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Spatial and seasonal variations in the physicochemical parameters of water quality of a tropical reservoir, Nigeria

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ABSTRACT. In this study, the physicochemical properties of a water supply reservoir in the Esa-Odo community, Obokun Local Government Area of Osun State, Nigeria, were determined. Thirteen selected sampling stations over the three reaches of Esa-Odo reservoir along its main axis were monitored between February 2017 to December 2018 with a view to determining the seasonal and spatial variations in the general physicochemical water quality parameters of the reservoir water. From each sampling station, surface water samples were collected bi-monthly for two annual cycles (rainy and dry seasons). The collected water samples were treated and analyzed for physicochemical water quality parameters using standard instrumental and non-instrumental methods. The data obtained were analyzed using appropriate descriptive and inferential statistics. The result of the analyses of the reservoir water showed an increasing clarity from the upstream to the downstream stations with regard to water temperature, depth, transparency, turbidity, and colour. The water was generally near neutral (pH: 7.01 ± 0.04 - 7.07 ± 0.50) but slightly more near neutral in the rainy season than during the dry season. The water in the reservoir can be classified as a dilute salt bicarbonate freshwater with mean conductivity at the three reaches ranging from 113.39 ± 1.67 μScm^{-1} to 115.24 ± 2.46 μScm^{-1}. Ca^{2+} and HCO_3^- were the dominant cation and anion, respectively, at all stations investigated irrespective of seasons of sampling. The mean values of most parameters determined were within permissible limits, making the river water suitable for most probable domestic and industrial uses and livestock support.

Keywords: reservoir, water quality, physico-chemical parameters, spatial variation, seasonal variations

1. Introduction

Water quality assessment is of immense importance to the management of fisheries, pollution control, irrigation and sewage reservoir and impoundment (Adakole et al., 2008). The Osun River is one of the two major rivers in the Ogun-Osun River Basin of Nigeria. Its headwaters and those of its primary tributaries (River Ayinba, R. Erinle, R. Oba, and R. Otin) rise from the central highlands in Southwestern Nigeria and drains most of the composite states (Oyo, Osun, Ekiti, and Ogun States) before emptying down its main course about 270 km into the Lekki Lagoon. (Ayodele and Adeniyi, 2006). The Osun River Basin, especially in the upper basin, is remarkable for its many impoundments and fish farming (Elliot, 1979). Most of the impoundments within the basin were created primarily for the provision of public water supply with fisheries development as a major ancillary benefit. To fully derive the benefits of impoundments and/or fish ponds and to ensure their good management and rational exploitation, adequate scientific information is required especially information on the physicochemical water quality.

Biological processes and some anthropogenic activities have been reported by Omoniyi et al. (2017) to influence river water and impoundments both in quantity and in quality, with physical and chemical quality parameters being mostly impacted by human activities. Bagenal and Braum (1978) reported that the physical and chemical properties of water bodies impact the species composition, abundance, productivity and physiological condition of aquatic organisms. Determination of physical and chemical properties of water in an aquatic ecosystem is, therefore, an important tool for the characterization of the system, assessing the recharge capacity and the sustainable use of its living resources (Carvalho et al., 2010).

Ayodele and Adeniyi (2006) reported Esa-Odo Reservoir to be one of six major impoundments on the

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Osun River, which showed a high degree of similarity both in zooplankton fauna composition and in water quality. Despite the age of Esa-Odo Reservoir, there is a dearth of in-depth information on its physicochemical water quality. This study, therefore, seeks to provide information on the spatial and seasonal variations in the physicochemical water quality of the reservoir.

2. Materials and methods

2.1. Study area

Esa-Odo Reservoir, an impoundment on the Osun River located in Esa-Odo community, Obokun Local Government Area, Osun State, is one of the typical reservoirs, which was created in 1973 (Fig. 1). The reservoir was impounded primarily for water supply, flood control and fisheries. The climate of the Esa-Odo town where the reservoir is located is a tropical continental climate of Koppen Af type humid tropical rainforest climate (Ifabiyi, 2005; Adediji and Ajibade, 2008). The rainy season over the basin is basically characterized by two maximum rainfalls with peaks in July and September/October separated by a short dry spell in August. The dry season is shorter according to Adediji and Ajibade (2008) and usually lasts for about five months (November to March).

