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Comparison of Investigated Levels of Physicochemical Parameters in Qua Iboe River, Oruk Anam, Nigeria with Portable Water Standards

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This research was carried out for comparision of status of physicochemical parameters in Qua Iboe River, Oruk Anam, Nigeria with portable water standards. Water samples were collected from five sampling locations in the study area for analysis of the physicochemical parameters in wet and dry seasons. Physicochemical parameters were determined using standard methods. Data generated were subjected to statistical analysis with Statistical Package for Social Science. The levels of some of the parameters were higher in dry season than wet season. Higher levels of some of the parameters were obtained in downstream than upstream and was ascribed to variation in levels of

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anthropogenic activities across the sampling locations. By extension, this indicated a likelihood of future escalation in levels of the physicochemical parameters in the river beyond permissiable limits given by World Health Organisation and other regulatory bodies in areas of higher levels of anthropogenic activities if the trend is not curbed. Comparatively, the levels of all the physicochemical parameters in the river water in both seasons were all within permissible limits for portable water standards set by World Health Organisation among other regulatory bodies. This implies that the river water quality supports life of aquatic organisms and also suitable for some domestic uses. Principal component analysis of some of the physicochemical parameters revealed positive correlation coefficients (loadings) with one another. Hence for sustainability of the river water quality by government, regulation of anthropogenic activities in the study area is strongly advocated.

Keywords: Physicochemical; analysis; comparison; Qua Iboe River; Oruk Anam.

1. INTRODUCTION

Water is one form of matter and constitutes a major component of living organisms as well as some non living things. Essentiality of water to life cannot be overemphasised. Deficiency of water in living things has numerous adverse health implications. ‘‘Prolonged deficiency can result in extinction of life of the organisms involved. Evidence of the water deficiency in plants is obvious through leaves shading in dry season as a result of high rate of dehydration of soil moisture due to increase in temperature. It is worthy of note that although water is essential to life, not all kinds of water are suitable for life sustainability’’ [1,2]. ‘‘According to World Health Organisation, [3], water whether used for the purpose of drinking, food production, irrigation, domestic utility, has an important impact on health. Therefore standards to maintain the quality of surface water are very important. It is in the light of this that WHO and other national and international regulatory organisations set up standards for portable water for human consumption. Investigations on toxicity of trace metals to organisms in the aquatic environment reveal that physicochemical parameters have a considerable influence on the toxicity and accumulation of metals in organisms’’ [4,5]. Most water quality parameters that are frequently monitored include temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), hardness, electrical conductivity (EC), organic matter, etc. ‘‘Water quality is usually described according to its physical, chemical and biological characteristics. Interference in ecological balance of water quality in aquatic ecosystems results from activities capable of causing severe damage to aquatic life directly or indirectly. These activities include land clearing, land utilization, stream and river dredging, building of factories and industries, transportation of all forms, provision of electricity, drilling of all types, oil exploration and utilization and a host of other activities carried out by man aimed at solving his social and economic problems’’ [6,7]. ‘‘Water quality is continually threatened due to increasing inputs of the end products of anthropogenic activities and this attracts greater attention of government in the control of water pollution. This is because contaminants in air, soil or on land ultimately end up in the aquatic ecosystem through local precipitation, water run-off and leaching of rocks and solid wastes’’ [8,9]. Investigation of the physicochemical parameters in water samples from Qua Iboe River, Ikot Ekpene stretch, Nigeria, revealed that the levels recorded were all within permissible limits set by World Health Organisation [1,6]. Assessment of physicochemical properties and water quality index of borehole water in Mkpat Enin Local Government Area by {13] revealed that the levels of all the parameters were within permissible limits set WHO. Analysis of bioaccumulation of trace metals in fish from Issiet River, Uruan, Nigeria carried out by [2] revealed that the levels of some of the parameters were above permissible limits set by WHO. ‘‘Water quality parameters are given prime consideration in water pollution control as life of aquatic organisms and plants depend principally on their levels. For example, different aquatic organisms show different behavioural changes at different temperatures, so knowing the temperature of a water body is very important. In aquatic ecosystem, a temperature range of 25 to 30°C is favorable for survival of aquatic organisms’’ [1,6,10]. ‘‘Furthermore, researchers have revealed that hydrogen ions concentration (pH) in water has significant implication on the bioavailability of trace metals in aquatic water bodies. pH value of drinking water is an important index of acidity and alkalinity. The results of the analyses revealed that high or low pH levels of a river is capable of affecting the aquatic lives and alter the toxicity of pollutants in one form or the other in the river’’ [2,8]. ‘‘Dissolved oxygen (DO) level in water is a reflection of the potential for the oxidation of organic matter in the water and indicates the ability of the water body to support lives of aquatic organisms. It is also an index of the physical and biological processes going on in water. Permissible limits of DO in aquatic ecosystem capable of supporting aquatic life fall between 8 – 10 mg/L as given by WHO [10,9]. ‘‘Total dissolved solid (TDS) is a parameter that influences the taste of water’’ [11,5,12]. ‘‘Total hardness is imparted to water quality due to the presence of calcium and magnesium ions. Hard water is generally undiserable because it forms precipitate with soap, produces scales in boilers on heating and causes increase in boiling point which is unsuitable for cooking’’ [6,10,13]. Other physicochemical parameters such as electrical conductivity, turbidity, alkalinity also have negative effects on aquatic organisms and plants at elevated levels. ‘‘Researchers have revealed that elevated levels of water quality parameters are known to results from tremendous anthropogenic activities such as agriculture, lumbering, road construction, fishing, transportation of all forms, automobile works, establishment of numerous upstream and downstream industries among others leading to an interference in ecological balance of these parameters in aquatic ecosystems’’ [5,12, 14].

