



Analyzes of Physico-chemical Parameters of Surface Waters from Ogunpa River, Ibadan, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author OP designed the study and wrote the first draft. Author AAJ reviewed the draft and performed statistical analysis. Author AE wrote the protocol and managed analyses of the study. Author OO managed the literature searches. All the authors read and approved the final manuscript.

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ABSTRACT

Physico-chemical indices of waters from Ogunpa River were examined for locational differences; seasonal variation; and to know if gradient effect is associated with the pollution dynamics. Data obtained were analyzed and compared with WHO thresholds for those parameters in water. Test results gave the following mean values viz:-Total Suspended Solids (TSS) 226.81mg/L, Total Dissolved Solids (TDS) 278.14 mg/L, Temperature (T°C) 27.18°C, pH 7.57, Electrical Conductivity (EC) 191.28 μ s/cm, Sulphate (SO_4^{2-}) 0.03 mg/L, Phosphate (PO_4^{2-}) 0.03 mg/L, Nitrate (NO_3^-) 0.02 mg/L, Chloride(Cl^-) 0.03 mg/L, Total Hardness (TH) 185.71mg/L, Alkalinity (Alk) 180.14 mg/L, Dissolved Oxygen (DO) 8.60 mg/L, Biochemical Oxygen Demand (BOD) 0.59 mg/L and Chemical Oxygen Demand (COD) 109.89 mg/L. Variation arising from locations and seasonal effects were analyzed using ANOVA at $P < 0.05$ and the outcome presented no seasonal variation in all the parameters except for Cl^- , TH, Alk, and COD. Also no significant variation between the test locations except for PO_4^{2-} and BOD. When compared to WHO recommended limits, values obtained were generally lower except for TH and COD that were above. It is concluded that surface waters from Ogunpa River, at the time of study, is within the recommended WHO values for normal survival and living of aquatic organisms.

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1. INTRODUCTION

Every form of life on earth depends on water in one form or the other for its subsistence. Humans can survive only few days without water, whereas, one can live for weeks without food. Water is especially valuable to human health, medicine, agriculture and industry. It is on record that the human body is mostly water and that the functionality of the human brain depends on water. Suffice to say, that the average human brain is 77-78% water [1].

The physico-chemical characteristics of a water body can be significantly altered by human activities such as various agricultural practices and irrigation. Municipal effluents and industrial discharges into water bodies have negative impact on the water qualities by reducing water flow rate [2]. Depending on the quality and quantity of waste input, the physical, chemical and biological balance of receiving waters may be significantly modified resulting in pollution and associated consequences [3].

Polluted water has various effects on humans, for domestic purposes as well as industrial and agricultural uses. Thus, it is important to test for water quality and purity before it is used for drinking. Water must be tested for different physicochemical parameters to ascertain its quality. Water contains different types of floating, dissolved, suspended and microbiological impurities. Some physical tests are required for ascertaining its physical appearance such as temperature, colour, odour, pH, turbidity hardness TDS, etc, while chemical tests should be performed for its BOD, COD, dissolved oxygen alkalinity, hardness and other characters [4]. It is recommended that drinking water should pass these entire tests and should contain the required amount of minerals. Albeit, all these criteria have been enforced only in the developed industrialized countries for monitoring the quality of drinking water [5].

In Nigeria, attempts have been made to analyze the physico-chemical parameters of water in some water bodies. Significant among these are the assessment of physico-chemical properties of water from Moro Lake [6]. Which, according to the author, should be the baseline for assessing further changes experienced in the lake. Also, a study conducted on Ogbe Creek which recorded high total dissolved solids, biological oxygen

