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The Seasonal Variations in Hydrological Factors in the Activity Zones: An Essential Examination of the Ecosystem in Badagry Creek, Lagos, Nigeria

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Abstract: The season is a pivotal representative in ascertaining the health status of a coastal ecosystem in a changing climate condition. The physico-chemical parameters of Badagry Creek were spatially and temporally investigated for twelve months (July 2017 to May 2018 for dry and wet seasons). Water samples were collected bi-monthly from nine stations, grouped into five activity zones during the water flow, covering upper, middle and lower courses. Seasonal variations in the physicochemical characteristics of Badgry Creek were found to be significantly different (<0.05) in salinity, phosphate, total suspended solids (TSS), total dissolved solids (TDS), depth, and dissolved oxygen (DO). Data were analysed using descriptive statistics, ANOVA and Spearman correlation at $\alpha_{0.05}$.

The wet season had greater values of conductivity (551.27±79.09µS/cm; 412.77±42.7µS/cm) , pH (7.43±0.39: 7.41±0.41), salinity (5.04±1.11ppt: 1.22±0.40ppt), DO (6.72±0.26: 5.39±0.58mg/l), and chloride (Cl^-, 684.51±82.50 µmol/L: 674.22±73.44 µmol/L) than the dry season respectively. An increase in salinity during the wet season indicates the seawater intrusion and the waste discharge effluents from domestic and aquaculture processes into the stream from the higher course. Significant differences were observed between the Aquaculture (AQ) and Aquaculture combined Dredging (AQ_DG) zone for Sulphate and Chloride (Cl^-).

The Biological Oxygen Demand (BOD) varied significantly between zones; they were 3.12±0.74mg/l in the Aquaculture zone (AQ) to 4.00±0.42 mg/l in the Domestic Waste (DW) zone and 2.10± 0.5 mg/l in the Aquaculture and Dredging (AQ_DG) zone to 19.2±9.44 mg/l in the Domestic Waste (DW) zone, respectively. The Highest value of TOM in DW station indicates anthropogenic effluents from domestic waste in this zone. The seasons were used to describe variations in Badagry Creek's physicochemical parameter values because the wet season noted higher parameter values, which may be related to an influx of water from the upper to the lower course.

Keywords: Dry season, wet season, salinity, domestic waste, aquaculture, sand dredging.

I. Introduction

Seasonal variations are one of the factors that determine the level of impact of climate change in marine ecosystems, previous studies from Chibwe *et al.*, 2024, had reiterated the changes that occurred in abundance of living organisms such as plankton, seasons and human activity in the areas that drain the rivers have an impact on the prevalence of campylobacter in rivers. Oases and rivers/lakes in dry regions are extremely vulnerable because of the overuse of water resources and the brittleness of the local ecological environment. Oasis shrinking, river drier conditions, and lake drying are examples of increasingly frequent occurrences (Chibwe *et al.,* 2024). Non-climatic stresses on fisheries, such as pollution, habitat loss, and overfishing, are likely to get worse due to climate change (Sumailia *et al.*, 2011; Etongo and Arrisol, 2021). The structure and productivity of marine and coastal ecosystems, as well as fish populations, are impacted by a number of factors, including rising temperatures, changed precipitation patterns, sea level rise, ocean acidification, and variations in dissolved oxygen concentration (Johanessen and Miles, 2011; Etongo and Arrisol, 2021). As a result, there is less vegetation and more frequent dust storms and deserts. This puts human health and survival in grave danger and has a substantial negative impact on the ecological stability of oases in arid regions and the basin ecosystem. (Zhang *et al.,* 2023), This indicates that the restoration of inland river ecosystems is significantly impacted by ecological water transfer, and plant restoration in numerous basins has been thoroughly studied (Lv *et al.,* 2012, Zhang *et al.,* 2015, Lv *et al.,* 2024). Fishery catches in tropical rivers are typically strongly correlated with seasonal fluctuation caused by the yearly food pulse (Castello et al., 2013; Pinaya et al., 2016; Furtado et al., 2023). The rise and fall in water levels are directly proportional to the richness of fish species. This suggests that changes in the cycle's intensity may have an effect on the features of local fish communities and fishery productivity (such as the composition and diversity of the catches; (Lowe-McConnell, 1999; Barthem and Fabré, 2004; Furtado et al., 2023). There are categories of parameters and indicators, such as, flow rate, water temperature, electrical conductivity (EC), dissolved oxygen (DO), pH, and REDOX potential, that are used in rating the health condition of marine ecosystems, this can be aligned to report of Yang *et al.,* 2024 on acid mine drainage, and based statement on 143 coal mines in Pennsylvania, USA. This study aimed to establish the physico-chemical parameters variation, (i) seasonally and (ii) spatially.