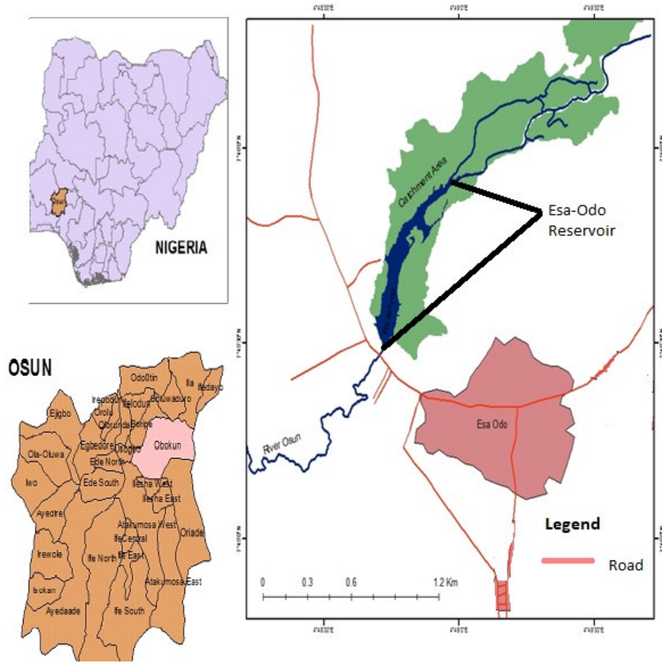

Fig.1. Map showing Nigeria, Osun state and the location of the study area in relation to the adjoining local government areas.

2.2. Sampling stations

The sampling area consists of thirteen sampling stations that were established across the entire water supply reservoir whereby the reservoir was divided along two habitat types, comprising three sections along its major axis (upstream, mid-basin and downstream) as well as along two zones (littoral and open water) across its width for the purpose of selecting sampling stations for the study. Information on the grid coordinates and elevation of each of the sampling stations obtained using Global Positioning System (GPS) is presented in Table 1. The sampled points on Esa-Odo Reservoir are shown in Figure 2.

2.3. Sample collection

Field surveys were conducted at every two-month intervals for a period of two annual cycles from February 2017 to December 2018, covering both the dry and rainy seasons. At each of the sampling stations, water samples were collected into clean, properly rinsed 5-litre capacity plastic bottle containers. The storage and treatment of samples were done according to APHA et al. (1995). Hand held portable (Jenway 4071) conductivity meter was used to measure water pH and electrical conductivity. Water transparency was measured using a Secchi disc. Collected samples were analyzed for colour, turbidity, sulphate and nitrate using

Table 1. The geographical location of water sampling stations in Esa-Odo study area.

S/N	Reference code	Site description	Grid coordinate		Elevation (m)
1	Inflow	River water inflow to the reservoir	N07’45’986”	E004’49’275”	349 ± 2
2	1S	Surface sample of the first sampling station on the reservoir	N07’45’919”	E004’49’021”	349 ± 2
3	1B	Bottom sample of the first sampling station on the reservoir	N07’45’919”	E004’49’021”	349 ± 2
4	2S	Surface sample of the second sampling station on the reservoir	N07’45’670”	E004’48’730”	350 ± 2
5	2M	Mid-point sample of the second sampling station on the reservoir	N07’45’670”	E004’48’730”	350 ± 2
6	2B	Bottom sample of the second sampling station on the reservoir	N07’45’670”	E004’48’730”	350 ± 2
7	2L1	First littoral station of the second sampling station on the reservoir	N07’45’656”	E004’48’748”	351 ± 2
8	2L2	Second littoral station of the second sampling station on the reservoir	N07’45’663”	E004’48’710”	352 ± 2
9	3S	Surface sample of the third sampling station on the reservoir	N07’45’534”	E004’48’702”	353 ± 2
10	3M	Mid-point sample of the third sampling station on the reservoir	N07’45’534”	E004’48’702”	353 ± 2
11	3B	Bottom sample of the third sampling station on the reservoir	N07’45’534”	E004’48’702”	353 ± 2
12	3L1	First littoral station of the third sampling station on the reservoir	N07’45’511”	E004’48’739”	350 ± 2
13	3L2	Second littoral station of the third sampling station on the reservoir	N07’45’540”	E004’48’674”	351 ± 2

applicable standard colorimeter methods (Golterman et al., 1978; APHA et al., 1995). The concentrations of chloride ion, organic matter, alkalinity, acidity, calcium ion, and magnesium ion were determined using applicable standard volumetric analyses described by Golterman et al. (1978).

