured temperature values of 26, 25.7 degrees Celsius observed during the month of August and September, respectively highlight a favourable upwelling year 2023 that might positively impact the abundance of halieutic resources. Further investigation of primary productivity and surface chlorophyll surface over our study period are needed to fully support our finding. The lower temperature values measured during the boreal summer season coincide well with the maximum observed salinity values characteristic of upwelling's water masses. This consequently will increase sea water oxygen concentrations in response to higher photosynthetic activities. This in line with the observed higher water oxygen levels > 7.8 mg/l. We found similar mean dissolved oxygen in both seasons around 5,7 mg/l with relatively similar lower mean seasonal temperatures and higher salinity. This suggest that the marine biota in the Togolese coastal water around the fishing zone according to the sea water quality standard for marine biota during the two years was favourable[41]. DO levels were generally lower (<4 mg/l) during the dry season months (January, October and December) This can be attributed to the low mixing of surface and bottom waters due to enhance stratification rate due to the heat gain during the winter boreal when the zonal winds activities are weak[1,5]. In fact, reduced mixing leads to less nutrients input in the stratified mixed layer as consequence a weaker primary productivity. During the month of December 2022, we luckily found a dead Tortoise around our sampling area highlighting a relatively severe ocean deoxygenation state in this zone. Further investigations are also needed to provide the main physical or biogeochemical processes. We found also that the DO was strongly inversely correlated to temperature. This is in line with previous studies[1]. In fact, increased water temperature will significantly reduce the solubility of sea water and enhanced loss of oxygen. The pH values ranged from 7.63 to 8.06 and seasonally 7,94 to 7,84 from dry season to rainy season, respectively. This indicate a slightly alkaline condition, a higher buffer capacity of Togolese coastal water. In general, the pH values range we found are in line with previous study[1]. Referring to the seawater quality standard for marine biota, namely 7 – 8.5, the pH conditions of the surface waters around the fishing zone is relatively good for the growth and development of aquatic biota. Seasonal changes in mean salinity was considerable 35.2, 34.7 from dry season to rainy season, respectively. This suggests that the influence of the freshwater intrusion in the surface waters off Togolese coastal is considerable. In fact, increase precipitations during the summer boreal and rivers/lagoon discharge could explained the changes we observed. Hydrogen ion concentration (pH) show weak positive correlation with salinity in this study ($r= 0.02$, p-value > 0.05). This result suggests that the state of the seasonal variation in pH in Togolese coastal water is less affected by local variation in salinity changes due to fresh water input or evaporation processes. In this study, we do not include the chlorophyll-a concentration, and turbidity data which are a key water quality parameters[1]. This is due to the lack of observations due to instrument limitation. Including those parameters are necessary to fully derived water quality index in this environment.

Conclusion

This study has revealed that there are no significant seasonal variations in water quality parameters in coastal waters of fishing zone over the study period. This suggests that the marine biota in these coastal waters around the fishing zone is relatively good for the growth and development of aquatic biota. A continuous monitoring is needed to further provide the most dominant parameters contributing to the fluctuations of water quality in this area, both in seasonal and spatial time scales for an optimal management of this coastal system. Further studies are recommended to assess the impact of human activities, such as heavy metals pollution due to hydrocarbons, oil accidental spilling, eutrophication due to human activities on the water quality parameters off the Togolese coast.

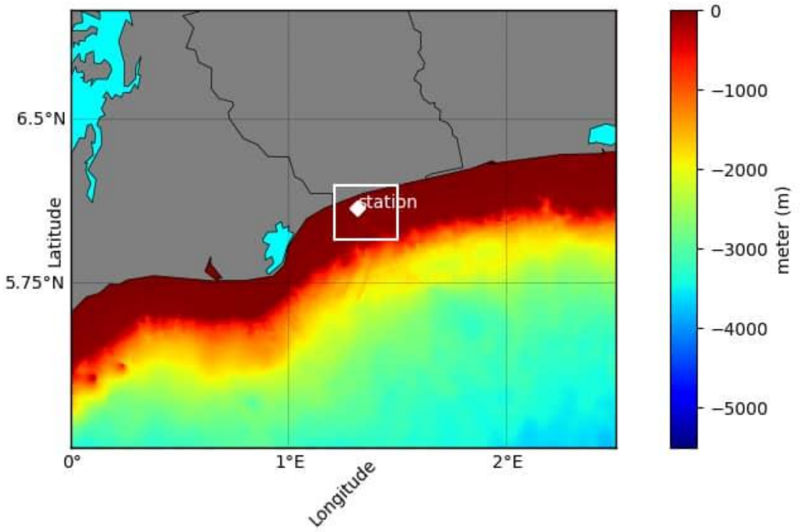


Figure 1: Location of the sampling station. With dot represents the exact position of the location where we collect the water quality parameters. The bathymetry data shown in background are from GEBCO database available at https://www.gebco.net/data_and_products/gridded_bathymetry_data/