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II. Sampling and Analysis

2.1 Study Area

Lagos popularly known as the centre of excellence is blessed with features of mangrove swamps, lagoons, creeks, deltaic major tributaries, wetlands, and some of which are particularly noteworthy, like Badagry (Agboola *et. al.*, 2008). For the inhabitants, Badagry Creek is crucial for both agricultural and recreational uses (Olaide- Maseaku, 2010). But there's a chance of contamination. mostly impacted by fecal pollution from aquaculture, animal production, deteriorating wastewater treatment facilities, and agricultural practices. Furthermore, these marine water bodies' declining water quality is a result of an increasing population, haphazard settlements, inadequate water resource management, and malfunctioning wastewater infrastructure. The brackish Badagry Creek is incredibly rich in flora and fauna. It has provided transportation for the city of Lagos, employment opportunities for fishermen, industrial and manual sand dredging, ecotourism, and disposal sites for waste from homes, businesses, and aquaculture. The creek stretch is separated into three primary courses for this study in order to record the primary human activities that may be relevant to the physicochemical parameters, which are established in conjunction with the primary seasons (dry and wet seasons).

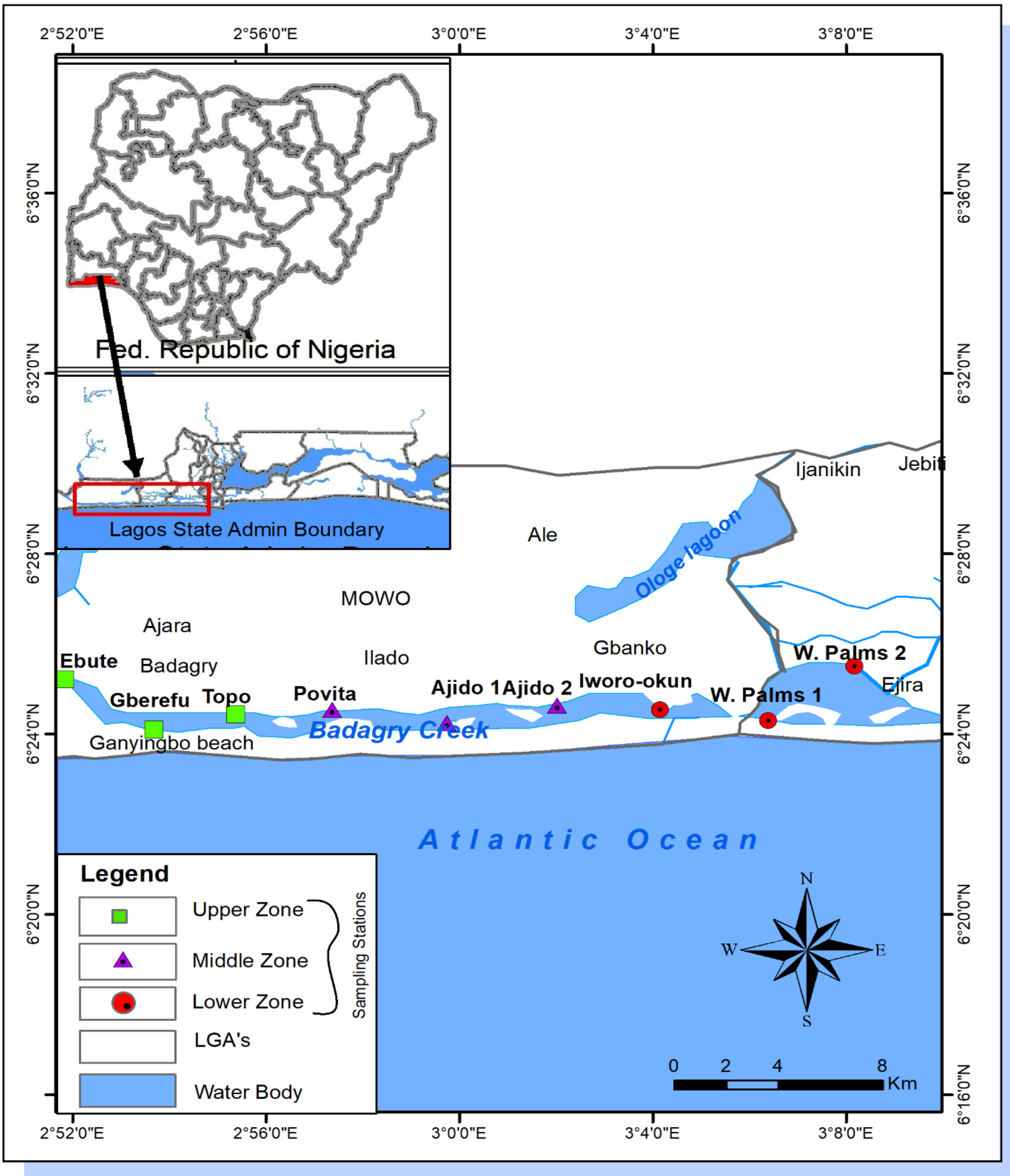

Figure 3.1: Study area's map showing sampling stations.

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Table 3.1: Anthropogenic activities grouping of sampling stations

Water zone	Stations	Site	Anthropogenic Code	Anthropogenic groups
Upper zone	Station 1	EBUTE	DW	Domestic waste
Upper zone	Station 2	GBEREFU	DW	Domestic Waste
