Journal of Agricultural Science and Technology A 14 (2024) 193-205
doi: 10.17265/2161-6256/2024.05.003

Variations in Water Quality Index and Physicochemical Properties of Surface Water and Bottom Sediments of Selected Coastal Beaches of Niger Delta, Southern Nigeria

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Abstract: This study aimed to determine variations in water quality index (WQI) and physicochemical properties of surface water and bottom sediments of selected coastal beaches of Niger Delta, Southern Nigeria. The water quality of the river is categorized into five classes, which are classes I, II, III, IV and V based on the WQI (derived from the determination of DO, BOD, COD, TSS and ammonia and pH). Water and bottom sediment samples were analysed using standard procedures. During the wet season, physicochemical parameters such as potential hydrogen (pH), electrical conductivity (EC), dissolved oxygen (DO), total dissolved solids (TDS) and salinity showed significant difference ($p < 0.05$) across all the locations. During the dry season, parameters like EC, EA, pH, sodium (Na), sulphate (SO_4), chloride (Cl^-), potassium (K), effective cation exchange capacity (ECEC) and calcium (Ca) showed significant difference ($p < 0.05$) across all the six sampled beaches while phosphate (PO_4) did not show any clear significant difference across all the sampled locations. The general trend in the levels of physicochemical parameters revealed that temperature and pH were within those recommended by World Health Organization (WHO) and United States Environmental Protection Agency (USEPA) for both wet and dry season but EC and TDS were above the WHO and USEPA limit. Twenty one (21) water quality parameters from six sampling locations were studied and by applying WQI, the state of the six beach water was very unsuitable for drinking, swimming and recreational activities as at the time of this study. The water is only suitable for irrigation purpose.

Key words: Physicochemical, sediment, surface water, WQI, beach, recreation.

1. Introduction

Coastal beach water and sediment quality monitoring is necessary in present day society, especially for beaches affected by urban effluents. Studies on water and sediment quality in the aquatic environment are still popular in the evaluation and management of beach ecosystems in many countries [1]. This is due to the changes in water chemistry of beaches and drainages can be the results of domestic, industrial or agricultural discharges which may in turn lead to aquatic ecosystem degradation such as deterioration of water quality in the rivers and drainages [2]. Therefore, the determination of physicochemical parameters of the water and sediment samples can act as indicators of water pollution due to both natural and anthropogenic inputs.

An environmental assessment study has always proven to be helpful in ascertaining the safety of the environment. Hence, this study aimed to determine variations in water quality index (WQI) and physicochemical properties of surface water and bottom sediments of selected coastal beaches of Niger delta, southern Nigeria.

2. Methodology

2.1 Study Area

This research was conducted in Ibeno beach in Akwa- Ibom State, Okpoama beach (Brass) in Bayelsa State, Port-Harcourt Tourist beach in Rivers State,

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Marina's beach in Cross River State, Asaba (Otuogo) beach in Delta State and Agenebode beach in Edo State all in South-South geopolitical zone popularly known as Niger Delta region. The Niger Delta region in Nigeria is situated in the Gulf of Guinea between longitude 50 °E to 80 °E and latitude 40 °N to 60 °N (Fig. 1.) and it is the largest mangrove forest vegetation in Africa and the third largest in the world [3]. The Niger Delta is classified under the tropical rainforest that is located in the North of the Delta [4] which is located between 4 °N to 10 °N of the equator with an altitude that is less than 1,000 m and a mean annual rainfall that is always high and not the same within the region [3]. The annual rainfall ranges from 3,000 mm to 4,800 mm with a wet season between July and September and a dry season from December to February. Average monthly temperature is 27 ℃ [5]. Over 50% of the Niger Delta is water with thousands of creeks [6] and accounts for majority of the fresh water swamps in Nigeria [7].