In Oruk Anam, elevated levels of anthropogenic activities around the study area have been carried out over the years and since this has a positive relationship with levels physicochemical parameters in aquatic ecosystems hence this research to quantify the levels of the physicochemical parameters to assess the potential of the river to support life of aquatic organisms and suitability for domestic uses.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is Qua Iboe River (QIR) which drains through Oruk Anam, Akwa Ibom State, Nigeria. It lies between the latitude of 04^{o}28’31.0’’ and 07^{o}10’12.4’’N and longitude of 06^{o}65’41.2’’ and 06^{o}52’50.5’’E.

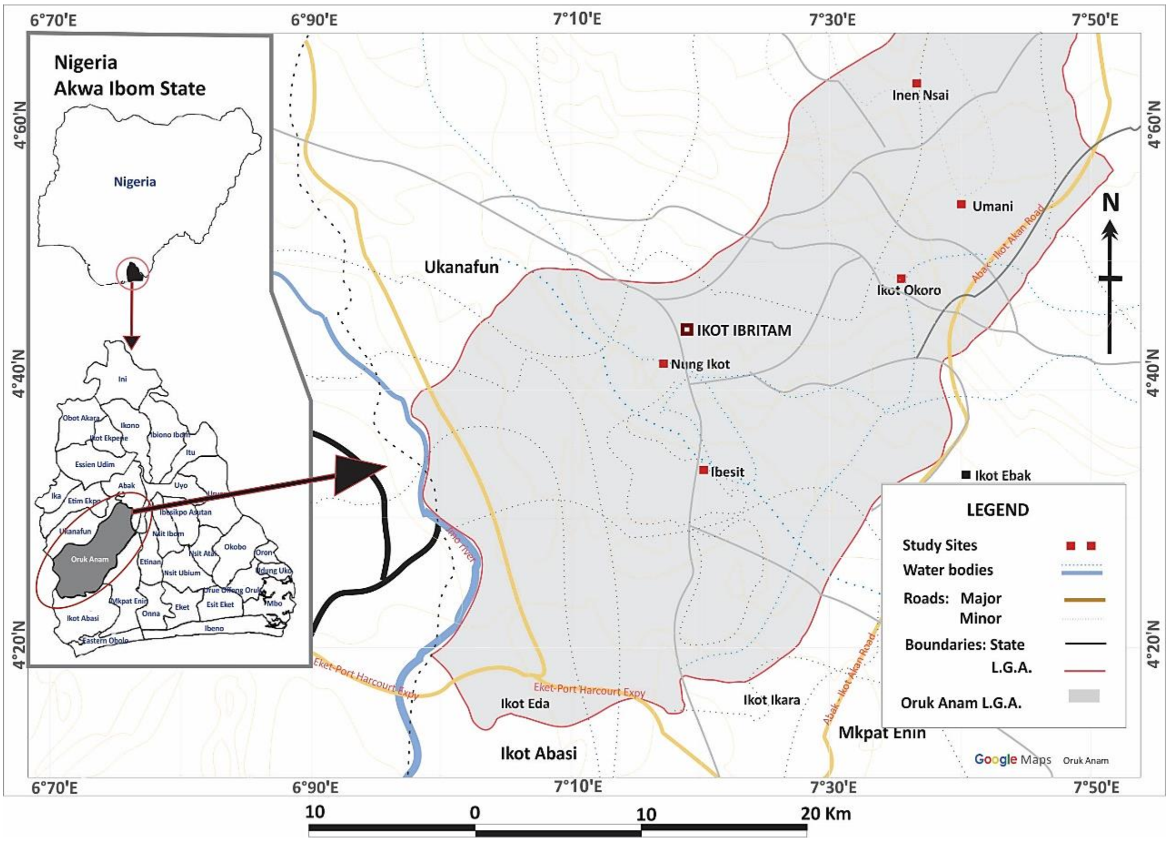

Fig. 1. Map of study area

Predominant anthropogenic activities in the study area include agriculture, fishing, industrial activities, sand mining, lumbering and automobil activities among others.

2.2 Water Samples Collection

Water samples for dissolved oxygen (DO) determination were fixed on site with 2 mL of Winkler solutions 1 and 11 while samples for biochemical oxygen demand (BOD) were incubated for five days before analysis.

2.3 Determination of Physicochemical Parameters

2.3.1 Temperature

Temperature measurement was done *in-situ* using a multi parameter meter Hach Sension 156 model 51935-10-11. This was achieved by dipping the instrument to about 5 cm of the surface water for about five minutes to obtain a stabilised level before taking reading.

2.3.2 Determination of pH

