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Correlation Study of The Spatio-Temporal and Seasonal Variations of Physicochemical Parameters in Kazaure Reservoir, Jigawa State, Nigeria

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Abstract

The aim of the study was to assess the pollution status of Kazaure Reservoir in terms of Spatio- temporal and seasonal variations of physicochemical parameters and established statistical relationship between them. Water samples were collected in triplicates from four selected sites (A, B, C and D) between January to December. Twelve parameters were analyzed following the standard procedures of APHA (2010). The results revealed the pollution status of the reservoir to be lower in Site D and higher in site C as indicated in the mean spatial ranges of water temperature (24.7 ± 1.9 to 34.3 ± 1.6 °C), transparency (11.2 ± 1.87cm to 32.0 ± 6.0cm), total suspended solids (114.6 ± 14.5 mg/l and 218.0 ± 17.4 mg/l), total dissolved solids (68.0 ± 5.26 mg/l to 187.3 ± 3.25 mg/l), conductivity (119.0 ± 14.5µS/cm and 202.0 ± 19.5 µS/cm), salinity (51.5 ± 6.51 mg/l and 80.9 ± 7.92 mg/l), BOD (10.80 ± 1.77 mg/l and 17.7 ± 1.53 mg/l), nitrate (11.3 ± 0.57 mg/l to 19.7 ± 2.08 mg/l) and phosphate (8.7 ± 1.47 to 18.0 ± 1.00 mg/l). Higher pollution level in dry than wet season is evident in the study. While TDS, pH, salinity, conductivity differed significantly between wet and dry seasons (P<0.05), no significant seasonal variation was recorded in the remaining parameters (P>0.05). Pearson Correlation Coefficient showed strong positive correlation between Temperature with BOD (r=0.883) and Nitrate (r=0.908), TDS with salinity (r=0.953), pH with TSS (r=0.868) and alkalinity (r= 0. 894), Conductivity with alkalinity (r= 0.845), BOD (r=0.831), TSS (r=0.838) and TDS (r=0. 987). Strong negative correlation existed between Transparency with TDS (r=− 0.855) and pH (r=−0. 837), Salinity and pH (r = -0.801) DO and BOD (r=−0.893). The elevated mean values of BOD, Nitrate and Phosphate in all the sampling sites exceeding standard limits of WHO (2018) throughout the study period indicated pollution loading traced back to detergents and soaps used for laundry, agricultural runoff, human and animal wastes and increased concentration of wastes by decreased water volume. It is therefore recommended that washing off of waste and excessive use of phosphate fertilizers should be prevented. Kazaure Reservoir should be revisited by relevant authourities to prevent its collapse and reduce the impact of pollution aggravated by reduced water volume from source.

Keywords: Correlation, Kazaure reservoir, Physico chemical parameters, Pollution status, Spatial and seasonal variations.

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INTRODUCTION

Water pollution in Nigeria continues to be a lingering problem of great concern. Worako (2015) attributed the problem to increase in population growth and increasing human demand of water for domestic, industrial and agricultural purposes. In the process of utilizing it for these diverse purposes, it is directly or indirectly altered in composition or condition to the extent that it becomes unsuitable or less suitable for specific or general use. Thus, becoming impaired due to increased deposition of wastes from various sources which involves almost every significant human activity. Adeyemi *et al*. (2022) highlighted that in any environment there is a strong relationship between water pollution and human activities ranging from increased population, farming to economic growth and urbanization, which influence the concentration of pollutants in reservoirs depending on location and season. Therefore, understanding the impacts of pollutants on water depends on the parameters measured. In view of the above, Physicochemical parameters as indispensable environmental factors are measured to detect pollution status (Agarwar and Rajwar, 2010).

Water scarcity is one of the major challenges affecting the people of Kazaure town (Ali and Rilwanu, 2017). Yet with such scarcity, Kazaure Reservoir being the major source of water basically utilized for consumption, domestic, irrigation and fishing purposes is not exempted from the negative impacts of pollution. Wastes enter the water body from various sources, one of the major identifiable indications of water quality deterioration in the reservoir is its discouraging aesthetic appearance with uncomfortable faint odour. Being a water body of smaller town that is often unnoticed by researchers, understanding its pollution status is of paramount importance for sustainable management. The aim of the study was to assess the pollution status of the reservoir in terms of spatio- temporal and seasonal variation of physicochemical parameters and to establish correlation between the parameters.