Samples for Dissolved Oxygen (DO) and five-day Biochemical Oxygen Demand (BOD_5) were collected into oxygen bottles and were fixed *in situ* with Winkler's reagents as described by Golterman et al. (1978). BOD_5 samples were collected in black reagent bottles and incubated in a dark cupboard at room temperature (28 ± 30°C) for five days, after which they were treated for dissolved oxygen determinations. The values of DO and BOD (after five days of incubation in the dark) were determined in the laboratory using the standard method described by Golterman et al. (1978). Sodium and potassium ions were determined using flame emission spectrophotometer (Flame Analyzer), FP640 model. The error of ionic balance in the analysis of the major ions was estimated based on the agreement between the sum of major anions (HCO_3^-, $SO4^{2-}$ and Cl^-) and the sum of the major cations (Ca^{2+}, Mg^{2+}, Na^+, and K^+), expressed in % milliequivalent per liter. The data obtained were subjected to appropriate descriptive statistics, ANOVA and cluster analysis.

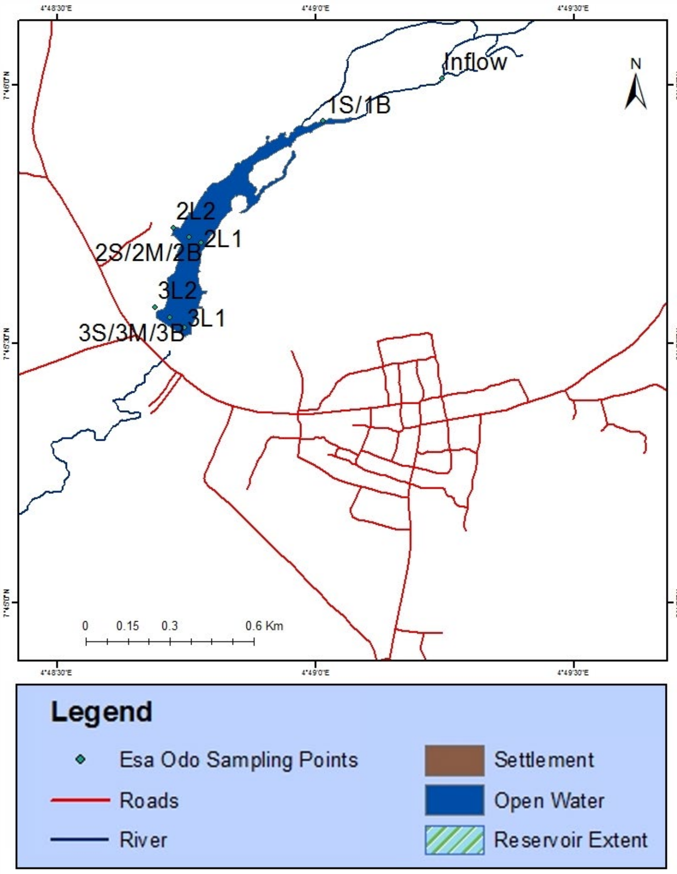

Fig.2. Map showing all the sampling points on Esa-Odo Reservoir during the period of study.

3. Results and discussion

3.1. Spatial and seasonal variations in reservoir water physical characteristics

None of the means of physicochemical parameters of water quality analyzed in the three zones of the reservoir (up, mid and down streams) showed statistically significant variation ($p > 0.05$). However, the water temperature mean value was the highest in the mid-stream portion of the reservoir followed by the mean temperature of water in the downstream section (Table 2). The lowest water temperature recorded in the upstream region could be attributed to the presence of trees with dovetailing branches at the portion of the reservoir, which probably obstructed direct penetration of incident solar radiation, causing the water in the zone to be cooler than in the other part of the reservoir.