Levels of pH in water samples were determined at the site using pH meter with model HACH SENSION 3. The instrument used was standardised with two buffer solutions of pH 4.0 (potassium hydrogen phthalate) and pH 6.85 (a mixture of potassium di-hydrogen phosphate and di-sodium hydrogen phosphate buffer) [1,6,10].

2.3.3 Electrical conductivity (EC)

Levels of EC were measured with conductivity Scan Meter model 1560. The Meter probe was calibrated by immersing it into a solution of known electrical conductivity and then rinsed with deionised water for each measurement [2,7,8].

2.3.4 Dissolved oxygen (DO) by winkler's method

In this method, oxygen is usually fixed on site. ''Aliquot of 100 mL was withdrawn from the treated water sample and 5 mL manganese sulphate, 5 mL alkali-iodide-azide, 1 mL of tetraoxosulphate (VI) acid and 1 mL of starch indicator were added to the solution and stirred. The solution was then titrated with 0.025 M sodium thiosulphate ($Na_2S_2O_3.\ 5H_2O$) solution until the colour changed from blue to colourless indicating end point'' [1,15,12]. The level of DO in the sample was obtained using Equation 1.

DO (mg/L) = Volume of 0.025 M $Na_2S_2O_3.5H_2O$ used Equation 1

2.3.5 Biochemical oxygen demand (BOD)

In the determination of BOD, the water samples were kept in an incubator at 20ºC in the dark for five days after which the DO test was repeated and BOD calculated by taking the difference between the initial and final concentrations of oxygen present after incubation [16,2,13]. DO was measured using equation 2.

BOD_5 (mg/L) = DO (initial) – DO (final). Equation 2

Where: BOD_5 = Biochemical Oxygen Demand after 5 days, DO (initial) = dissolved oxygen before incubation, DO (final) = dissolved oxygen after 5 days.