MATERIALS AND METHODS

The Study Area

Kazaure Reservoir formerly called Muhammad Ayuba Dam is found between old and new Kazaure town (Cikin gari and kanti) whose source of water is River Katsina. The Dam naturally receives rain water and artificially receives waste water from the town. The reservoir is located on 12°39^{1}10^{11}N and 8°24^{1} 43^{11}S and constructed for multiple functions of flood control, irrigation, as well as for human consumption and domestic activities. It is also utilized for fishing and recreational activities.
Four (4) sampling sites were chosen as follows:

Site A – This site is characterised by stagnant water located within Latitude 12°64'35.79"N and Longitude 8°41'23.48"E.

Site B – This site characterised by various anthropogenic activities, located within Latitude 12°38'40.40"N and Longitude 8°25'24.68"E.

Site C- This site is characterised by anthropogenic and fishing activities, located within Latitude. 12°38'22.63"N and Longitude. 8°25'23.61"E.

Site D- This site is less disturbed by anthropogenic activities, located within Latitude 12°38'35.29"N and Longitude 8°25'20.60"E.

Collection of samples
The water samples were collected in brown 250ml capacity sample bottles on fortnight basis between 8:00 – 10:00 a.m. from January to December and analyzed for twelve parameters.

Determination of Physicochemical Parameters
Temperature, pH, Salinity, DO and BOD were measured using U-10 Horiba multi water checker. Transparency was measured using Secchi Disc and Tape, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Conductivity, Alkalinity, Nitrate, and Phosphate were analyzed using Spectrophotometer Hach DR/2010 model as described by APHA (2010).

Statistical Analyses
All statistical analyses were carried out using the Statistical Package for Social Science (SPSS 20) software. All experiments were performed in triplicates and the numerical values were expressed using descriptive statistics as mean ± standard deviation to answer research questions. Student's paired t-test was used to determine seasonal variation of the parameters. One way ANOVA was used to compare means of the different parameters and separated by Least Standard Deviation (LSD). Means were considered significantly different at $P<0.05$. Pearson's product moment correlation was also computed to determine the strength of relationship between the parameters.

RESULTS

Spatio- temporal and Seasonal Variations
Table 1 presents the mean spatial values of physicochemical parameters in Kazaure Reservoir. The mean temporal variations are presented in Tables 2-3 and Seasonal variations are shown in Table 4. Correlation coefficient (r) values for the parameters are shown in Table 5.

Table 1: Mean Spatial Variations in concentration of Physicochemical Parameters in Kazaure reservoir, Jigawa State, Nigeria

Parameters	SITES				WHO
	A	B	C	D	(2018)
Temperature (°C)	30.2 ± 1.7[a]	31.9 ± 1.2[a]	34.3 ± 1.6[a]	24.7 ± 1.9[b]	<30
Transparency (cm)	16.0 ± 1.35 [a]	19.7 ± 3.31[a]	11.2 ± 1.87[a]	32.0 ± 6.0[b]	>25
TSS (mg/l)	194.7 ± 16.6 [a]	192 ± 15.3[a]	218 ± 17.4[a]	114.6 ± 14.5[a]	<500
TDS (mg/l)	115.3 ± 2.08 [a]	120.6 ± 6.7[b]	187.3 ± 3.25[b]	68.0 ± 5.26[a]	<500
pH	6.78 ± 1.1[a]	6.92 ± 0.51[a]	7.12 ± 1.05[a]	7.56 ± 0.83[a]	6.5-9.5
Salinity (mg/l)	74.7 ± 2.04[a]	73.7 ± 3.22[a]	80.9 ± 7.92[a]	51.5 ± 6.51[b]	500
Alkalinity (mg/l)	35.7 ± 6.7[b]	41.6 ± 6.99[a]	46.4 ± 3.72[a]	36.0 ± 5.24[b]	<200
Conductivity (µS/cm)	151.7 ± 8.02[a]	161.0 ± 17.6[b]	202.0 ± 19.5[a]	119.0 ± 14.5[a]	<1000
D.O (mg/l)	4.80 ± 1.06[a]	3.97 ± 0.52[a]	3.31 ± 0.10[a]	5.96 ± 1.30[b]	5.0-9.0
BOD (mg/l)	13.3 ± 1.85[ab]	14.1 ± 2.05[a]	17.7 ± 1.53[b]	10.80 ± 1.77[ab]	<10
Nitrate (mg/l)	15.3 ± 2.52[a]	16.7 ± 2.52[b]	19.7 ± 2.08[b]	11.3 ± 0.57[a]	<10
Phosphate (mg/l)	15.0 ± 1.00[a]	17.3 ± 0.5[b]	18.0 ± 1.00[b]	8.7 ± 1.47[b]	<5