Upper zone	Station 3	TOPO	DG_DW	Dredging and Domestic Waste
Middle zone	Station 4	POVITA	DG	Dredging
Middle zone	Station 5	AJIDO 1	DG	Dredging
Middle zone	Station 6	AJIDO 2	DG	Dredging
Lower zone	Station7	IWORO	AQ_DG	Aquaculture and Dredging
Lower zone	Station 8	WHISPERING PALMS 1	AQ	Aquaculture
Lower zone	Station 9	WHISPERING PALMS 2	AQ	Aquaculture

III. Collection of Water Samples

Water samples were collected from the surfaces of each station (nine stations; under the five groups activity) with a 1dm^3 water sampler and stored in 1.0 litre screw – capped plastic containers and stored in the refrigerator at $4^0C \pm 1^0C$ prior to analyses. The parameters determined were Salinity, pH, Alkalinity, Chloride, Dissolved Oxygen, Total Dissolved Solid, Nitrate, Nitrite, Phosphate, Sulphate using Lamotte Tracer, multimeter Water Kit, Code 1766, P.O Box 329, Chaster town, Maryland 21620 USA. www. Lamotte.com and APERA PC60 Premium Multi- parameter Tester. ISO 900/ 2015.APERA Instruments, LLC. www.apera inst.com.

BOD determination was carried out in glass bottle (3000ml) filled with 250 ml water at each station and fixed according to Winkler's method using Maganous sulphate and Alkaline Potassium Iodide reagents for dissolved oxygen determination. Air and surface water temperature was determined using mercury -in- glass thermometer *in situ*. The samples were preserved as recommended by APHA (1989).

Transparency: This was measured using a 15cm diameter Secchi disc. The point (length of rope submerged in cm) at which the disc disappeared when it was being lowered into the water and the point at which it reappears when it is being withdrawn shall be taken. The exercise shall be repeated twice at different locations within the body of water and the average shall be determined.