2.3.6 Total dissolved solids (TDS)

Total dissolved solid was determined by first taking the weight of an empty crucible. The water sample (50 mL) was put into the weighed crucible and heated on a hot plate until the sample evaporated. The residue and the crucible were dried, cooled and reweighed [17]. TDS was determined using Equation 3.

$TDS = W_2 - W_1$ Equation 3

W_2 = Weight of crucible and residue
W_1 = Weight of empty crucible

2.3.7 Chloride

Mohr's method which employs silver nitrate ($AgNO_3$) as titrant and potassium chromate (K_2CrO_4) as the end point indicator were used. The chloride ions present in the sample was precipited as white silver chloride. ''Water samples (50 mL) each was put in a clean conical flask. K_2CrO_4 indicator (2 drops) were added and titrated with 0.02 M $AgNO_3$ until the colour changed from yellow to brick red indicating the presence of chromate'' [6,7,9]. The concentration of chloride in the sample was calculated using Equation 4.

Concentration of Cl^- (mg/L) = $\frac{Vol.\ of\ AgNO3\ X\ 1000\ X\ 35.5}{50\ cm3\ of\ sample\ used}$ Equation 4

2.3.8 Sulphate

''The filtered water sample (100 mL) was measured into 250 mL conical flask. Dilute HCl was added in drops till acidic to litmus and evaporated to about 50 mL; the solution was boiled while barium chloride was added until all the sulphate was precipitated. It was digested in water bath at 40^{o}C until the precipitate had settled. The precipitate was filtered into a preweighed ashless filter paper and washed a number of times with hot water until the filtrate was chloride free ($AgNO_3$ test). The filter paper and sample were transferred into a preweighed crucible and was ashed in the furnace at 500^{o}C for 1 hour. The content was transferred into the desicator for cooling and the weight of the precipitate alone was obtained by difference'' [1,2,9]. The concentration of sulphate in the sample was calculated using Equation 5.

$$SO_4\ (mg/L) = \frac{(mgBaSO4 \times 411.5)}{(ml\ of\ sample)} \qquad \text{Equation 5}$$

2.3.9 Phosphate

Phosphate determination using Ultraviolet/Visible (UV/V) spectrophotometer was carried out to indicate the suitable absorbance measurement with appropriate wavelength using a 5 cm cell. The sample (10 mL) was poured into 100 mL measuring cylinder and 5 mL of ammonium molybedate added. The sample solutions were then measured into the 5 cm cell. The cell was properly cleaned to dryness before setting it into the UV/V spectrophotometer. Absorbance for each sample solution was read after 30 seconds at a phosphate wavelength of 420 nm. Phosphate level in the sample was estimated using Equation 6 [1,17, 6].

$$PO_4^{3-}\ (mg/L) = Ab \times Df \qquad \text{Equation 6}$$

Where: Ab = PO_4^{3-} absorbance from UV/V spectrophotometer, Df = dilution factor concentration, Df for PO_4^{3-} = 55.56. Therefore, PO_4^{3-} conc. (mg/L) = Ab x 55.56

2.3.10 Quality control and assurance

The implementation of laboratory quality assurance and quality laboratory methods, including the use of standard operating procedures, guaranteed the quality of the analytical data.

2.4 Statistical Analysis

The generated data were processed using Statistical Package for Social Sciences (SPSS).

3. RESULTS AND DISCUSSION

Comparision of the levels of physicochemical parameters in Qua Iboe River in both wet and dry seasons with portable water standards were presented as shown in Table 1. Results in Tables 2 and 3 showed Principal Component Analysis (PCA) for physicochemical parameters in water samples in wet and dry seasons respectively. Figs. 2 and 3 presented factor loading plots for physicochemical parameters in wet and dry seasons respectively.