Mean values with different superscript alphabet in a row differ significantly ($p<0.05$)

Table 2: Mean Monthly Variations in concentration of Physico-chemical Parameters in Kazaure Reservoir, Jigawa State, Nigeria

Months	Temperature (°C)	Transparency (cm)	TSS (mg/l)	TDS (mg/l)	pH	Salinity (mg/l)	Alkalinity (mg/l)	Conductivity (µs/cm)
January	21.53±1.2^{ab}	25.89±4.5^{ab}	175.33±5.8^{ab}	178.70±3.9^{a}	7.03±0.6^{ab}	75.67±1.53^{a}	38.33±4.72^{a}	168.00±3.74^{a}
February	23.67±1.9^{ab}	30.98±1.6^{ab}	110.67±1.2^{b}	181.00±3.5^{a}	6.27±0.2^{a}	75.20±5.27^{a}	44.80±4.52^{b}	175.20±6.26^{a}
March	23.47±2.8^{a}	27.93±1.8^{ab}	195.33±11.3^{ab}	201.67±5.8^{a}	6.23±0.6^{a}	78.26±5.47^{a}	47.33±6.11^{b}	188.67±19.06^{b}
April	34.13±7.2^{ab}	26.50±1.4^{ab}	253.33±7.9^{b}	207.00±4.6^{a}	6.48±0.2^{a}	82.84±13.07^{a}	49.33±7.57^{b}	198.70±19.50^{b}
May	32.43±1.7^{ab}	21.07±1.6^{ab}	174.66±8.5^{ab}	160.00±3.7^{a}	7.55±1.00^{a}	67.33±7.02^{a}	36.97±4.85^{b}	142.33±13.31^{a}
June	30.17±1.2^{a}	18.15±0.4^{ab}	181.6±7.9^{ab}	150.00±10.8^{a}	6.90±1.1^{a}	61.13±10.73^{a}	38.87±6.57^{a}	140.00±7.54^{a}
July	30.67±2.4^{ab}	16.56±0.9^{ab}	177.67±7.2^{ab}	126.66±3.5^{a}	8.00±0.9^{b}	61.70±11.04^{a}	31.76±1.65^{a}	137.00±5.71^{ab}
August	28.93±5.2^{ab}	16.56±1.2^{ab}	185.00±1.5^{ab}	117.00±6.3^{a}	8.56±1.0^{a}	48.83±3.41^{b}	35.10±4.59^{a}	171.66±9.07^{a}
September	28.33±2.7^{a}	15.83±2.5^{ab}	173.33±7.7^{ab}	63.00±4.5^{ab}	7.70±0.9^{a}	44.53±7.3^{b}	40.26±6.86^{b}	145.60±4.57^{a}
October	30.87±1.9^{ab}	17.37±2.2^{ab}	185.33±6.5^{a}	114.33±7.6^{a}	7.73±0.6^{a}	49.00±6.2^{b}	32.50±3.12^{a}	122.40±8.02^{ab}
November	27.67±3.9^{ab}	23.30±1.0^{ab}	176.33±5.4^{a}	152.33±7.7^{a}	7.25±0.3^{a}	60.17±4.7^{b}	34.30±7.15^{a}	126.33±5.68^{a}
December	25.00±2.5^{b}	17.63±1.9^{ab}	179.00±12.5^{a}	129.67±7.6^{a}	7.26±1.2^{a}	59.50±11.7^{ab}	35.00±4.58^{a}	138.10±5.82^{ab}

Mean values with different superscript alphabet in a column differ significantly ($p<0.05$)

Table 3: Mean Monthly Variation in concentration of Physico-chemical Parameters in Kazaure Reservoir, Jigawa State, Nigeria