The analysis of variance was applied to the data (ANOVA), Speaman correlation, non-parametric test for two or more treatments, IBM-SPSS 24, for descriptive analysis, frequency analysis for significance at ∞0.05 (Fox *et al.*, 2012)

IV. Results and Discussion

4.1 Physico- Chemical Parameters of Water

Water Temperature

Surface water temperature across the anthropogenic zones was fairly stable and all the five zones showed similar trend with seasonal changes. Surface water temperature values throughout the sampling duration were 27˚C in the month of July, 2017 at stations under DW and 33˚C in May 2018 in AQ. The mean surface water temperature were 29±1.59˚C, 30±1.67˚C, 29.72±1.74˚C, 29.66±1.21˚C, and 29.5±1.5˚C, respectively for DW, DW_DG, DG, AQ_DG, and AQ zones, with an outstanding mean of 29.53±0.43˚C (Table 4.2), Season –wise mean surface water temperature was slightly higher in dry season 30.00±0.68˚C and lower in wet season 27.98±.46˚C. the result of ANOVA showed that there was no significant difference (P>0 .05) in water temperature among the zones and seasons.

Air Temperature

Mean air temperature (Table 4.1) 29±1.81˚C; DW recorded least, DW_DG; 29.5±2.81˚C, DG; 30.11±1.81˚C, AQ_DG; 30.33±1.5˚C) and the highest AQ ;30.58±1.83˚C. The results observed showed no significant difference (P> 0.05) across zones in air temperature.

pH

The range of pH values is 6.8 to 8.3. The maximum value was reported at the AQ_DG zone, while the lowest value was recorded at station 8 (Whispering Palms 1) during the dry season in March 2018 in AQ zone. The two zones in lower course, AQ_DG and AQ, more alkaline environments were observed in January during the dry season and May during the rainy season. Table 4.1 displays the mean pH values for each zone. The lowest value was 7.26±0.31, followed by the DW zone (7.40±0.38), the AQ zone (7.45±0.43), the DW_DG (7.56±0.6) zone, and the highest value (7.7±0.41) in the AQ_DG zone.

Electrical Conductivity

The average values of electric conductivity are shown in Table 4.1. The zone designated for DG_DW had the lowest values (3540±5129 µS/cm), while the zone designated for AQ_DG recorded the maximum value (13373±18435 µS/cm). In DG zone (9283±12100 µS/cm), the AQ (10446±12930 µS/cm), and DW value (4645±4976 µS/cm), the mean values grew significantly.

Transparency

The zones with the lowest spatially (zone) mean transparency were DG_DW; 0.67±0.2 and DW; 0.89±0.42, respectively, according to Table 4.1. The zone with the highest mean value was AQ_DG; 0.97±0.49m. The average transparency measure overall in (Table 4.2) recorded non significant value (P>0.05) among the zones in the variance transparency mean values studied.

Salinity

The mean salinity values were (Table 4.1; fig 4.1) 2.41±1.20ppt; DW, 2.83±2.00 ppt; DG_DW, 2.44±0.80 ppt; DG, 6.66±3.95 ppt; AQ_DG, and 3.25±0.93 ppt; AQ PSU, respectively. The wet season and AQ_DG produced the greatest salinity value.

Alkalinity

Throughout the course of the investigation, the alkalinity value ranged from 20 to 80 mg/L; the lowest value, 41.55±15.36 mg/L, was recorded in DG and highest of 56.66±16.03mg/L in AQDG zone.

Water Depth

The study period saw observations of water depths ranging from 0.72 meters to 3.24 meters. Table 4.1 presents the mean depth values of 1.93±.77m; DW ,1.47±0.88m; DG_DW, 1.86±0.91; DG, 1.48±0.66m: AQDG, and 1.37±0.55m; AQ.

Biochemical Oxygen Demand

The study (Table 4.1) examined the mean values of Biochemical Oxygen Demand across five distinct Anthropogenic activity zones. The values ranged from 1.37± 0.99mg/l, 1.11±1.02 mg/l, 1.01±0.76 mg/l, 1.38±1.11 mg/l, and 1.43±1.15 mg/l, representing the five zones, (DW, DGDW, DG, AQDG, and AQ).