3.1 Temperature

As shown in Table 1, temperatures of the water samples obtained ranged between 27.0 and 30.0^{o}C across the sampling locations with a mean of 29.2± 0.49 for wet season and between 29.0 - 32.0^{o}C with a mean of 30.3± 0.24 for dry season. Comparatively, levels recorded in all the sampling locations in dry season were higher than levels recorded in the respective locations in wet season. Temperature levels recorded in this study in both seasons were higher than levels reported by [18,9] but were within the WHO permissible limits of 29.0 – 40.0^{o}C. This temperature range supports the survival of aquatic organisms and plants in the study area.

3.2 Hydrogen Ion (pH)

Hydrogen ion concentrations recorded in water samples ranged between 6.3 - 6.9 with the mean of 6.5± 0.5 and between 7.1 - 7.4 with the mean of 7.2± 0.06 during wet and dry season respectively. On the pH scale, pH of 7.0 indicates a neutral solution, pH values smaller than 7.0 indicate acidity, pH values larger than 7.0 indicate alkalinity. The mean levels of pH in this study were consistent with levels reported by [2,12] and agreed with standards of 6.5 - 8.5 set up WHO, USPH and NSDWQ.

3.3 Total Dissolved Solids (TDS)

Levels of TDS in water samples in this research ranged from 70.50 - 97.73 mg/L with mean level of 87.08± 0.02 mg/L and between 86.00 - 124.00 mg/L with a mean level of 87.08 ± 0.02 mg/L during wet and dry seasons respectively. The taste of water could be affected by the concentration of dissolved solids. In addition, it affects turbidity as well as density of water [6,15]. Levels of TDS in water samples reported in this study were below maximum permissable limit of 500 mg/L given by regulatory bodies.

Table 1. Levels of Physicochemical parmeters of Qua Iboe River, Oruk Anam for Wet and Dry Seasons Compared with Water Quality Standards

		Inen Nsai	Umani	Ikot Okoro	Nung Ikot	Ibesit	Mean	WHO	USPH	NSDWQ
Temp	Wet	27.01	29.02	30.08	30.10	29.20	29.20±0.49	29 - 40		
	Dry	29.01	29.67	30.90	30.01	30.34	30.34±0.24		-	-
pH	Wet	6.50	6.90	6.80	6.30	6.40	6.50±0.57	6.9 -8.5		
	Dry	7.20	7.13	7.30	7.40	7.41	7.20±0.06		6.5-8.5	6.5-8.5
TDS	Wet	70.50	73.50	96.80	96.88	97.73	87.08±0.02			
	Dry	86.00	92.67	107.00	123.00	124.00	106.50±0.01	500	500-1500	500
EC	Wet	119.13	110.40	119.63	121.18	123.36	118.74±2.24			
	Dry	133.33	132.70	145.00	167.33	167.67	149.21±15.57	300	300	1000
DO	Wet	6.13	6.10	8.90	10.01	11.50	8.58±0.17			
	Dry	5.53	6.00	7.30	9.50	10.40	7.74±0.26	-	-	-
BOD	Wet	2.05	2.60	3.09	3.10	4.50	3.06±0.01			
	Dry	2.04	2.50	3.02	3.05	4.01	2.92±0.01	-	-	-
NO_3^-	Wet	1.32	1.26	1.63	1.67	1.74	1.52±0.20			
	Dry	1.32	1.45	1.85	1.97	2.04	1.61±0.31	40 - 50	-	50
NO_2^-	Wet	0.01	0.02	0.02	0.02	0.05	0.02±0.14			
	Dry	0.02	0.02	0.02	0.02	0.02	0.02±0.01	3	-	0.2
PO_4^{3-}	Wet	0.23	0.22	0.24	0.26	0.31	0.25±0.25			
	Dry	0.23	0.23	0.30	0.32	0.33	0.28±0.10	0.3	0.3	-
SO_4^{2-}	Wet	5.13	5.01	5.23	5.26	5.29	5.18±0.12			
	Dry	5.18	5.91	6.05	6.14	6.15	5.20±0.55	200-250	250	1000
Cl^-	Wet	19.01	19.43	21.92	26.50	35.20	24.4±1.04			
	Dry	18.20	18.41	19.50	25.30	34.60	23.20±5.06	200-600	250	250

3.4 Electrical Conductivity (EC)

Levels of EC obtained in water samples ranged from 110.40 - 123.36 µS/cm with a mean level of 118.74 ± 2.24µS/cm and from 132.70 - 167.67 µS/cm with a mean level of 149.21±15.57 µS/cm for wet and dry seasons respectively. Comparatively, higher levels were recorded in dry season than wet season in all locations and could be ascribed to dilution and concentration effects of the volume of water in wet and dry seasons respectively. Levels recorded across all sampling locations were lower than levels reported by [10] but were consistent with levels reported by [12] In general, levels recorded in this study were below maximum limits of 250µS/cm recommended for drinking water by WHO and other regulatory bodies.