Months	DO (mg/l)	Parameters BOD (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)
January	3.47±0.80^{a}	12.73±1.16^{a}	12.73±1.16^{b}	12.73±1.16^{a}
February	3.56±0.40^{a}	12.40±1.63^{b}	12.40±1.63^{b}	12.40±1.63^{a}
March	4.18±0.19^{a}	10.00±1.00^{b}	10.00±1.00^{b}	10.00±1.00^{b}
April	3.21±0.26^{a}	15.16±2.02^{ab}	15.85±3.65^{b}	12.73±2.61^{b}
May	4.30±0.96^{b}	10.86±1.21^{a}	18.33±2.52^{ab}	13.33±3.51^{b}
June	4.19±0.31^{a}	12.04±0.52^{a}	17.00±2.00^{ab}	13.33±3.52^{b}
July	4.54±0.30^{b}	11.5±1.23^{a}	13.00±1.00^{a}	15.33±2.89^{b}
August	4.76±0.39^{b}	14.33±1.52^{ab}	12.00±1.00^{a}	15.67±1.15^{b}
September	4.35±1.17^{b}	10.66±1.53^{a}	14.80±2.55^{b}	17.33±1.52^{ab}
October	4.39±1.18^{b}	10.97±2.05^{a}	14.00±1.00^{b}	14.00±2.64^{b}
November	4.97±0.72^{ab}	6.97±1.21^{b}	12.67±1.53^{a}	17.67±1.16^{ab}
December	5.66±0.60^{ab}	8.15±0.1.20^{b}	12.33±1.53^{a}	14.00±1.00^{b}

Mean values with different superscript alphabet in a column differ significantly ($p<0.05$)

Table 4: Mean Seasonal Variations in Concentration of Physicochemical Parameters in Kazaure Reservoir, Jigawa State, Nigeria

Mean values with different superscript alphabet in a row differ significantly (p<0.05)

	1	2	3	4	5	6	7	8	9	10	11	12
1	1											
2	-.432	1										
3	-.182	**-.855****	1									
4	.528	-.120	.209	1								
5	.355	**-.837****	-.768	-.004	1							
6	-.222	.261	**.953****	.175	**.801****	1						
7	-.129	.724	.632	.242	**894****	.695*	1					
8	-.199	-.657	**.838****	**.987****	-.516	.679	**.845****	1				
9	-.026	-.632*	-.553	-.124	.524	-.630*	-.670*	-.635*	1			
10	**.883****	-.541	.229	.278	.012	.256	.385	.881**	**-.893***	1		
11	**.908****	.392	.430	-.011	-.468	.495	.452	.236	**-.877***	.309	1	
12	.472	-.670*	-.651*	.219	.582*	-.702*	-.426	-.498	-.649	-.410	.563	1

Table 5. ~~Pearson Correlation Coefficient~~ between Physico-chemical Parameters of Kazaure Reservoir, Jigawa State, Nigeria (January-December, 2018)

Parameters	Dry season (November-April)	Wet season (May-October)	P Value
Temperature (°C)	34.00±2.00^{a}	19.30±0.26^{b}	0.00
Transparency (cm)	17.37±2.1^{a}	33.60±0.9^{a}	0.07
TSS (mg/l)	147.67±7.1^{a}	262.67±15^{a}	0.06
TDS (mg/l)	60.36±2.47^{a}	161.67± 12.1^{b}	0.02
pH	8.27±0.33^{a}	6.40±0.60^{b}	0.01
Salinity (mg/l)	84.63±3.40^{a}	44.53±10.0^{b}	0.03
Alkalinity (mg/l)	47.6±5.96^{a}	33.17±2.51^{a}	0.09
Conductivity (μS/cm)	202.00± 29.4^{a}	127.00±13.2^{b}	0.01
D.O (mg/l)	4.13 ±1.30^{a}	6.67±0.81^{a}	0.10
BOD (mg/l)	14.00±4.35^{a}	4.41±0.63^{a}	0.07
Nitrate (mg/l)	16.85±5.19^{a}	11.66±1.52^{a}	0.19
Phosphate (mg/l)	15.83±3.33^{a}	9.71±2.44^{a}	0.20

**Strong significant correlation Key: 1=Temperature 2=Transparency 3=Total dissolved solids 4=Total suspended solids 5=pH 6=Salinity 7=Alkalinity 8=Conductivity 9=Dissolved oxygen 10=Biochemical oxygen demand 11=Nitrate 12=Phosphate