Nitrate

Table 4.1 displays the mean concentration values of nitrate in each of the three zones: DG: 0.18±0.11µmol/L; DG_DW : 0.2±0.12µmol/L; DW : 0.22±0.11µmol/L; whereas the mean values for AQ and AQ_DG were 0.25±0.05µmol/L and 0.25±0.07µmol/L, respectively.

Phosphate

In the three zones DW, DG, AQ, the mean concentration values of phosphate (Table 4.1) were 0.02±0.02µmol/L. However, DGDW and AQDG, the values varied to 0.04±0.07µmol/L and 0.03±0.03µmol/L each.

Sulphate

Table 4.1 depicts the differences in sulphate concentrations between the zones. DGDW;11.83±4.35µmol/L<AQ; 16.16±5.14µmol/L, DW; 20.5±4.98µmol/L < DG;31.27±15.83µmol/L< AQDG; 34.83±33.12µmol/L in increasing order. The rainy season recorded (23.11±16.98µmol/L) and the dry season recorded (24.40±15.58µmol/L) had the greatest mean value.

Chloride

Chloride concentration went from 616.66 ±16.3 mg/l; DG DW to 793.33±27.3 mg/l; AQDG (Table 4.1). Across the DW, DGDW, DG, AQDG), and AQ, the mean values were 656±87.65, 616.66±16.32 mg/l, 663±1.87 mg/l, and 793.33±27.3 mg/l. The AQDG had value of 793.33±27.3 mg/l, stated as highest mean value.

Table 4.1: Means of Physico-chemical Parameters of Badagry Creek, Each Anthropogenic zone Activities zones

PHYSICO CHEMICAL PARAMETERS	DOMESTIC WASTE ZONE ACTIVITIES	DREDGING AND DOMESTIC WASTE ZONE	DREDGING ZONE ACTIVITIES	AQUACULTURE AND DREDGING ZONE ACTIVITIES	AQUACULTURE ZONE ACTIVITIES	Significance
pH	7.4±0.38[ab]	7.56±0.16[ab]	7.26±0.39[a]	7.7±0.41[b]	7.45±0.43[ab]	**>0.05**
Temperature (˚c)	29±1.59[a]	30±1.67[a]	29.72±1.74[a]	29.66±1.21[a]	29.5±1.5[a]	**>0.05**
Transparency (m)	0.89±0.42[a]	0.67±0.2[a]	0.9±0.43[a]	0.97±0.49[a]	0.94±0.46[a]	**>0.05**
Alkalinity (mg/L)	44.5±8.18[a]	45.66±10.61[a]	41.55±15.36[a]	56.66±16.03[a]	52.41±19.77[a]	**>0.05**

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Total suspended solids (mg/L)	13.67±5.87^{a}	12.63±3.29^{a}	13.11±5.7^{a}	12.83±3.2^{a}	10.99±3.82^{a}	**>0.05**
Total Dissolved solids (mg/L)	331.16±85.43^{a}	267.33±33.21^{a}	334.38±53.84^{b}	246.66±39.71^{a}	268±37.02^{a}	**>0.05**
Dissolved oxygen (mg/L)	6.33±1.24^{a}	6.66±1.53^{a}	5.66±1.23^{a}	6.08±0.91^{a}	6.04±1.26^{a}	**>0.05**
Nitrate(µmol/L)	0.22±0.11^{a}	0.2±0.12^{a}	0.18±0.11^{a}	0.25±0.05^{a}	0.25±0.07^{a}	**>0.05**
Phosphate (mg/L)	0.02±0.02^{a}	0.04±0.07^{a}	0.02±0.02^{a}	0.03±0.03^{a}	0.02±0.02^{a}	**>0.05**
Sulphate(µmol/L)	20.5±4.98^{ab}	11.83±4.35^{a}	31.27±15.83^{b}	34.83±33.12^{b}	16.16±5.14^{a}	**<0.05**
Salinity	2.41±4.16^{a}	2.83±4.91^{a}	2.44±3.43^{a}	6.66±9.68^{a}	3.25±3.22^{a}	**>0.05**
Chloride (µmol/L)	656±87.65^{ab}	616.66±16.32^{a}	663±71.87^{ab}	793.33±27.32^{c}	701.66±45.49^{b}	**<0.05**
BOD (g/L)	4±0.42^{b}	3.91±0.73^{b}	3.58±0.82^{ab}	3.75±0.52^{ab}	3.12±0.74^{a}	**<0.05**
Conductivity (µS/cm)	46.45±49.76^{a}	35.4±51.29^{a}	92.83±121.01^{a}	133.73±184.35^{a}	104.46±129.36^{a}	**>0.05**
Air Temperature (˚C)	29.25±1.81^{a}	29.5±2.81^{a}	30.11±1.81^{a}	30.33±1.5^{a}	30.58±1.83^{a}	**>0.05**
Total organic matter (sediment) (mg/l)	19.2±9.14^{a}	5.52±0.81^{b}	2.53±0.57^{b}	2.1±0.5^{b}	5.5±1.12^{b}	**<0.05**