3.5 Dissolved Oxygen (DO)

Levels of DO recorded in water samples ranged between 6.10 - 11.50 mg/L with a mean level of 8.53 ± 0.17 mg/L and from 5.53 - 10.40 mg/L with a mean level of 7.74±0.26 mg/L in wet and dry seasons respectively. As expected, levels recorded in dry season were lower than levels obtained in wet season due to effect of higher temperatures. Comparatively, DO levels recorded in this study were higher than that reported by [8,19] but were below permissible limits of 13.0 – 14.0 mg/L stipulated by [3]. ‘‘Without dissolved oxygen, there will be no survival of aquatic life forms in any water body. Adequate dissolved oxygen is necessary for good water quality. Excessive levels can cause harm to aquatic life such as gas bubble disease; vessels blood flow blockage resulting in death among others’’ [17,7].

3.6 Biochemical Oxygen Demand (BOD)

Levels of BOD obtained in water samples in this study ranged from 2.05 - 4.50 mg/L with mean level of 3.06 ± 0.01 mg/L and between 2.03 - 4.01 mg/L with mean level of 2.92±0.01 mg/L in wet and dry seasons respectively. Levels of BOD recorded in this study were higher than levels reported by [1,12] but were within permissible limits for drinking water as well as levels required for aquatic life given as 10 mg/L [3].

3.7 Chloride

Chloride levels in water samples ranged from 19.01 - 35.20 mg/L with mean levels of 24.41±1.04 mg/L and from 18.20 - 34.60 mg/L with mean level of 23.20±5.06 mg/L in wet and dry seasons respectively. The result revealed no significant differences in the levels for both seasons. The results obtained were higher than those recorded by [15] but were within WHO permissible limits of 250 mg/L for drinking water quality.

3.8 Nitrate

Nitrate levels obtained in water samples ranged from 1.26 - 1.74 mg/L with mean levels of 1.52±0.20 mg/L and between 1.32 - 2.04 mg/L with mean levels of 1.61±0.31 mg/L in wet and dry seasons respectively. The results revealed no significant differences in the levels for both seasons. The levels of nitrate in this study were similar to levels recorded by [2,9] and were below maximum permissible limit of 50 mg/L set up by WHO for drinking water quality.

3.9 Sulphate

Sulphate levels recorded in water samples in this research ranged between 5.01 - 5.29 mg/L with mean levels of 5.18±0.12 mg/L and also between 5.18 - 6.15 mg/L with mean levels of 5.20±0.55 mg/L in wet and dry seasons respectively. ‘‘Sulphate reducing bacteria produce hydrogen sulphide and lower the aesthetic quality of the water by imparting an unpleasant taste and odour. It also increases corrosion of metals and concrete pipes’’ [4,20]. Sulphate levels obtained in all the sampling locations in both seasons were consistent with levels reported by [15,5,12], and were within recommended limits for drinking water.

3.10 Phosphate

Phosphate levels obtained in water samples ranged from 0.22 - 0.31 mg/L with mean level of 0.25±0.25 and from 0.23 - 0.33 mg/L with mean levels of 0.28±0.10 mg/L in wet and dry seasons respectively. Phosphorus pollution accelerates a process called eutrophication, which is essentially the process of a river’s biological death due to depleted bioavailable oxygen. The levels recorded in this research were below the WHO permissible limit of 250 mg/L and were consistent with levels reported by [1,12,8].