Discussion

During the study period, the mean spatial value of water temperature varied between 24.7 ± 1.9°C in site D and 34.3± 1.7°C in site C with the highest temporal value recorded in the month of April. The relatively high water temperature recorded in the month of April was attributed to the characteristic of hot weather in Kazaure and a response to time and period of sampling. Seasonal variation indicated higher mean temperature in dry season (34.00±2.00 °C) than wet season (19.30±0.26 °C) with significant variation between the two seasons. This clearly indicated seasonal dynamics caused by the uniqueness of the two main seasons in Nigeria and depreciation of water quality overtime due to change in seasonal activities and rainfall pattern. Similar reports were made by Nafi'u and Ibrahim (2017) and slightly varies with the findings of Muhammed *et al.* (2017) who recorded lower temperature values in his study on Kazaure Reservoir.

Transparency mean spatial values ranged from 11.2 ± 1.87cm recorded at Site C to 32.0 ± 6.0 cm recorded at Site D. Temporal and seasonal mean values throughout the study period indicated no significant difference (P>0.05). This could be the reason for the poor aesthetic appearance observed during sampling throughout the study period. The higher transparency of 33.60±0.9cm recorded in wet season may be linked to the effect of rainfall which dilutes the water and reduces concentration of solutes. Lower transparency mean values of 17.37±2.1cm are not separated from the climatic nature accompanied by high evaporation. The findings of this study contradicted the work of Abubakar *et al*. (2015), who reported that Kazaure Reservoir recorded higher transparency in dry season than wet season.

Total suspended solids values ranged between 114.6 ± 14.5 mg/l in Site D and 218 ± 17.4 mg/l in Site C. The higher TSS values in site C may be attributed to a number of anthropogenic activities emanating from the site that tend to accumulate faecal waste, decaying plants and animal matter. Similar trend was reported by Iwar (2021). Temporal variation recorded highest TSS value (253.33±7.9 mg/l) in April which is associated with reduced water volume making suspended solids to be at higher concentration levels. However, overall seasonal variation revealed higher wet season values (262.67±15.0 mg/l). This is attributed to high suspended sediment load in the arid tropics as a result of scanty vegetation in the area, which fails to prevent erosion by intense seasonal rainfall. The insignificant seasonal variation (P>0.05) is an indication of continuous infiltration of suspended materials regardless of season which tends to affect the Reservoir.

The mean spatial values of Total Dissolved Solids ranged from 68.0 ± 5.26 mg/l in site D to 187.3 ± 3.25mg/l in Site C with the highest temporal value recorded in April (207.00±4.6 mg/l). However, there is no cause for alarm as the TDS values recorded throughout the study period in all the sampling sites across all seasons have not exceeded the WHO guidelines of 500mg/l . The lowest value of 63.00±4.5 mg/l recorded in September differed significantly from the remaining sampling months. This finding is attributed to cool winds at the end of rainy season and reduced surface runoff which allows gradual settling of the suspended matter. Similar findings were reported by Okpanachi and Yaro (2019). Total Dissolved Solids recorded lower dry season mean values (60.36±2.47 mg/l) and higher wet season values (161.67± 12.1 mg/l) with significant seasonal variation that could be associated with soil erosion or surface run-off during the rainy season. The findings of this study are in line with the work of Hayek *et al.* (2021) who recorded lower dry season values. On the contrary, Sunday *et al.* (2019) reported higher wet season TSS values.

The mean spatial values of pH range varied between slightly acidic (6.78 ± 1.1) in Site A to slightly alkaline (7.56 ± 0.83) in Site D. The findings of this study differs from the pH range (7.20 – 7.90) reported by Oladeji (2020) in the previous limnological study of the Reservoir. They were however within the WHO (2018) guidelines range (6.5-9.5). Thus, the pH range obtained in this study is within the permissible limits of fresh water bodies. The significant variation in pH mean dry season values (8.27±0.33) and wet season values (6.40±0.60) indicated that the former are slightly alkaline and the latter are slightly acidic. This may not be unconnected with the numerous anthropogenic engagements along the course of the Reservoir that leads to higher concentration of organic matter in dry season. The trend recorded in this study contradicts a phenomenon common in most Nigerian fresh water bodies of higher pH values rainy season. Usman (2015) recorded higher pH values in wet than dry season. However, Iwar *et al*. (2021) reported similar trends with the current study.