The association among TSS, Alkalinity, Transparency, and Nitrite were found to be highly susbstantial (positive), the correlation, (Table 4.4), displayed positive among the pairs, Conductivity; Salinity (0.5), TSS; Alkainity (0.8), TSS; Transparency (0.5), TSS; Nitrite (0.6), Nitrate; Transparency (0.6), Transparency; Alkalinity (0.8) and Nitrate; Air temperature (0.6). The relationship between Nitrate and both transparency and Transparency was found to be highly notable (positive). The agreement association between conductivity and salinity, is an indication of discharge of ions in the creek.

Table 4.2: Spearman correlation analysis of the physico-chemical parameters

	pH	SALINITY	Cl^{-}	PHOSPHATE	DO	ALK	ATEMP	NITRATE	WT	BOD	TRAN	SULPHATE
PH												
SALINITY	.28*											
CHLORIDE	.44**	.34*										
PHOSPHATE	-0.10	-0.10	0.04									
DO	0.03	-0.04	0.11	0.05								
ALKALINITY	0.17	.44**	0.22	0.25	-.45**							
AIRTEMP	.28*	.37**	0.16	-0.15	-.37**	0.17						
NITRATE	.33*	0.15	.34*	0.12	0.05	0.10	0.16					
WaterTemp	0.07	.28*	-0.06	0.11	-.46**	.38**	.63**	0.12				
BOD	-0.10	0.00	-0.09	.33*	0.14	0.13	-0.11	-0.15	0.04			
TRANSPARENCY	0.13	.30*	0.01	0.21	-.48**	.72**	.314*	0.12	.32*	0.09		
SULPHATE	-0.15	0.11	-0.13	-0.01	-0.16	0.16	0.16	-0.12	0.18	0.23	.27*	
NITRITE	0.21	-.44**	0.13	-.31*	.36*	-.65**	-0.24	0.13	-.47**	-.37**	-.63**	-.35*

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DEPTH	-0.16	-0.14	0.00	0.22	-0.16	0.26	-0.22	-0.18	-0.06	0.08	.34*	0.15
TSS	-0.03	.50**	0.17	0.17	-.35**	.80**	-0.03	0.09	0.26	0.11	.51**	0.21
TDS	0.17	-.44**	-0.04	0.08	0.01	-.29*	0.10	0.10	-0.04	0.07	-0.05	-0.05
TOM	0.03	-0.01	-.29*	0.07	-0.01	0.21	-0.17	0.06	0.01	0.16	0.15	-0.11
CONDUCTIVITY	0.20	.56**	.42**	-0.19	-0.23	.30*	0.24	-0.02	0.13	-0.24	0.18	0.08
STATION	0.04	0.22	.37**	-0.11	-0.11	0.17	.33*	0.17	0.07	-.40**	0.11	-0.09