3.11 Nitrite

Nitrite levels obtained in water samples in this study ranged between 0.01 - 0.05 mg/L with a mean level of 0.02±0.14 mg/L and from 0.01 -

0.02 mg/L with mean level of 0.02±0.01 mg/L in wet and dry seasons respectively. The results obtained were consistent with levels recorded by [13] and were within the WHO permissible limits for drinking water standards.

3.12 Principal Component Analysis (PCA) of Physicochemical Parameters in Water for Wet Season

The PCA analyses of the physicochemicalcal parameters in water in wet season revealed that three latent factors were identified, of which factor 1 explained 47.514%, of total variance, factor 2 explained 22.876% and factor 3 explained 9.823% (Table 2). The most important latent factor, factor 1, had high positive correlation coefficient (loadings) with TSS, TDS, EC, DO, chloride, nitrate and sulphate and with negative loading with only pH. The second most important factor, factor 2, had high positive loadings with nitrite, BOD, phosphate, COD while the third factor accounted for 9.823% with negative loading with temperature.

Table 2. PCA for physicochemical parameters in water during wet season

	Component		
	F1	**F 2**	**F 3**
Temp	.246	.251	-.749
Ph	-.799	-.061	.040
TSS	.677	.031	-.069
TDS	.877	.181	.003
EC	.771	.425	-.029
DO	.910	.223	.133
BOD	.240	.844	-.296
COD	.783	.548	-.158
Chloride	.815	.346	.081
Nitrate	.913	.331	.041
Sulphate	.898	.362	-.002
Phosphate	.490	.772	.031
Nitrite	.102	.926	.179
Turbidity	.278	.215	.797
Eigen values	6.652	3.203	1.375
% Variance	47.514	22.876	9.823
Cum %	47.514	70.390	80.213

PCA = Principal Component Analysis

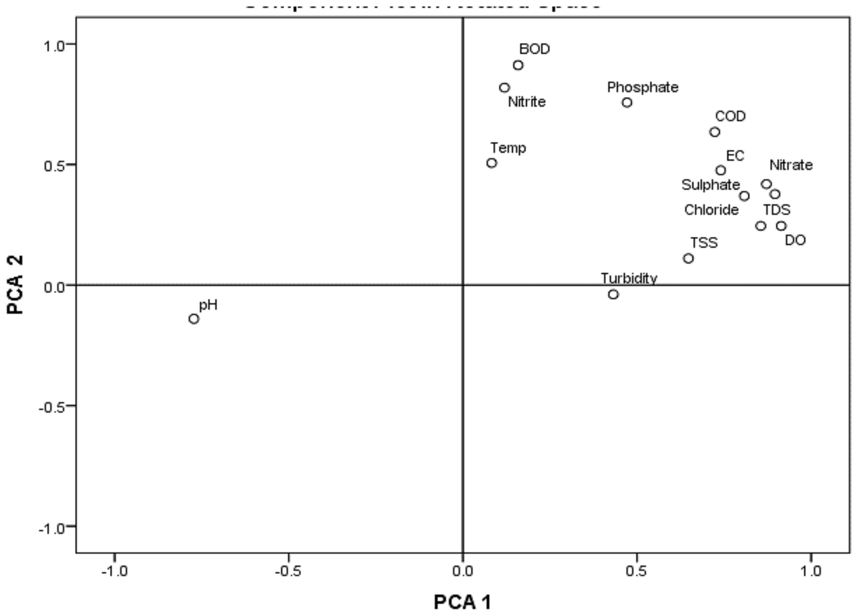

Fig. 2. Factor loadings plot for physicochemical parameters in water during wet season

Table 3. PCA for physicochemical parameters in water during dry season

	Component		
	PCA 1	**PCA 2**	**PCA 3**
Temp	.640	-.555	-.334
Ph	-.844	-.169	-.321
TSS	.896	.083	.385
TDS	.917	.215	.294
EC	.907	.204	.199
DO	.311	.904	-.126
BOD	.393	.759	.171
COD	.891	.345	.140
Chloride	.905	.351	.205
Nitrate	.882	.331	.268
Sulphate	.623	.466	.479
Phosphate	.920	.337	.127
Nitrite	.268	-.043	.927
Turbidity	.448	.203	.393
Eigen values	7.737	2.550	1.928
% variance	55.264	18.215	13.770
Cum %	55.264	73.479	87.249