Table 1: Chronogram of field measurements and data at sampling station located at: Longitude: 1°18'47.79”; Latitude: 6°5'49.90"

Date of sampling	Seasons	Sampling time (GMT)	Temperature (°c)	Salinity (PSU)	Dissolved Oxygen (mg/l)	pH
29/01/2022	Dry season	10:05	28.6	-	3.9	8.06
31/05/2022	Rainy season	13:06	28.0	35.07	7.34	7.63
18/10/2022	Rainy season	17:06	28.2	34.7	5.18	7.97
16/12/2022	Dry season	15:05	28.2	35.4	4.03	8.02
28/02/2023	Dry season	18:10	28.8	34.9	7.64	7.85
10/05/2023	Rainy season	16:01	30.5	34.2	2.63	7.87
30/08/2023	Dry season	11:39	26	35.3	7.52	7.83
11/09/2023	Rainy season	11:55	25.7	35.2	7.84	7.89

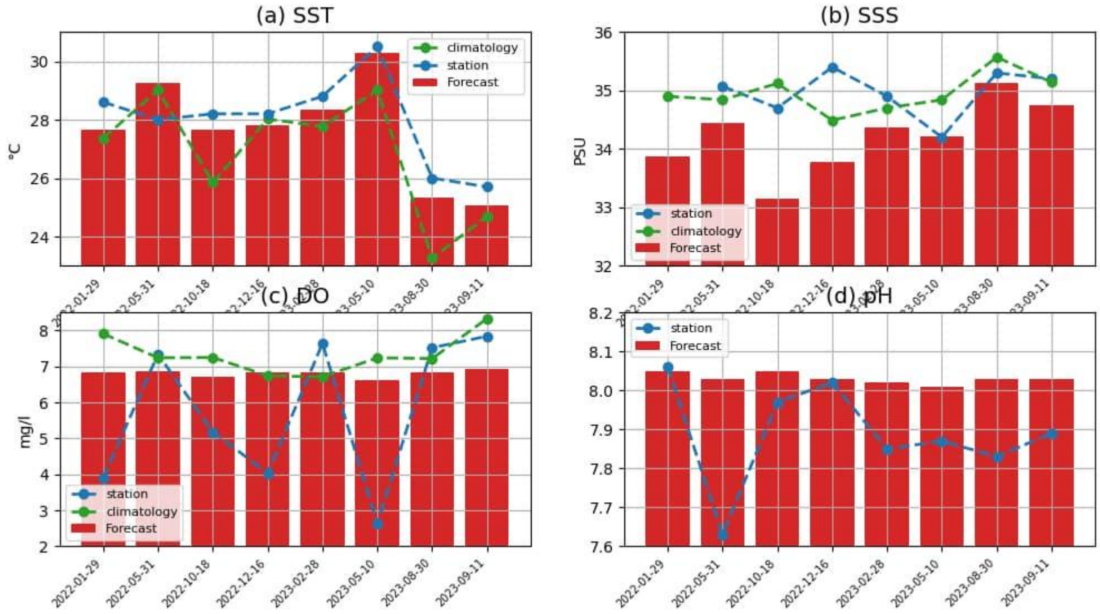


Figure 2. Time series of Water quality parameters (a) Sea Surface Temperature (SST), (b) Sea Surface Salinity (SSS), (c) Dissolved Oxygen (DO), (e) water pH monitored from January 2022 to September 2023 at the Port of Lome station (Blue line dash plot). The green dash dot line represents the climatology from World Ocean Atlas (WOA18[7]). The bar plots on top show the global ocean biogeochemistry analysis and forecast data from marine Copernicus data base. Both climatological and forecast data were average in the selected box (1.25E – 1.50 E; 5.95 N – 6.20 N) represented around the sampling station in white colour (Figure 1).

Table 2: Average, standard deviation (SD), and range of water quality parameters measure during the Dry and Rainy seasons.