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

NOTE: ATEMP=AIR TEMPERATURE, WT=WATER TEMPERATURE, BOD= BIOLOGICAL OVYGEN DEMAND, CL= CHLORIDE, DO-DISSOLVED OXYGEN, ALK=ALKALINITY, TOM=TOTAL ORGANIC MATTER, TRAN=TRANSPARENCY, TSS= TOTAL SUSPENDED SOLID, TDS= TOTAL DISSOLVED SOLID, ST=STATION

Table 4.3: Seasonal variation of Physico-chemical parameters of Badgry Creek, Nigeria

PARAMETERS	DRY SEASON	WET SEASON	P VALUE
Salinity (ppt)	1.22±0.40	5.04±1.11	< 0.05
Biochemical Oxygen Demand (mg/l)	3.64±0.89	3.61±0.10	>0.05
Total Dissolve Solid (mg/l)	307.44±60.43	296.00±70.68	< 0.05
Nitrate (µmol/L)	0.23±0.02	0.20±0.01	> 0.05
Water Temperature (˚C)	29.44±0.97	29.63±2.02	>0.05
Sulphate (µmol/L)	24.40±15.57	23.11±16.98	> 0.05
Transparency (m)	0.92±0.35	0.87±0.48	> 0.05
Depth (m)	1.90±0.79	1.46±0.73	< 0.05
pH	7.41±0.41	7.43±0.39	>0.05
Chloride (µmol/L)	674.22±73.44	684.51±82.50	> 0.05
Dissolved Oxygen (mg/l)	5.39±0.11	6.72±0.26	< 0.05
Phosphate (µmol/L)	0.03±0.04	0.01±0.00	<0.05
Alkalinity	50.04±14.66	43.48±15.52	>0.05
Air Temperature (˚C)	29.66±1.41	30.30±2.28	
Conductivity (µS/cm)	412.77±42.7	551.27±79.09	>0.05
Total Suspended Solid (mg/l)	14.40±5.46	10.96±13.4	< 0.05
Total Organic Matter (mg/l)	7.20±1.43	7.16±1.61	<0.05

V. Discussion

Total organic matter was highest at DW site, and several times lower at other sites,slightly higher value noted during the dry season than wet season, this could be connected to the solid waste discharge from the jetty, market, municipal and house hold waste because of the nearness of the zone to the city. Surface water at the AQ_DG site was more brackish compared to other parts of the creek, a referral of the sea incursion into the creek in that zone. Alkalinity is a composition of ions, the common ion found in natural water are, Mg^{2+} , Ca^{2+}, HCO^-_3 ,highest amount registered in downstream , which revolved in dredging and aquaculture disturbances, this was associated with larger amounts of Ca and Mg ions are leached out due to the prolonged runoff period and increased evaporation intensity of recharge sources, the extended duration of the flow, it is a corroboration of previous work of (Yang *et al.*, 2024) that worked on the acid mine drainage , Wuma river basin , China. TSS and TDS were highest recorded values in DW zone, that corresponds to the low transparency value in the same zone, which denotes turbidity in marine environment, this gained the credibility that large amount of dissolved particles in DW could turn out to increase nutrient, the validation these findings is directly linked to the former works of (Chibwe *et al.*, 2024), on

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turbidity as a direct pointer for enrichment of nutrient that supported the growth of Campylobacter species in an Eastern Cape town river.TDS was highest at DW and DG sites. DW site showed the lowest mean surface water temperature while values were higher at the DG_DW site. BOD and nitrates did not significantly differ across sites, while sulphate level in surface water seemed to be lowest at the DG_DW site.Transparency and depth also did not differ across the major anthropogenic sites in the creek.

VI. Conclusion

The physicochemical parameters of the Badagry Creeks have demonstrated seasonal and temporal variations, with a level of significance (<0.05). These parameters include the biochemical oxygen demand, total organic matter, salinity, sulphate, total dissolved solids, and total suspended solids, which may be related to changes in the climate and disturbances caused by human interference. The significant need for breakdown from debris and household wastes has resulted in the weakly negative collaboration between Biochemical Oxygen demand and Total Organic Matter. Due to erosion, salinity reached a high concentration during the wet season, registering the entrance of current from the nearby sea into the creek.

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