The mean water depth was highest in the upstream section followed by the downstream section; the mean depth in the mid-stream portion of the reservoir was the smallest. The variation in the mean depth at various sections of the reservoir could be topographical in nature attributable to various events at the bottom of the reservoir. Also, turbidity mean value was found to increase from the upstream to mid-stream region of the reservoir with the lowest value recorded in the downstream portion of the reservoir. The higher turbidity value recorded in the mid-stream zone of the reservoir was probably attributable to the high retention of small particles of authochthonous and allochthonous materials as a result of less mixing of water. This portion of the reservoir was also noticed to be the region with the highest fishing activities during the period of study.

Mean apparent colour values were observed to increase from downstream to the upstream region of the lake, while the mean true colour value was the highest in the mid-stream section of the reservoir followed by the downstream section. Seasonal variations in the levels of the investigated physical parameters of the water quality of Esa Odo Reservoir are shown in Table 3. On the other hand, water temperature mean value was significantly higher ($P < 0.05$) in the rainy season than in the dry season, as presented in Table 3, and this may have resulted due to the fact that because of the distance and logistics, most of the sampling period of this study was done in the afternoon when the sun must have set, which may have probably slightly increased the water temperature. Also, the cumulative effect of higher occurrence of rainy season values (26.32 ± 0.19 mgL^{-1}) than the dry season values (25.50 ± 0.24 mgL^{-1}) may have contributed to the slightly higher mean value of water temperature in the rainy season. Other physical parameters; transparency, depth, turbidity, true colour ($P > 0.05$), and apparent colour ($P < 0.05$), have higher mean values in the rainy season than in the dry season (Table 3). Similar observations on the turbidity and colour of some other tropical water bodies were made by Omoniyi et al. (2017), Adebisi (1981), Ikomi et al. (2003) and Idowu et al. (2013) which was attributed to the influx of inorganic and organic materials from over land run-off during the rainy season than that of the dry season. However, contrast to their observations was the fact that the mean water clarity (transparency) was slightly higher in the rainy season than in the dry season, this could be as a result of the Statistical influence of

Table 2. Spatial variation in the investigated physicochemical parameters of water quality of Esa-Odo Reservoir during the period of study.