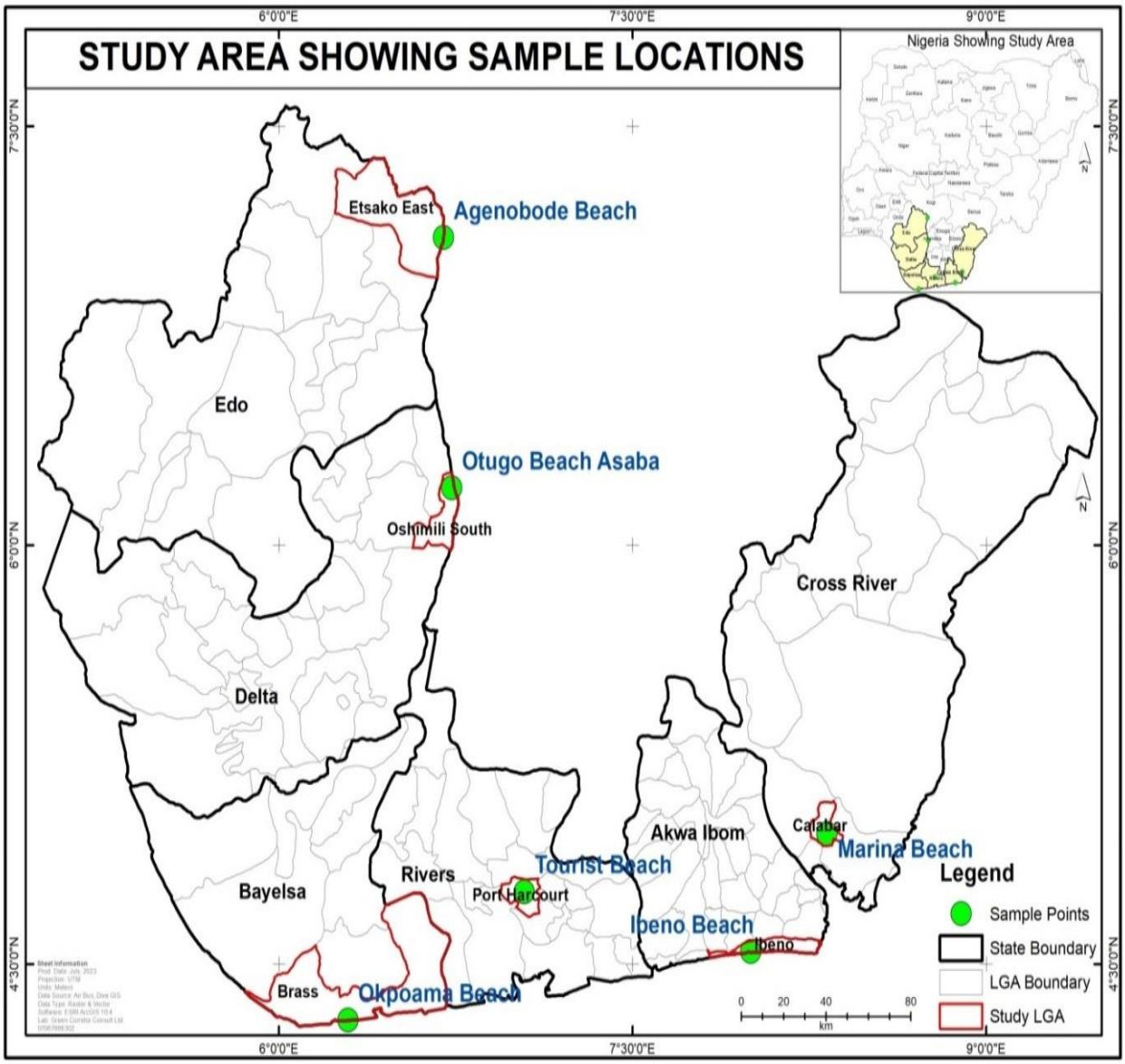

Fig. 1 Sampling location and states.
Source: Map created using Air Bus Diva GIS and ESRI ArcGIS (ver. 10.4).

2.2 Water Sample Collection

Water and sediment samples were collected multiple times between the months of March 2023 to February 2024 from the six sampling locations. Sampling was carried out between 7: 00 am and 11: 00 am (Nigerian time). Temperature, pH, electrical conductivity (EC), total dissolved solids (TDS) were analyzed in situ using handheld equipment. Sterilized 1 L plastic containers were used to collect water samples at chest level (1 m). To collect water from the beaches, the lid of the bottle was removed without touching the mouth of the bottles. The bottle was turned upside down at 20 cm below the surface. Then, the bottle was turned upward and when the bottle was approximately 2/3 filled, it was lifted above the surface and the lid was placed back [8].

2.3 Sediment Sample Collection

Sediment samples were collected from the six selected beaches with the help of a hand auger randomly after using transects to divide the beach area into different square metres and analysed for physicochemical parameters. The shape of the sampling location also determined how the sediment samples were collected. Samples collected were placed in an ice box and transported to Quality Laboratory, Edo State within 24 h for further analysis using the method of US EPA [9].

2.3.1 Determination of WQI

The water quality of the river is categorized into five classes: I, II, III, IV and V based on the WQI (derived from the determination of DO, BOD, COD, TSS and ammonia and pH), in Table 1 below, to determine whether the beach water is clean, slightly polluted or polluted based on the WQI and INWQS. The WQI was calculated based on six parameters; namely the mean of DO, BOD, COD, TSS, ammonia and pH values [10]. The procedure of calculation consists of 3 steps: to identity sub-index (SI) equation based on the value of parameter, to calculate sub-index (SI) of every parameter, and to calculate WQI. The formula is given below:

$$WQI = 0.22SI_{DO} + 0.19SI_{BOD} + 0.16SI_{COD} + 0.16SI_{SS} + 0.15SI_{AN} + 0.12SI_{pH} \quad (1)$$

where SI refers to the sub-index for each parameter, and the coefficients are the weighting factors derived from the opinion poll. SI_{DO} = Sub-Index of DO, SI_{BOD} = Sub-Index of BOD, SI_{COD} = Sub-Index of COD, SI_{SS} = Sub Index of TSS, SI_{AN} = Sub-Index of ammonia and SIpH = Sub-Index of pH. For this study, the WQI of each river zones (i.e. upstream, middle and downstream) was calculated.

2.3.2 Determination of Surface Water Physicochemical Properties

Determination of total hardness (TH), dissolved oxygen (DO), chloride, calcium, magnesium, nitrate-nitrogen and phosphate-phosphorus was done using standard methods applicable to them.

Table 1 Class description for water quality indices.

Class	WQI values	Description
I	> 92.7	Conservation of natural environment. Water Supply I: Practically no treatment necessary. Fishery I: Very sensitive aquatic species.
II	76.5-92.7	Water Supply IIA: Conventional treatment required. Fishery IIA: Sensitive aquatic species. IIB: Recreational use with body contact
III	51.9-76.5	Water Supply III: Extensive treatment required. Fishery III: Common, of economic value and tolerant species; livestock drinking.
IV	31.0-51.9	Irrigation
V	< 31.0	None of the above

Source: Nurul-Ruhayu et al. [11].

2.4 Sediment Analysis

Sediment analysis for the determination of macro and micro levels of element was done using the method of Allen et al. [12].

2.4.1 Determination of Physical Properties of Sediment

Particle size (PS): The particle size distribution was analyzed using hydrometer, a method described by [13].

2.4.2 Determination of Chemical Properties of Sediment

Determination of pH, total nitrogen, phosphorus, exchangeable bases (Mg, Ca, K and Na), total organic carbon and organic matter, exchangeable acidity and percentage base saturation was all done using the applicable standard methods.

2.5 Statistical Analysis

All statistical analyses were conducted using SPSS (version 26). All the data for heavy metal parameters were subjected to descriptive analysis to characterize the water and sediment samples in terms of the physical and chemical properties of the study area.

3. Results

Table 2 WQI for beach water samples during the wet and dry season.