Variables/Seasons	Dry Season (Average ± SD; Min - Max)	Rainy Season (Average ± SD; Min - Max)
Temperature (°c)	27,9±1,29°C (26 – 28.8)	28,1±1,96°C (25,7 – 30,5)
Salinity	35,2±0,26 (34,9– 35,4)	34,7±0,5 (34,2 – 35,2)
Dissolved Oxygen (mg/l)	5,77±2,08 (3,9 – 7,64)	5,74±2,37 (2,63 – 7,84)
pH	7,94±0.12 (7,83 – 8,06)	7,84±0,15 (7,63 – 7,97)

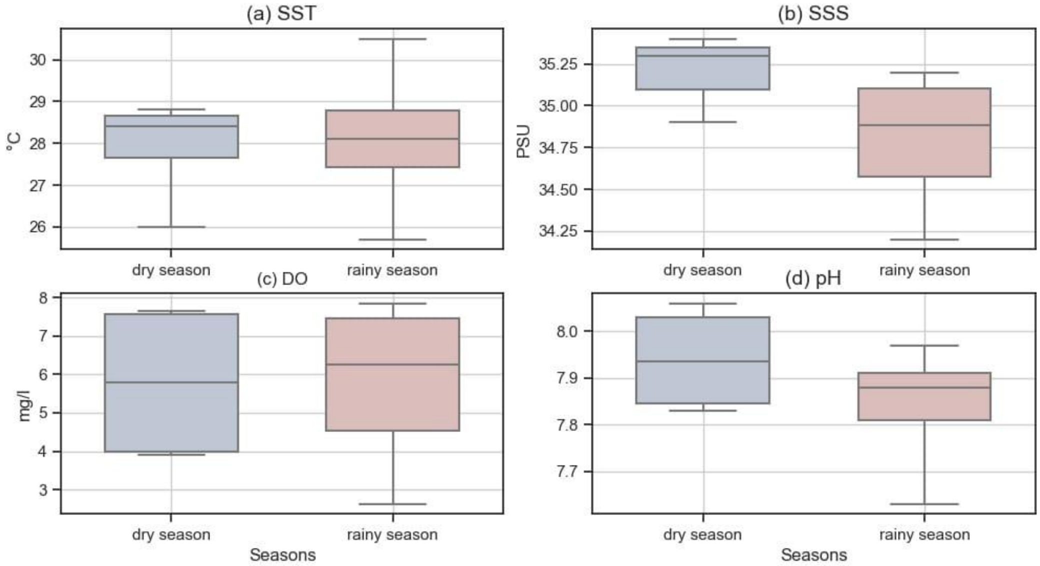
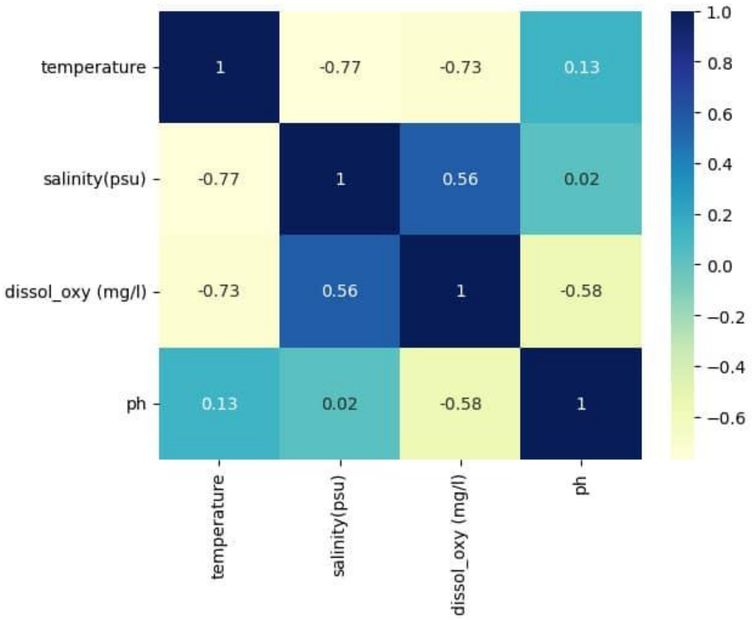


Figure 3. Seasonal variation of water quality concentration (a) Temperature, (b) salinity, (c) DO=dissolved oxygen and (d) water pH based on box plot analysis

Table 3: Correlation matrix of water quality parameters.



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