Source: Researcher's field data (2021). PCA = Principal Component Analysis

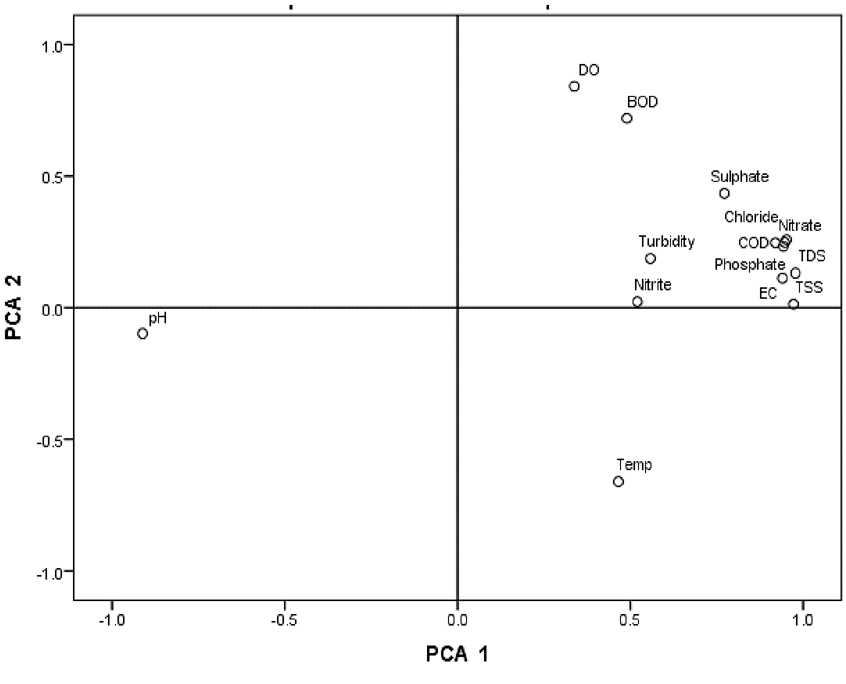

Fig. 3. Factor loadings plot for physicochemical parameters in water in dry season

The results of the two factor loading plots as shown in Fig. 2 revealed that pH had different source compared with other physicochemical parameters while the BOD, nitrate were similar and the source of COD, EC, sulphate, nitrate, chloride, TSS, DO, TDS were more similar than that of turbidity. Turbidity and pH showed more different source compared to other physicochemical parameters.

3.13 PCA for Physicochemical Parameters in Water for Dry Season

For the dry season for physicochemical parameters in water, three latent components were identified, of which component 1 explained 55.264% of total variance, component 2 explained 18.215%, and component 3 explained 13.770% (Table 3). The most important latent component, component [21-23].

3.14 Factor Loadings Plot for Physicochemical Parameters in Water

1, had high positive correlation coefficient (loadings) with TDS, phosphate, EC, chloride, nitrate, TSS, and temperature with negative loading with only pH. The second most important component, component 2, had high positive loadings with DO and BOD while the third component had with high positive loading with only nitrite. The result of the two factor loading plots as shown in Fig. 3 revealed that pH and temperature had different sources compared with other physicochemical parameters while the source of DO and BOD were more similar than that of sulphate, chloride, COD, nitrate, turbidity, EC, TSS, COD.

4. CONCLUSION

The results of the investigated levels of the physicochemical parameters obtained in water samples from the river showed varriation in levels across all the sampling locations and also between the two seasons. The levels obtained in downstream were higher than levels recorded in upstream which reflect variation in levels of anthropogenic activities across the sampling locations. Higher levels of some of the parameters were recorded in dry season than wet season. Generally, comparison of the results of the investigated levels of the physicochemical parameters in the study area with portable water standards revealed that the river water quality supports life of aquatic organisms and also suitable for some domestic uses.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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