Parameter	Up stream (n = 36)			Mid-stream (n = 58)			Down stream (n = 60)			ANOVA	
	Min	Max	Mean ± S.E	Min	Max	Mean ± S.E	Min	Max	Mean ± S.E	F	P
Water temperature (°C)	23.00	29.00	25.83 ± 0.25	20.00	33.00	26.19 ± 0.26	22.80	33.40	26.04 ± 0.26	0.397	0.673
Depth (m)	0.00	4.70	2.08 ± 0.28	0.00	4.55	1.97 ± 0.16	0.00	4.70	2.06 ± 0.14	0.096	0.909
Transparency (m)	0.00	2.10	0.88 ± 0.11	0.00	1.65	0.73 ± 0.08	0.00	2.00	0.76 ± 0.08	0.691	0.502
Turbidity (NTU)	3.63	113.72	62.34 ± 4.54	0.37	136.92	63.76 ± 3.87	3.63	144.11	59.58 ± 3.60	0.329	0.720
Apparent colour (Pt.Co)	66.00	95.00	78.58 ± 1.28	66.60	97.50	81.19 ± 1.07	66.60	97.50	82.17 ± 1.04	2.301	0.104
True colour (Pt.Co)	43.97	95.00	72.93 ± 1.48	43.97	95.00	74 45 ± 1.06	43.97	94.00	73.83 ± 1.17	0.347	0.708
Total Dissolved Solids (mgL^{-1})	65.40	331.00	90.18 ± 7.61	63.50	153.00	81.75 ± 2.06	61.70	174.00	81.54 ± 2.29	1.437	0.241
pH	6.45	7.60	7.07 ± 0.50	6.40	7.55	7.07 ± 0.04	6.20	7.60	7.01 ± 0.04	0.821	0.442
Conductivity (μScm^{-1})	80.00	133.80	115.24 ± 2.46	82.00	135.70	113.39 ± 1.67	90.00	132.80	114.56 ± 1.45	0.261	0.771
Alkalinity ($mgCaCO_3L^{-1}$)	14.00	76.00	48.72 ± 2.53	16.00	83.00	51.19 ± 1.80	0.00	103.00	53.35 ± 2.53	1.086	0.340
Total Hardness ($mgCaCO_3L^{-1}$)	17.16	73.56	43.70 ± 2.09	15.12	89.88	47.00 ± 2.47	17.16	88.74	46.24 ± 1.87	0.812	0.446
Acidity ($mgCaCO_3L^{-1}$)	8.00	32.00	16.55 ± 0.93	6.00	32.00	18.86 ± 0.71	0.00	38.00	19.37 ± 0.49	2.597	0.078
Bicarbonate (mgL^{-1})	5.81	142.45	56.21 ± 5.90	3.05	142.45	58.05 ± 4.34	3.05	130.21	57.68 ± 3.94	0.038	0.963
Dissolved Oxygen (mgL^{-1})	1.60	14.00	7.28 ± 0.34	0.00	9.35	6.34 ± 0.29	1.80	11.60	6.89 ± 0.24	2.542	0.082
Biological Oxygen Demand (mgL^{-1})	0.40	11.20	4.15 ± 0.35	0.80	6.80	3.51 ± 0.23	0.40	13.60	3.89 ± 0.26	1.317	0.271
Calcium (mgL^{-1})	4.84	20.19	11.83 ± 0.62	2.54	26.00	12.72 ± 0.78	2.54	22.00	12.67 ± 0.50	0.467	0.627
Magnesium (mgL^{-1})	0.79	7.43	3.54 ± 0.28	0.09	8.31	3.95 ± 0.26	0.27	13.54	3.55 ± 0.28	0.728	0.484
Sodium (mgL^{-1})	5.43	7.92	6.71 ± 0.12	2.23	8.21	6.53 ± 0.13	3.53	9.28	6.57 ± 0.13	0.403	0.669
Potassium (mgL^{-1})	3.70	7.88	5.76 ± 0.19	3.07	11.15	5.62 ± 0.17	2.12	7.82	5.57 ± 0.15	0.268	0.765
Sulphate (mgL^{-1})	0.56	22.11	5.11 ± 0.81	0.07	23.85	5.92 ± 0.83	0.28	24.20	5.16 ± 0.74	0.330	0.719
Chloride (mgL^{-1})	3.25	13.81	7.34 ± 0.49	2.54	15.90	7.67 ± 0.46	2.89	13.15	7.02 ± 0.34	0.668	0.514

Table 3. Seasonal variation in the investigated physicochemical parameters of water quality of Esa-Odo Reservoir during the period of study.