Salinity values have not exceeded the set limits (500mg/l) as they ranged between 51.5 ± 6.51mg/l in Site D to 80.9 ± 7.92 mg/l in Site C. However, the salinity levels in dry season (84.63±3.40mg/l) were slightly higher than wet season mean values (44.53±10.0 mg/l) with significant variation between the seasons ($P<0.05$). This could be attributed to increased evaporation and high concentration of ions in the water. Similar findings were reported by Sila (2019) while Hayek *et al.* (2021) reported a contradictory finding of higher salinity values in wet season ranging between 259.33 mg/l to 418 mg/l than dry season values ranging between 206.17mg/l to 384.33 mg/l.

Conductivity mean values varied between 119.0 ± 14.5 µS/cm in Site D and 202.0 ± 19.5 µS/cm in Site C. The highest value recorded in site C could be due to the agricultural and other human related activities close to the site. However, throughout the study period all conductivity values recorded were below the threshold of 1000 µs/cm for freshwater bodies. Similar findings were reported by Kpikpi and Bubu-davies (2021). Higher dry season values (202.00± 29.4 µs/cm) and lower wet season values (127.00±13.2 µs/cm) were recorded, with significant seasonal variation. Higher dry season values may be attributed to excessive evaporation leading to concentration effects of salts at this period of the year when the water level is low and water abstraction for dry season irrigation could have also contributed to the higher values of these ions in the season and consequently increased the concentration of dissolved salts. On the other hand, lower wet season values are attributed to dilution of water sources by rainwater which reduces conductive ions, hence low conductivity during high rainfall months. Similar findings were reported by Sila (2019).

Alkalinity mean values ranged between 35.7 ± 6.7 mg/l in Site A and 46.4 ± 3.72 mg/l in Site C. The range of these values are within the WHO permissible standard (< 200 mg/l) for alkalinity of fresh water bodies. These findings are in tandem with the reports of Olorode *et al.* (2015). The recorded higher dry season values (47.6±5.96 mg/l) than wet season values (33.17±2.51mg/l) with no significant seasonal variation was recorded ($P > 0.05$). This contradicted the findings of Tibebe *et al*. (2022) for recording higher wet season values.

Nitrate and Phosphate mean values ranged between 11.3 ± 0.57mg/l to 19.7 ± 2.08 mg/l and 8.7 ± 1.47 mg/l to 18.0 ± 1.00 mg/l with highest values recorded in Site C and lowest values recorded in Site D respectively. Elevated values of phosphate and nitrate in Site C could be attributed to the impact of fertilizer from agricultural activities around the study area. The values recorded in this study were much higher than the standard limits for fresh water set by WHO (2018). Similarly, the values recorded were also higher than what was reported by Aminu (2013). Abubakar *et al.* (2015) in their prior studies of the reservoir recorded lower nitrate and phosphate values ranging between 0.3-0.7mg/l and 4.2-10.5mg/l respectively. This is a clear indication of the impact of environmental dynamics on the reservoir overtime. In the present study the major source of phosphate is traced back to detergents and soaps used for laundry activities, while the nitrate is found as a result of discharge of vehicle wash, laundry waste, agricultural runoff, human and animal waste. This is in line with the findings of Ajayan and Kumar (2016). The poor aesthetic appearance of the reservoir observed by the plain eye during sample collection also supports the interpretation of nutrients concentration that lead to excessive algal growth in the reservoir. The dry season mean values of both Nitrate (16.85±5.19 mg/l)) and Phosphate (15.83±3.33 mg/l) were higher than wet season values (11.66±1.52mg/l) and (9.71 ± 2.44 mg/l) respectively with no significant seasonal variation in both parameters ($P>0.05$). This justifies that the reservoir records higher pollution level in the dry than wet season due to stagnant nature and low water volume majorly resulting from damming. Similar reports were made by Patil and Bhosale (2019), while the reports of Adesakin *et al*. (2020) contradicted the findings of the current study.