Location	Wet season		Dry season	
	WQI (%)	Class	WQI (%)	Class
Tourist	58.4	III	62.1	III
Okpoama	53.1	III	60.6	III
Ibeno	49.9	IV	28.0	IV
Asaba	49.8	IV	54.3	IV
Marina's	58.3	III	55.7	III
Agenebode	51.2	III	50.0	IV
Mean	53.4		51.8	

Table 3 The mean (± SD) of water parameter in the selected recreational beaches for wet season.

Water parameter	Locations							
	Tourist Beach	Okpoama Beach	Ibeno Beach	Asaba (Otugo beach)	Marina's Beach	Agenbode Beach	Mean	WHO limits
pH	7.18 ±0.13^{c}	8.18 ±0.13^{b}	6.78 ±0.13^{e}	6.74 ±0.11^{f}	7.16 ±0.11^{d}	8.46 ±0.11^{a}	7.41	6.5-9.2
Temperature (℃)	28.22 ±0.13^{b}	28.88 ±0.13^{a}	28.18 ±0.13^{bc}	28.18 ±0.13^{bc}	28.22 ±0.1^{3b}	27.28 ±0.37^{c}	28.16	20-35 ℃
TDS (mg/L)	25,265.40 ±37.55^{e}	35,164.00 ±7.38^{c}	55,621 ±8.94^{a}	55,419.00 ±4.08^{b}	25,265.80 ±37.88^{e}	34,164.00 ±7.38^{d}	38,483.2	500-1,000 mg/L
EC (µs/cm)	50,558.80 ±34.74^{c}	70,328.80 ±7.01^{b}	111,256.60 ±3.91^{a}	111,256.60 ±3.91^{a}	50,558.80 ±34.74^{c}	70,228.80 ±7.01^{b}	77,364.73	1,000.0 µs/cm
Turbidity (mg/L)	15.42 ±0.10^{c}	125.72 ±0.84^{a}	125.22 ±0.42^{ab}	125.22 ±0.42^{ab}	15.42 ±0.10^{c}	125.72 ±0.84^{a}	88.78	5.0
Salinity (mg/L)	4,863.45 ±1.21^{f}	6,460.24 ±2.22^{d}	10,668.18 ±2.32^{bc}	10,670.18 ±2.35^{b}	13,989.60 ±2.82^{a}	6,060.24 ±2.22^{de}	8,785.31	1,000 mg/L
DO (mg/L)	2.30 ±0.10^{c}	4.70 ±0.12^{a}	3.52 ±0.08^{b}	3.52 ±0.08^{b}	2.30 ±0.10^{c}	4.70 ±0.12^{a}	3.50	4.0 mg/L
BOD (mg/L)	0.76 ±0.06^{c}	2.37 ±0.04^{a}	1.82 ±0.08^{b}	1.82 ±0.08^{b}	0.76 ±0.05^{c}	2.37 ±0.04^{a}	1.65	6.0 mg/L
PO_4 (mg/L)	0.03 ±0.00^{b}	0.02 ±0.00^{c}	0.06 ±0.09^{a}	0.06 ±0.09^{a}	0.03 ±0.00^{b}	0.02 ±0.00^{c}	0.03	5 mg/L
Ca (mg/L)	318.18 ±1.29^{bc}	381.83 ±1.55^{b}	423.68 ±2.38^{a}	423.68 ±2.38^{a}	318.18 ±1.29^{bc}	381.83 ±1.55^{b}	374.56	75.00 mg/L
Mg (mg/L)	515.60 ±0.87^{d}	862.50 ±4.16^{c}	2,577.60 ±7.20^{a}	2,577.40 ±6.88^{b}	515.60 ±0.87^{d}	862.50 ±4.16^{c}	1,318.53	50.00 mg/L
TH (mg/L)	2,920.12 ±2.22^{c}	4,521.64 ±1.81^{b}	12,103.94 ±3.59^{a}	12,103.94 ±3.59^{a}	2,920.12 ±2.22^{c}	4,521.64 ±1.81^{b}	6,515.23'	100.0 mg/L

Data are mean values (±SD) of three replicates. Means in the same column with different superscript letters are significantly different ($p < 0.05$) (Fisher's LSD). DO: dissolved oxygen, TDS: total dissolved solid, EC: electrical conductivity, BOD: biological oxygen demand, PO_4: phosphate, Ca: calcium, Mg: magnesium, TH: total hardness.

Table 4 The mean (±SD) of water parameter in the selected recreational beaches for dry season.