Parameter	Dry season (n = 51)			Rainy season (n = 103)			ANOVA	
	Min	Max	Mean ± SE	Min	Max	Mean ± SE	F	P
Water temperature (°C)	20.00	29.00	25.50 ± 0.24	23.00	33.40	26.32 ± 0.19	6.610	0.011*
Transparency (m)	0.00	1.30	0.69 ± 0.59	0.00	2.10	0.81 ± 0.07	1.426	0.234
Depth (m)	0.00	3.50	1.38 ± 0.14	0.00	4.70	1.88 ± 0.16	1.051	0.307
Turbidity (NTU)	6.90	82.36	56.40 ± 2.83	0.37	144.11	64.48 ± 3.07	2.828	0.095
Apparent colour (Pt.Co)	43.97	82.20	80.01 ± 0.77	55.40	95.00	81.43 ± 0.89	9.591	0.002*
True colour (Pt.Co)	70.90	99.00	70.89 ± 1.36	60.30	97.50	75.32 ± 0.75	1.059	0.305
pH	6.40	7.50	6.99 ± 0.05	6.20	7.60	7.04 ± 0.03	2.219	0.138
Conductivity (μScm^{-1})	80.00	131.50	111.98 ± 1.74	82.00	135.70	115.42 ± 1.24	2.561	0.112
Alkalinity ($mgCaCO_3L^{-1}$)	24.00	103.00	57.94 ± 2.31	0.00	76.00	48.24 ± 1.30	15.611	0.000*
Total Hardness ($mgCaCO_3L^{-1}$)	34.00	89.88	57.92 ± 1.85	15.12	88.74	40.56 ± 1.36	55.384	0.000*
Acidity ($mgCaCO_3L^{-1}$)	10.00	36.00	19.90 ± 0.83	0.00	38.00	17.84 ± 0.60	3.972	0.048
Bicarbonate (mgL^{-1})	28.80	123.60	69.44 ± 2.76	3.05	142.45	51.55 ± 3.53	11.062	0.001*
Dissolved Oxygen (mgL^{-1})	2.00	14.00	7.01 ± 0.28	0.00	10.80	6.65 ± 0.20	1.069	0.303
Biological Oxygen Demand (mgL^{-1})	1.20	11.20	4.16 ± 0.27	0.40	13.60	3.64 ± 0.19	2.448	0.120
Calcium (mgL^{-1})	7.91	26.00	15.62 ± 0.62	2.54	21.23	10.95 ± 0.40	42.977	0.000*
Magnesium (mgL^{-1})	1.67	8.27	4.67 ± 0.20	0.09	13.54	3.22 ± 0.20	20.230	0.000*
Sodium (mgL^{-1})	3.53	7.33	6.06 ± 0.10	2.23	9.28	6.85 ± 0.09	28.685	0.000*
Potassium (mgL^{-1})	2.12	7.23	5.50 ± 0.17	3.58	11.15	5.70 ± 0.12	0.992	0.321
Sulphate (mgL^{-1})	0.07	12.46	2.94 ± 0.40	0.39	24.20	6.68 ± 0.63	15.849	0.000*
Chloride (mgL^{-1})	2.89	13.81	7.53 ± 0.42	2.54	15.90	7.24 ± 0.30	0.302	0.583
Nitrate (mgL^{-1})	1.32	6.63	4.42 ± 0.24	0.04	8.18	4.57 ± 0.19	0.212	0.646

Note. * - $P < 0.05$

the sample sizes obtained in both seasons (dry season: n = 51; rainy season: n = 103). In addition to that, many studies have reported that wind-driven sediment resuspension, which is a generally phenomenon in shallow reservoirs, usually have negative impacts on water clarity (transparency); a condition more prevalent in the reservoir during the dry season (i.e., shallower) than rainy season. Also, it could be probably due to the availability of favorable temperature conditions from increased solar inputs during the dry season period which could favour the growth of phytoplankton in the reservoir and eventually lowers the water clarity (transparency) in the dry season (Somasundaram et al., 2021).

3.2. Spatial and seasonal variations of chemical characteristics of the water in reservoir

The mean hydrogen ion potential (pH) values at the stations showed that the reservoir was generally slightly alkaline with mean pH values in the three portions of the reservoir, ranging between 7.01 and 7.07 over the two annual cycles studied. (Table 2). The overall range (6.2 – 7.6) falls within the WHO permissible limits of 6.5 to 8.5 (WHO, 2017) for drinking water and also for most aquatic life (6.5 to 8.5) (USEPA, 1994). During daylight, algae and underwater plants remove carbon dioxide from the water as part of the sunlight-driven process of photosynthesis. The relative rates of respiration and photosynthesis within the pond determine whether there is a net addition or removal of carbon dioxide, and, therefore, whether pH falls or rises (Craig and Louis, 2008). Acidification of water recorded during the dry season could be attributed to increased metabolism, elevated microbial degradation of organic debris and concentrated dissolved solids in warmer water during this period (Rajasegar, 2003; Tukura et al., 2012; Omoniyi et al., 2017).