Dissolved Oxygen recorded spatial mean values ranging between of 3.31 ± 0.10 mg/l in Site C to 5.96 ± 1.30mg/l in Site D. Site C is the first major recipient of the anthropogenic influence of waste discharge causing higher pollution in the site. This low value could be linked to the depletion of dissolved oxygen in water due to high temperature and increased microbial activity emanating majorly from intense fishing and agricultural activities as well as deposition of human and animal wastes. Low DO concentrations may result in anaerobic conditions and cause bad odour in water. Similar reports were made by Titilawo *et al.* (2019). Judging from the results, the higher DO of 5.96 ± 1.30mg/l in Site D indicated better water quality. This could be indicative of high re-aeration rates and rapid aerobic oxidation of biological substances attributed to much lesser activities in the area. The maximum DO (5.66±0.60) recorded in the month of December coincides with cool harmattan winds which reduces water temperature. Adedeji (2019) highlighted that lower temperature increases the ability of water to hold oxygen and also reduces rates of microbial activity. Seasonal variation recorded lower DO mean values (4.13 ±1.30mg/l) in dry season and higher mean values (6.67±0.81mg/l) in wet season with no significant difference between seasons ($P>0.05$). The higher values in wet season could be due to increased aeration and continuous dilution of water bodies as a result of rainfall. Olorede *et al. (*2015) documented similar findings. However, the lower DO in dry season below the WHO standard limits of 5mg/l implies that the reservoir is more polluted around this time, since it was observed during sampling that water scarcity pushes inhabitants to visit the reservoir for varying activities, discharging wastes into the water. The seasonal variation reports coincide with the findings of Olarenwaju (2017).

Biochemical Oxygen Demand (BOD) values ranged between 10.80 ± 1.77 mg/l in Site D and 17.7 ± 1.53 mg/l in Site C. The values recorded in all the sampling sites for this study exceeded the WHO limits of 10 mg/l for fresh water. Dirisu and Olomukoro (2015) also made similar assertion. The values recorded in this study are higher than reports from the work of Abubakar *et al. (*2015) on the reservoir. Elevated BOD level in site C is an indication of water pollution in the area due to the presence of excessive microbial activities that consumed the dissolved oxygen. This report on the link between BOD and increased microbial activities coincides with the findings of Hasan *et al.* (2019) and Hayek *et al.* (2021). Higher dry season mean BOD values (14.00±4.35 mg/l) and lower wet season values (4.41±0.63 mg/l) showed no significant seasonal variation. Thus, alerting continuous infiltration of waste in the reservoir regardless of season. Ojekunlea (2020) also observed higher dry than wet season values.

The correlation coefficient (r) between various pairs of the parameters show mutual relationship. Strong positive correlation coefficient (near +1) means a good relationship of two parameters increasing or decreasing in the same direction and strong negative correlation coefficient (near -1) means an inverse relationship of one parameter increasing as the other decreases. The study recorded a strong positive correlation between Temperature and BOD (r=0.883),Nitrate and Temperature (r=0.908), TSS and pH (r=0.868), TSS and conductivity (r=0.838), TDS and Conductivity (r= 0. 987), pH and alkalinity (r=0. 894), Salinity and TDS (r=0.953), Alkalinity and conductivity (r= 0.845), Conductivity and BOD (r= 0.831). A significant negative correlation existed between Transparency and TDS (r=− 0.855), Transparency and pH (r=−0. 837), Salinity and pH (r = -0.801), DO and BOD (r=−0.893).

Conclusion

The physico-chemical parameters of Kazaure Reservoir revealed the existence of temporal, spatial and seasonal variations during the study period. Spatial variation in the reservoir revealed site C to be more polluted than the remaining sampling sites for recording the highest mean values of temperature TSS, TDS, salinity, conductivity, turbidity, BOD, nitrate and phosphate with low DO mean values. Consequently, site D was the least polluted with lower mean values of these parameters and high DO mean value. This trend indicated pollution threat associated with environmental dynamics and varying activities characterizing different sites. Seasonal variation showed that the reservoir had higher pollution level in dry season than wet season due to the stagnant nature and low water volume of the reservoir aggravated by damming from water source, which is a warning sign of reservoir collapse. Strong positive and negative correlations were established between most of the parameters. It is therefore recommended that cleaning and washing off of waste as well as the excessive use of phosphate fertilizers by farmers should be prevented to reduce high organic pollution of the reservoir. Kazaure Reservoir should be revisited to prevent its collapse and reduce the impact of pollution aggravated by reduced water volume from source. Thus, understanding the pollution status of the reservoir will help in developing restoration and pollution control strategies.

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