Water parameter	Locations							
	Tourist Beach	Okpoama Beach	Ibeno Beach	Asaba (Otugo beach)	Marina-s Beach	Agenbode Beach	Mean (%)	WHO Limits
pH	7.66 ±0.05^{cd}	8.52 ±0.08^{b}	6.30 ±0.73^{f}	6.80 ±0.07^{e}	7.62 ±0.08^{c}	9.20 ±0.28^{a}	7.68	6.5-9.2
Temperature (℃)	30.24 ±1.65^{a}	30.08 ±0.28^{b}	19.02 ±14.83^{f}	28.98 ±0.84^{e}	29.60 ±0.47^{c}	29.46 ±0.58^{d}	27.89	20-35 ℃
TDS (mg/L)	26,265.40 ±37.54^{e}	36,164.00 ±7.38^{c}	56,621.00 ±8.94^{a}	56,619.00 ±7.42^{b}	26,265.80 ±37.88^{e}	35,164.00 ±7.38^{d}	39,516.5	500-1,000 mg/L
EC (µs/cm)	51,558.80 ±34.74^{e}	71,328.80 ±7.01^{c}	121,256.60 ±3.91^{ab}	121,258.00 ±1.41^{a}	51,558.80 ±34.74^{e}	71,228.80 ±7.01^{d}	81,364.96	1,000.0 µs/cm
Turbidity (mg/L)	15.62 ±0.53^{c}	125.72 ±0.53^{a}	125.22 ±0.84^{ab}	125.22 ±0.47^{ab}	15.42 ±0.42^{d}	125.72 ±0.10^{a}	88.82	5.0
Salinity (mg/L)	5,959.96 ±8.14^{f}	9,460.24 ±2.22^{c}	12,675.91 ±10.30^{a}	11,670.18 ±15.35^{b}	6,867.96 ±1.75^{e}	8,060.24 ±2.22^{d}	9,115.74	1,000 mg/L
DO (mg/L)	3.50 ±0.51^{e}	6.50 ±0.41^{a}	5.88 ±1.00^{b}	4.72 ±1.12^{c}	4.30 ±0.10^{cd}	5.70 ±0.12^{b}	5.1	4.0 mg/L
BOD (mg/L)	1.76 ±0.06^{f}	4.17 ±0.43^{bc}	3.84 ±1.21^{cd}	3.42 ±1.48^{de}	5.16 ±0.86^{a}	4.97 ±0.57^{ab}	3.88	6.0 mg/L
PO_4 (mg/L)	0.03 ±0.00^{c}	0.03 ±0.00^{c}	0.86 ±1.70^{a}	0.12 ±0.08^{b}	0.03 ±0.00^{c}	0.02 ±0.00^{d}	0.18	5 mg/L
Ca (mg/L)	332.18 ±5.81^{e}	391.83 ±1.55^{c}	433.72 ±2.43^{a}	429.68 ±6.61^{ab}	338.18 ±1.28^{d}	391.83 ±1.55^{c}	386.23	75.00 mg/L
Mg (mg/L)	525.60 ±0.87^{e}	882.50 ±6.88^{bc}	2,677.60 ±7.19^{a}	2,677.40 ±6.88^{a}	545.20 ±5.59^{d}	884.50 ±2.50^{b}	1,365.46	50.00 mg/L
TH (mg/L)	3,920.12 ±2.22^{d}	4,717.64 ±9.72^{c}	13,103.92 ±3.57^{a}	13,103.94 ±3.59^{a}	3,920.12 ±2.22^{d}	5,521.64 ±1.81^{b}	7,381.23	100.0 mg/L

Data are mean values (±SD) of three replicates. Means in the same column with different superscript letters are significantly different ($p < 0.05$) (Fisher's LSD). DO: dissolved oxygen, TDS: total dissolved solid, EC: electrical conductivity, BOD: biological oxygen demand, PO_4: phosphate, Ca: calcium, Mg: magnesium, TH: total hardness.

Table 5 The mean (± SD) of physicochemical characteristics for beach bottom sediment samples in wet season.

Physicochemical characteristics (sediment) wet season	Locations							
	Tourist Beach	Okpoama Beach	Ibeno Beacsh	Asaba (Otugo beach)	Marina's Beach	Agenobode Beach	Mean	WHO limits
pH	3.56 ±0.11^{e}	6.40 ±0.10^{c}	8.16 ±0.15^{b}	8.42 ±0.08^{a}	8.42 ±0.08^{a}	4.30 ±3.03^{d}	6.88	6.5-8.5 m
EC	11,154.00 ±16.36^{b}	16,504.00 ±27.02^{a}	5,505.80 ±22.55^{d}	6,156.20 ±15.61^{c}	6,156.20 ±15.61^{c}	4,937.32 ±28.14^{e}	8,402.25	1,500
EA	1.12 ±0.11^{b}	0.16 ±0.05^{c}	1.50 ±0.10^{b}	1.42 ±0.08^{b}	1.26 ±0.11^{b}	2.25 ±2.54^{a}	1.28	-
ECEC	1,238.93 ±3.11^{d}	1,320.38 ±9.90^{c}	5,714.27 ±6.25^{a}	5,253.46 ±15.72^{b}	1,217.58 ±5.58^{e}	784.05 ±7.25^{f}	2,588.11	-
Phosphate	19.73 ±0.08^{b}	27.51 ±0.34^{a}	9.78 ±0.13^{e}	9.81 ±0.12^{d}	9.81 ±2.41^{d}	13.59 ±11.04^{c}	15.03	5.0
Chloride	5,341.88 ±3.24^{b}	8,098.80 ±8.26^{a}	2,682.87 ±43.1^{d}	2,601.86 ±2.41^{d}	2,601.86 ±2.41^{d}	3,662.22 ±3.05^{c}	951.86	
Sulphate	301.52 ±1.21^{a}	135.00 ±3.30^{b}	52.05 ±0.57^{d}	52.55 ±0.81^{d}	52.55 ±0.81^{d}	77.17 ±69.63^{c}	111.80	240.0
Sodium	939.20 ±4.32^{c}	880.42 ±7.83^{e}	2,356.40 ±88.40^{a}	2,206.60 ±7.02^{b}	912.10 ±1.56^{d}	530.95 ±4.43^{f}	4,175.82	
Potassium	45.80 ±1.30^{e}	138.58 ±1.87^{c}	2,506.20 ±6.65^{a}	2,116.80 ±5.54^{b}	37.80 ±1.30^{f}	71.83 ±64.67^{d}	819.50	
Calcium	85.88 ±0.84^{d}	101.78 ±0.87^{c}	144.57 ±2.58^{a}	138.04 ±2.88^{b}	78.30 ±1.75^{e}	59.43 ±3.15^{f}	101.33	
Magnesium	190.33 ±0.32^{d}	199.44 ±1.31^{c}	879.40 ±7.99^{a}	790.60 ±5.27^{b}	188.12 ±1.19^{e}	121.11 ±5.00^{f}	394.83	

Data are mean values (±SD) of three replicates. Means in the same column with different superscript letters are significantly different ($p < 0.05$) (Fisher's LSD).

Table 6 The mean (± SD) of physicochemical characteristics for beach bottom sediment samples in dry season.