Conductivity is a measure of the ability of water to conduct electric current, and it is sensitive to variations in the concentration of dissolved solids, mostly mineral salts. The degree of dissociation of these solids into ions, the valency of each ion, ion mobility, and water temperature all have an influence on conductivity (Omoniyi et al., 2017). The conductivity mean value of water in Esa-Odo Reservoir during this study was the highest in the upstream region followed by the downstream and lowest in the midstream portion of the reservoir. The result also showed that the conductivity mean value of water in the reservoir was higher during the rainy season than in the dry season ($P > 0.05$). The conductivity result of this study slightly differs from what was recorded by (Omoniyi et al., 2017) for natural points of the Osun River where conductivity decreases down the three reaches of the river in the dry season. However, palm oil processing effluents very close to the upstream portion of the reservoir by the riparian farmers during the rainy season and anthropogenic activities around the downstream portion of the reservoir probably contributed to the elevated conductivity values recorded during the period of study. However, the range of conductivity values recorded (80 – 135 μScm^{-1}) for the entire reservoir didn't exceed the USEPA (1994) permitted limit (20 to 2000 μScm^{-1}) for freshwaters.

The range of the mean values of total hardness (43.70 ± 2.09 to 47.00 ± 2.47 $mgCaCO_3L^{-1}$) recorded in the three portions of Esa-Odo Reservoir showed that the water was generally soft with the hardness increasing down the course of the reservoir, having the highest value at the mid-stream portion (Table 2). The water mean total hardness during the dry season was significantly higher ($P < 0.0001$) than during the rainy season (Table 3). Both seasonal and spatial variations in the values of other salinity parameters (acidity and alkalinity) followed the same trend as they increased down the course of flow of the reservoir in the dry season (Table 3) with a mean range of alkalinity value in the three portions of the reservoir from 48.72 ± 2.53 to 53.35 ± 2.53 mgL^{-1}, and this corresponds to the work carried out by Omoniyi et al. (2017).

The Dissolved Oxygen (DO) concentration along Esa-Odo Reservoir zones was the highest in the upstream portion followed by the downstream portion and the lowest at the mid-stream portion (Table 2). Water movement at the upstream and downstream locations on the reservoir, which was noticed to be higher, as well as a higher density of trees plantation cover, might have contributed to the higher DO mean concentration recorded at these sections of the reservoir. Dry season mean value of DO higher than rainy season mean value (Table 3) could be attributed to the longer days of intense sunlight during this period, which most probably accelerated photosynthetic activities of phytoplanktonic organisms that release more dissolved oxygen as a by-product (Krishnamurthy, 1990). A similar observation was reported by Tukura et al. (2012) in the Mada River located in a semi-arid region in Nassarawa State, Nigeria, where, due to biological decomposition, deoxygenation rate was expectedly higher than oxygenation from the atmosphere during the rainy season. The range of DO observed in the three portions of the reservoir (≈ 0.0 to ≈ 14.0 mgL^{-1}) during the period of study, however, was reported by Stickney (2000) to be good for the production and survival of a large spectrum of aquatic biota.

The mean value of BOD_5 of water recorded in the reservoir during the period of study (Table 2) decreased from the upstream portion to the downstream portion with the least value recorded at the midstream portion of the reservoir. The direction of water flow that increases along its course was towards the point of discharge upstream. The higher amount of organic matter deposited in the upstream portion of the reservoir would probably increase the amount of microbial decomposition and most probably increase the biological oxygen demand from the upstream to the downstream portion. The dry season mean values of BOD_5 higher than rainy season mean values across the entire reservoir (Table 3) could be attributed to the increased water temperature during the dry season, which increases biological activities such as decomposition and microbial and algal respiration (Omoniyi et al., 2017; WMO, 1980).

On average, the cationic hierarchy (i.e., $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$) was the same for all the zones investigated during the period of study, suggesting a similar/common geology and/or similar weathering influence within the river basin. Calcium and magnesium ions (in that order) were the dominant cations in the reservoir water, having higher concentrations than other cations. The high Ca^{2+} content was probably responsible for the slightly alkaline nature of the water in the reservoir since calcium and magnesium combine with carbonate and bicarbonate ions in water to raise the alkalinity (Omoniyi et al., 2017). In the same vein, the uniform anionic hierarchy ($HCO_3^- > Cl^- > SO_4^{2-}$) shows that the water is of the bicarbonate type with the concentrations of bicarbonate ion being the highest at all stations investigated on the reservoir.