Sediment physicochemical parameters (dry season)	Locations							
	Tourist Beach	Okpoama Beach	Ibeno Beach	Asaba (Otugo beach)	Marina's Beach	Agenebode Beach	Mean	WHO limits
pH	5.96 ±0.55^{e}	6.68 ±0.084^{d}	8.63 ±0.22^{c}	8.70 ±0.10^{a}	8.68 ±0.15^{ab}	6.68 ±0.13^{d}	7.55	6.5-9.2
EC	12,374.00 ±440.84^{b}	17,904.00 ±571.60^{a}	6,302.00 ±422.12^{d}	6,214.20 ±77.17^{f}	6,247.20 ±102.83^{e}	8,327.00 ±17.38^{c}	9,561.4	1,500
EA	3.18 ±0.80^{a}	0.40 ±0.07^{e}	1.70 ±0.14^{b}	1.68 ±0.18^{c}	1.42 ±0.08^{d}	1.68 ±0.08^{c}	1.67	
ECEC	1,369.03 ±7.89^{e}	1,426.62 ±40.12^{c}	6,295.86 ±258.56^{a}	5,355.52 ±47.19^{b}	1,274.74 ±10.36^{f}	1,394.04 ±36.69^{d}	2,852.63	
Phosphate	24.93 ±1.46^{c}	30.11 ±1.05^{b}	10.81 ±0.45^{d}	10.61 ±0.49^{f}	10.81 ±0.12^{e}	42.70 ±1.34^{a}	21.66	5.0
Chloride	5,741.88 ±72.80^{c}	8,558.80 ±265.12^{a}	2,854.54 ±100.08^{d}	2,665.26 ±41.10^{f}	2,685.86 ±21.30^{e}	6,180.20 ±10.51^{b}	4,831.09	

Table 6 to be continued

Sulphate	392.92 ±10.73[a]	139.20 ±0.76[c]	58.95 ±1.76[f]	60.95 ±1.76[e]	67.15 ±1.88[d]	140.24 ±3.01[b]	132.04	240.0
Sodium	9,320.80 ±551.04[b]	9,543.00 ±126.49[a]	2,607.50 ±5.26[e]	1,926.80 ±6.42[f]	8,842.00 ±15.17[d]	9,204.40 ±8.82[c]	6907	
Potassium	100.62 ±5.82[d]	118.36 ±1.77[c]	268.90 ±12.95[a]	236.90 ±8.46[b]	97.14 ±1.61[e]	117.68 ±4.39[c]	156.6	
Calcium	98.08 ±1.68[f]	114.18 ±3.92[c]	153.91 ±2.69[a]	146.84 ±3.33[b]	88.30 ±1.75[e]	108.32 ±1.21[d]	118.27	25.0
Magnesium	194.23 ±0.21[d]	201.32 ±1.22[c]	880.25 ±4.54[a]	807.30 ±6.33[b]	190.13 ±1.13[e]	128.20 ±6.20[f]	400.23	

Data are mean values (±SD) of three replicates. Means in the same column with different superscript letters are significantly different ($p < 0.05$) (Fisher's LSD).

4. Discussion

4.1 WQI of Surface Water from Six Sampled Beaches during the Wet and Dry Season

Water is important in the life of humans, plants and other aquatic organisms. Access to clean water remains one of the major requirements of a healthy society. The result of this study showed the major physicochemical parameters used to assess the water quality of the six sampled coastal beaches in South-South Nigeria. Following the class description for water quality indices by Nurul-Ruhayu et al. [11] in Table 1, the ranking in the order of quality was Tourist beach > Marina's beach > Okpoama beach > Agenobode beach > Ibeno beach > Asaba beach during the wet and in the dry season. The water quality showed that none of the water from the beaches was suitable for drinking and recreational purpose as at the time of the study.

The WQI values recorded in the present study were 58.4, 53.1, 49.9, 49.8, 58.3 and 51.2 for the six sampled beaches (Tourist, Okpoama, Ibeno, Asaba, and Agenobode) respectively for the wet season and 62.1, 60.6, 28.0, 54.3, 55.7, 50.0 for the dry season. The values gotten in this study were higher in the dry season than in the wet season. The values observed in the present study were lower than that reported by Ayobahan et al. [14] who recorded cumulative WQI values of 234.45, 315.26, 248.08, 1,710.49 and 1,421.06 in five sampling stations respectively from a study on the anthropogenic activities on water quality of a section of Niger River. The poor WQI values observed in the present study must have been contributed by pH, EC, TDS, Ca, Cl^-, Na, K, PO_4, NO_3.

4.2 Physicochemical Composition for Beach Water Samples during the Wet Season

The physicochemical parameters revealed the underlying properties of water and further gave an insight into the portability and how safe the water is for swimming for both humans and aquatic organisms. Temperature plays an important role in determining the quality of water in an area and it can be influenced by several factors like thermal discharge, water body size and depth, geographical location and water source of the water [15]. Temperature showed no significant difference ($p < 0.05$) across all locations during the wet season but showed significant difference across all the locations during the dry season. Temperature values were generally higher in the dry season than in the wet season with an overall maximum of 28.88 ℃ and 30.24 ℃ for wet and dry season respectively. The levels of temperature between the six sampling points were relatively high. This might be due to the high temperature during the sampling periods, changes in solar radiation, cloud cover and sampling time [16]. These values are in tandem with the temperature values reported by Uttah et al. [15] and Mustapha [16].