3.3. Relationships between the sampling stations in relation to the physico-chemical characteristics of water quality

Figure 3 and Figure 4 show the relationships between the investigated stations and the respective determined physicochemical parameters of water quality during the dry and rainy seasons respectively. The clustering pattern of the stations both in the dry and rainy seasons were the same with the two distinct cluster groups identified, showing the interconnection that existed among the stations established on the reservoir. The mass of the reservoir water at a station, which virtually flows into the next station in the same reach/region, probably accounted for the deal of uniformity in the physicochemical conditions of the stations recorded in both dry and rainy seasons.

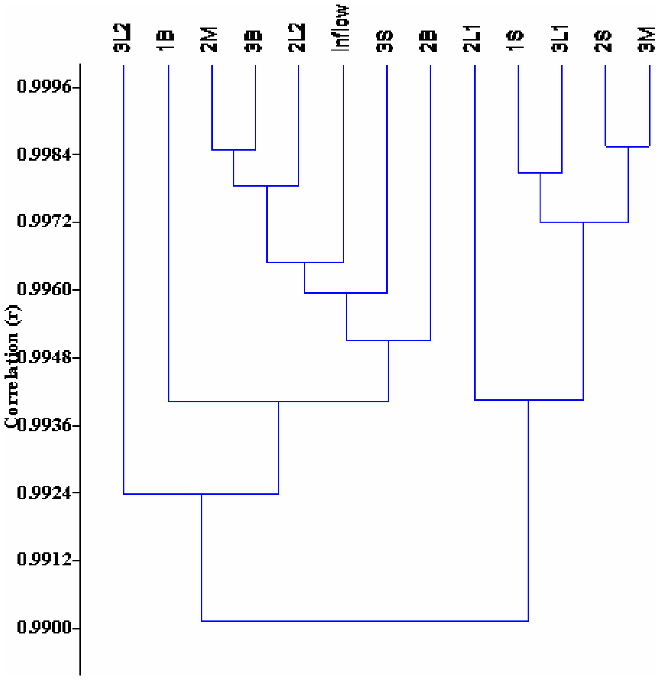

Fig.3. Relationship among the sampled locations based on the assayed water quality parameters in the dry season during the period of study.

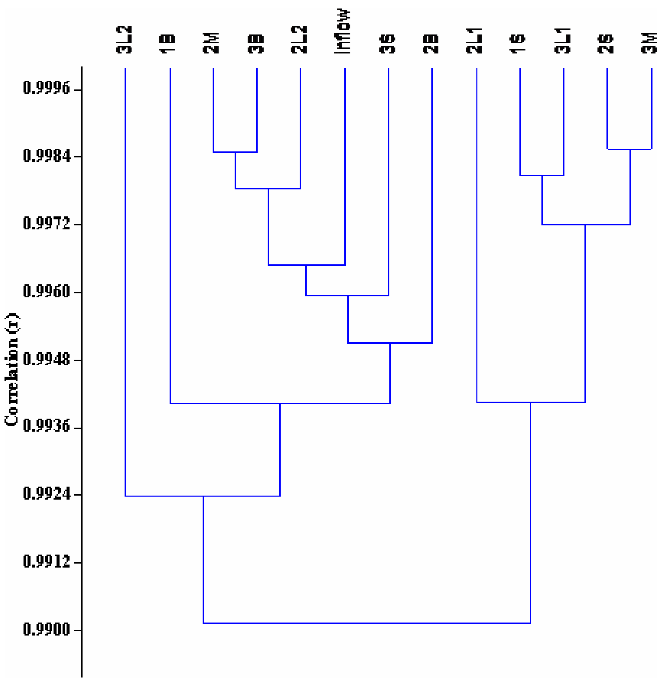

Fig.4. Relationship among the sampled locations based on the assayed water quality parameters in the rainy season during the period of study.

4. Conclusions

The study has shown that Esa-Odo Reservoir was generally moderately alkaline, soft, fairly clean, and dilute bicarbonate freshwater suitable for most probable domestic and industrial uses. The river water, if properly harnessed, could serve a good proportion of the population of communities as the reservoir that was originally designed to serve with a municipal water supply and aquatic livestock. However, there is a need for continuous monitoring and assessment as the riparian area of the reservoir becomes progressively utilized for agricultural and other anthropogenic activities.

Conflict of interests

The authors declare no conflict of interests.

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