The potential hydrogen ion (pH) in an aquatic ecosystem is the measure of hydrogen ions in a given sample and can be altered by biological activities due to changes that can threaten the life of the organisms [17]. The pH values for the two seasons ranged from slightly acidic to neutral and basic (6.7, 7.1 and 9.2). The pH values recorded were higher in the dry season than in the wet season. Most fish can tolerate pH values of about 5.0 to 9.0. The pH values for the six sampled beaches were within the stipulated values of 6.0-9.2 for

drinking water and water meant for full contact recreation [8]. The EU also sets pH protection limits of 6 to 10 for fisheries and aquatic life [18]. The pH values obtained in the beaches fell within this range. So many researchers have worked on the water pH in the Niger Delta but this present study agreed with the work of Okorafor et al. [19] who obtained a high pH value of 7.2-7.45 downstream and upstream of the lower Qua Iboe River in Akwa Ibom State. The pollution level in an aquatic environment or surface water can be estimated from the concentration of TDS present in the environment [20]. Excessive TDS can reduce water clarity, hinder photosynthesis, and lead to increased water temperatures [21].

The mean TDS values of surface water samples gotten from the six locations in this study was 38,483.2 mg/L for the wet season and 39,516.5 mg/L for the dry season. The TDS values recorded were higher in the dry season than the wet season. This result is in disagreement with the work of Okorafor et al. [19] who recorded lower values of 36.09 and 68.9 mg/L for the wet and dry season at Lower Qua Iboe River in Akwa Ibom State which he attributed to tidal influence of the river. The TDS values recorded in the present study are consistent with the values (1,176-1,678 mg/L) recorded by Akan et al. [22] in their work on assessment of pollutants in water and sediment samples in Lake Chad, Baga, North Eastern Nigeria. The high level of TDS recorded in this study may be due to the presence of dissolved organic matter from industrial waste discharge around the beaches and the high level of organic salts (sodium, pottasium, calcium, magnessium, chloride and sulfates).

The TDS levels recorded in the entire sample points were however, above the WHO guideline of 500-1,000 mg/L for the protection of fisheries and aquatic life and for domestic water supply. This constitutes a great danger to the tourists and swimmers who patronize the beaches for recreation. Conductivity is a measure of the ability of an object or material to allow electrical current to pass through it and it can be affected by various physicochemical properties including dissolved ions (such as salts of Ca, Mg, Na, K and Cl^-), pH, temperature and dissolved gases [23].

The mean value of EC obtained from the six sampled beaches was 77,364.73 µs/cm for the wet season and 81,364.96 µs/cm for the dry season. EC did not show any significant difference ($p > 0.05$) across all the locations during the wet season but showed significant difference during the dry season. The EC values recorded were higher in the dry season than the wet season. The high EC values recorded at the beaches might be attributed to an increase in the number of dissolved ions in the water from the Atlantic Ocean and temperature which causes the water to evaporate leaving the salts behind. The increase in value of EC recorded in the dry season might be connected to the fact that there is higher level of evaporation in the dry season causing the concentration of the ions to increase, like wise EC. Hence, evaporation exceeds precipitation during the dry season. This work is in agreement with the work of Mustapha [16], Kadiri [24] and Edori et al. [25] who observed higher conductivity values in the dry season than in the rainy season. The present study is at variance with the works of Okorafor et al. [19] who reported a lower EC value of 12.5 and 11.65 µS/cm upstream and downstream of Lower Qua Iboe River in Akwa Ibom State and Edori and Nna [26] who recorded lower EC values range of 11.60-15.61 µS/cm in effluent at discharge points into the New Calabar River along Rumuolumeni axis of River state. The recorded values of EC in all sampled beach surface water in this study were very high compared with the recommended values of 1,000 µS/cm for drinking water and 55,000 µS/cm for sea water which means that the water can cause problems for aquatic ecosystems and complications for humans as it is only suitable for flushing of toilets and for making concrete where the reinforcement is well covered and not suitable for swimming [27].

Turbidity is the measure of the cloudiness or haziness of a fluid caused by large number of individual

particles that are generally invisible to the naked eyes similar to smoke in air [28]. The mean turbidity values of surface water samples gotten from the six locations in this study was 88.78 mg/L during the wet season and 88.82 mg/L during the dry season. Turbidity values recorded for the six beaches did not show any significant difference across all the stations during the wet and dry season.

The turbidity figures recorded were higher in the wet season than in the dry season. The values recorded for turbidity in this study varied from 15.4 to 125.7 mg/L with a mean concentration of 67.90 ± 9.25 nephelometric turbidity unit (NTU). The reported range is higher than 76.00-96.70 NTU obtained by Ebigwai et al. [29]. The mean value obtained is also higher than 5.0 NTU stipulated by NESREA [30] for unpolluted water. Consequently, the anthropogenic activities in the study area may have attributed to the high levels of turbidity reported. The high turbidity of these water bodies is harmful to those exposed to these water bodies because according to Reza and Singh [31] high turbidity in water is directly related to high disease-causing microorganisms. This is not good news for the beach tourists especially the swimmers.

Salinity is the concentration of dissolved salts in a given volume of water [32]. The mean salinity of surface water recorded in the six sampled coastal beaches was 8,785.31 mg/L for the wet season and 9,115.74 mg/L for the dry season. The values recorded for salinity were higher in the dry season than the wet season. The high salinity values recorded in the six sampled beaches could be attributed to the high concentration of sodium, chloride, magnesium, calcium and potassium sulphate recorded in the beaches. The high salinity values recorded in the dry season could be attributed to evapocrystalization process and low precipitation indicating low dilution.

The mean DO of surface water recorded in the six sampled coastal beaches during the wet season was 3.50 mg/L and 5.1 mg/L during the dry season. The recorded values for DO were higher in the dry season than the wet season. The result of the present study agreed with the findings of Ebigwai and Nwanekwu [29] who reported DO content range of 1.21-3.6 mg/L in a river and disagreed with Grzywna and Sender [33] who reported DO range of 6.2-8.5 mg/L in River Tyśmienica. The low values of DO recorded in the present study could be tied to dumping of solid wastes, sewage discharge and high level of defecation in the river bank [34]. The present study equally compares favourably with observed mean value of DO ranges (4.35-4.82 mg/L) in the Siluko River, southern Nigeria by Oboh and Agbala [35] in Eleme River. The biological oxygen demand (BOD) is essentially a measure of the amount of oxygen required to remove waste organic matter from water in the process of decomposition by aerobic bacteria [36]. The mean BOD of surface water recorded in the six sampled coastal beaches during the wet season was 1.65 mg/L and 3.88 mg/L during the dry season. The BOD values recorded in the present study were higher in the dry season than the wet season. Generally, the BOD levels recorded in the entire sampling points were lower than the EU guidelines of 3.0 to 6.0 mg/L (BOD) for the protection of fisheries and aquatic life and for domestic water supply [18] meaning that there are no anthropogenic activities emanating from waste water discharge into the beach surface water. This work is at variance with the work of Akan et al. [22] who recorded BOD value of 83.66 mg/L in their work on assessment of pollutants in water and sediment samples in Lake Chad, Baga, North Eastern Nigeria.

The mean concentration of phosphate (PO_4) in surface water recorded in the six sampled coastal beaches during the wet season was 0.03 mg/L and 0.18 mg/L during the dry season. Phosphate did not show any significant difference across all the six locations in wet and dry season. PO_4 content for the wet season was relatively higher than the PO_4 content for the dry season. The present finding is in agreement with Olajire and Imeokparia [37] who reported that PO_4 levels fluctuated between 0.46 and 0.59 mg/L in the upstream

and downstream of the Osun river, Nigeria but disagreed with Mladenou et al. [38] who reported that the average PO_4 level in treated sewage in the downstream and upstream was 3.65 mg/L in Notwane River in South-Eastern Botswana. The levels of phosphate recorded from the entire water sampling location fall below the WHO maximum permissible limit of 5 mg/L phosphate [8]. The mean concentration of calcium (Ca) in surface water recorded in the six sampled coastal beaches during the wet season was 374.56 mg/L and 386.23 mg/L during the dry season. Calcium did not show any clear significant difference across all the sampled locations both during the wet season and dry season. The values recorded for calcium were higher in the dry season than the wet season. Calcium from the present study compared well with 63.10 to 172.40 mg/L reported by Ubuoh et al. [39] in their work on environmental pollution loads on surface water chemistry and potentially ecological risks of inland aquatic ecosystem in South Eastern State, Nigeria and is greater than the Ca values obtained by Ayobahan et al. [14] and Duru and Nwanekwu [36] who reported 0.10-1.49 mg/L and 0.73-2.64 mg/L. Calcium values obtained from the present study is greater than the 75.00 mg/L WHO permissible limit [8].

The mean concentration of magnesium (Mg) in surface water recorded in the six sampled coastal beaches during the wet season was 1,318.53 mg/L and 1,365.46 mg/L during the dry season. Mg showed no significant difference across all the sampled locations for both season. The values recorded for Mg were higher in the dry season than in the wet season. The finding of Mg in this study is at variance with that of Duru and Nwanekwu [36] who recorded Mg content in rivers to range from 0.01 to 0.31. The mean of magnesium gotten in the present study is far higher than the 50.00 mg/L WHO permissible limit in water [8]. This high Mg values recorded across the sampled locations could be attributed to the fact that the water comes direct from the ocean which contains much of weathered rock and other shell particles and the hardness goes with the ocean too.

TH is the amount of dissolved calcium and magnesium in water. Hard water is high in dissolved minerals, largely calcium and magnesium [28].

The mean concentration of TH in surface water recorded in the six sampled coastal beaches during the wet season was 6,515.23 mg/L and 7,381.23 mg/L for the dry season. The values for TH showed no significant difference for the wet and dry seasons. The TH values recorded were more in the dry season than in the wet season. The recorded values for the mean hardness in the present study (6,515.23 mg/L and 7,381.23 mg/L) exceeded that of the findings of Duru and Nwannekwu [36] whose values were between 18.6 and 36.01 mg/L. Ubuoh et al. [39] reported TH value of 123.3-226.7 mg/L with a mean value of 123.3 mg/L in their work on environmental pollution loads on surface water chemistry and potentially ecological risks of inland aquatic ecosystem in South Eastern State, Nigeria. Water hardness leads to rapid exhaustion of washing soap, and chiefly influenced by the presence of calcium and magnesium salts (Ca^{2+} and Mg^{2+}) [40]. The present study recorded TH values above the WHO standard of 100.0 mg/L [8].

4.3 Assessment of the Physicochemical Composition of Bottom Sediments in the Study Areas during the Wet and Dry Seasons

The mean magnesium content in sediment samples for the wet season was 394.83 mg/kg and 400.23 mg/kg for the dry season. The magnesium values recorded were higher in the dry season than in the wet season. This is in disagreement with the work of Yasser Ahmed et al. [41] who recorded low magnesium values of 27.24 ± 7.38 in their work on assessment the physicochemical characteristics of water and sediment in Rosetta beach, Egypt. The mean sulphate (SO_4) content in sediment samples from the six sampled beaches during the wet season was 111.80 mg/kg and 132.04 mg/kg for the dry season respectively. Sulphate values recorded in this study were significantly higher

in the dry season than in the wet season. Edori et al. [25] recorded high values (75.57 mg/kg) in the bottom sediments of Silver River in Bayelsa which he attributed to the amount of oil spillage in the study area. The mean value of sulphate (111.80 mg/kg and 132.04 mg/kg) obtained in this study is lower than 240.0 mg/kg recommended limit for unpolluted sediment by WHO [42]. Hence, the studied sediments may not have been polluted by the sulphate content. The values of sulphate observed in this assessment are in conformity with that of Edori and Nna [26] in the New Calabar. The mean phosphate (PO_4) content in sediment samples at the six sampled beaches in the wet season was 15.03 mg/kg and 21.66 mg/kg for the dry season respectively. Phosphate is required by living organisms for their normal metabolic and physiological processes [43]. Phosphate values recorded in this research were significantly higher in the dry season than in the wet season. Compared to the findings of Okorafor et al. [19], who obtained high sulphate values of 54.60 mg/kg and 62.18 mg/kg upstream and downstream of the lower Qua Iboe River in Akwaibom State, the present study has mean values lower than that. The mean chloride (Cl^-) content in sediment samples from the six sampled beaches for the wet season was 951.86 mg/kg and 4,831.09 mg/kg for the dry season respectively. Chloride values recorded in this research were relatively higher in the dry season than in the wet season. This high chloride value may be attributed to intrusion/deposition of salty ocean water into the coastal shorelines. The elevated level during the dry season may also be as a result of reduction in rainfall which washes off the soil content to the nearest underlying topography thereby allowing the content to percolate down the ground since the soil is more of sandy and a little of clay and silt.

Edori and Nna [26] recorded a value range of 4.32-43.87 mg/kg for chloride in effluents at discharge points into the New Calabar River along Rumuolumeni Axis, Rivers State. The Cl^- value recorded in this study is in disagreement with this.

The mean calcium (Ca) content of sediment samples from the sampled beaches for the wet season was 101.33 mg/kg and 118.27 mg/kg for the dry season. Calcium showed a high significant difference across all the beaches sampled and across all the seasons. Calcium according to Sheoran et al. [44] and Uchendu et al. [45] is an essential element that serves as a nutrient for aquatic fauna and flora. This research recorded a high level of calcium both during the wet and dry season, though the values for the dry season were slightly higher. This calcium may have come from shells and weathered rocks from the ocean. This study is in disagreement with the work of El-Amier et al. [46] who reported a value range of 24.77-63.89 in their work on assessment of the physicochemical characteristics of water and sediment in Rosetta beach, Egypt. It is equally at variance with Akan et al. [22] who reported a value range of 25.11-40.32 in their work on assessment of pollutants in water and sediment samples in Lake Chad, Baga, North Eastern Nigeria. The present study is in agreement with the work of Bano et al. [47] who recorded value range of 168.03 to 230.32 mg/kg in their work on impact Hokersar wetland: a protected wildlife reserve (Ramsar site NO. 1570) of Kashmir Himalaya. The mean sodium (Na) content recorded in sediment samples from the study area for the wet season was 4,175.82 mg/kg and 6,907 mg/kg for the dry season. Sodium showed a highly significant difference across all the six sampled locations and across all the seasons. Sodium values recorded in this study were significantly higher in the dry season than in the rainy season. This elevated level in the values of sodium in the sediment may not be unconnected with the ocean current and tidal movement which causes the ocean to empty its content on the coastal lines. The result of this study is in agreement with the works of Nwankwo et al. [48] who obtained similar value of 33.54 mg/kg for Na in their work on sediment contamination due to crude oil spillage in Akinima, Rivers State. The result of the present study is far higher (520.9-2,356 mg/kg) than that mentioned above

(33.54 mg/kg) showing the sediment is free from anthropogenic perturbation.

The mean potassium (K) content in sediment samples at study area for the wet season was 819.50 mg/kg and 156.6 mg/kg for dry season. This high level of sediment recorded in the study might be as a result of ocean deposition at the coast and consequent alluviation. This study agreed with the result of Osuji and Nwoye [49] who had higher values of 86.11 mg/kg in their research.

The mean pH content in sediment samples from the six sampled coastal beaches during the wet season was 6.88 mg/kg and 7.55 mg/kg for the dry season. The values recorded at Tourist beach, Okpoama beach and Agenobode beach were acidic while those of Ibeno beach, Asaba beach and Marina's beach were basic. The acidity levels recorded in the both beaches were more in the dry season than wet season. However, the results of pH for all the six sampled beaches for both dry and wet season fall within the acceptable range of 6.5-8.5 by WHO [50]. This range is agreement with 7.18-7.28 reported in sediments by Simeon et al. [51]. The mean EC value in sediment samples from the six sampled coastal beaches for the wet season was 8,402.25 μs/cm and 9,561 μs/cm for the dry season. The EC values recorded in the six sampled beaches were more in the dry season than in the wet season. The high level of EC might be connected with the high salinity level of the sediment caused by ocean water deposition at the coast. This EC range is consistent with that reported by Ezekiel et al. [52] who obtained 40.0-1,940.0 μS/cm in their work but inconsistent with that of Adesuyi et al. [53]. The mean EC value (8,402.25 μs/cm and 9,561.4 μs/cm) obtained in the present study is above the safe limit of 1,500.0 μS/cm by WHO [8].

The mean effective cation exchange capacity (ECEC) content in sediment samples from the six sampled coastal beaches for the wet season was 2,588.11 and 2,852.63 for the dry season. The ECEC values showed significant difference across all the six sampled beach locations both in wet and dry season. The ECEC values recorded were higher in the dry season than the wet season. The high values of ECEC recorded across all the sampled beaches indicate that the soil has high level of organic matter and water retention ability. Leinweber et al. [20] reported organic matter to be important for nutrient retention and supply. The ECEC of the study area ranged between 784 μS/cm and 5,714.2 μS/cm. This compares favourably with the range of 40.0-1,940.0 μS/cm with a mean of 528.75 μS/cm reported by Ezekiel et al. [52] in the sediment physical and chemical characteristics in Sombreiro River, Niger Delta, Nigeria.

5. Conclusion

The general trend in the levels of physicochemical parameters revealed that temperature and pH were within those recommended by WHO and USEPA for both wet and dry season but EC and TDS were above the WHO and USEPA limit. Twenty one (21) water quality parameters from six sampling locations in Rivers State, Bayelsa State, Delta State, AkwaIbom State, Cross River State and Edo State (South-South Nigeria) were studied and by applying WQI, the state of the six beach water was very unsuitable for drinking, swimming and recreational activities as at the time of this study. The water is only suitable for irrigation purpose. The WQI for this study provided a strong background for assessing the quality of the aquatic ecosystem while giving an insight into the contamination levels of the study areas.

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