demand, alkalinity and low values of dissolved oxygen and transparency [7]. Examination of physico-chemical characteristics of Ugborikoko/Okere stream as an index of pollution is another compelling contribution. Pretiemo-Clarke et al. [8] The assessment of water quality of Badagry Creek, which runs through Benin Republic and Nigeria, showed that the physical and chemical parameters of the creek represent optimum conditions that would support many organisms [9]. A study conducted on physico-chemical parameters and heavy metal content of water from mangrove swamps of Lagos lagoon [4]. The study was aimed at assessing its suitability for fish production and well as its safety for drinking purposes by collecting samples of water from three locations in the mangroves swamps of Lagos lagoon and all samples were analyzed for water quality parameters. The results favoured the production of brackish water fish. However, it is highly contaminated and therefore not suitable for drinking purpose. The ever-increasing threats to long term sustainability of Ogunpa River due to anthropogenic activities make the present study imperative. The physico-chemical profile of Ogunpa River was analyzed for water quality and its safety for drinking purpose by the community living around the water body.

2. METHODOLOGY

2.1 Study Area

Ogunpa River is situated in Ibadan, Oyo State Nigeria (Figs. 1,2) and is located between the coordinates of 7° 17', 14" and 3° 52' 3"E. It takes its sources from Ashi village and flows in a North-South direction through Old Bodija and New Bodija in Ibadan, Awolowo Avenue and eventually empties into Agodi Reservoir. The river serves as a source of water for domestic purposes such as car wash, bathing and agricultural activities. Domestic effluents and industrial agricultural wastes which contain both organic and inorganic matters dumped into the river add to the pollution level of the water body.

2.2 Determination of Physico-chemical Parameters

The physico –chemical parameters of surface water measured are: Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Temperature, Hydrogen ion concentration (pH), Electrical Conductivity (EC), Nitrate (NO₃)

Phosphate (PO_4^{3-}), Sulphate (SO_4^{2-}), Chloride (Cl^-), Total Hardness (TH), Alkalinity (Al), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD). The

physico-chemical parameters of the water samples from the river were analyzed in the laboratory following APHA 1995 and 1998 [10,11].

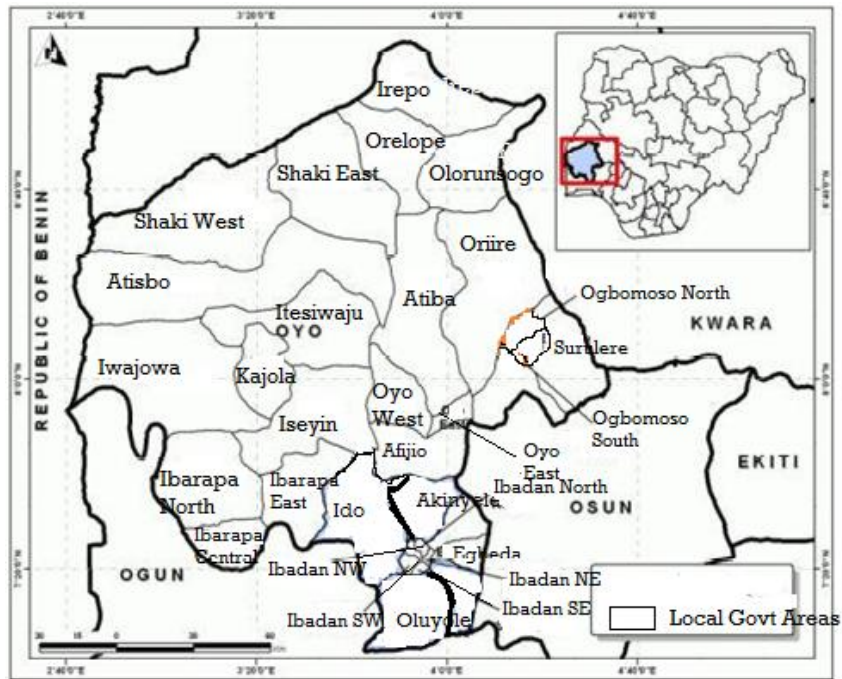


Fig. 1. Map of Oyo state (Inset' map of Nigeria showing location of Oyo State)

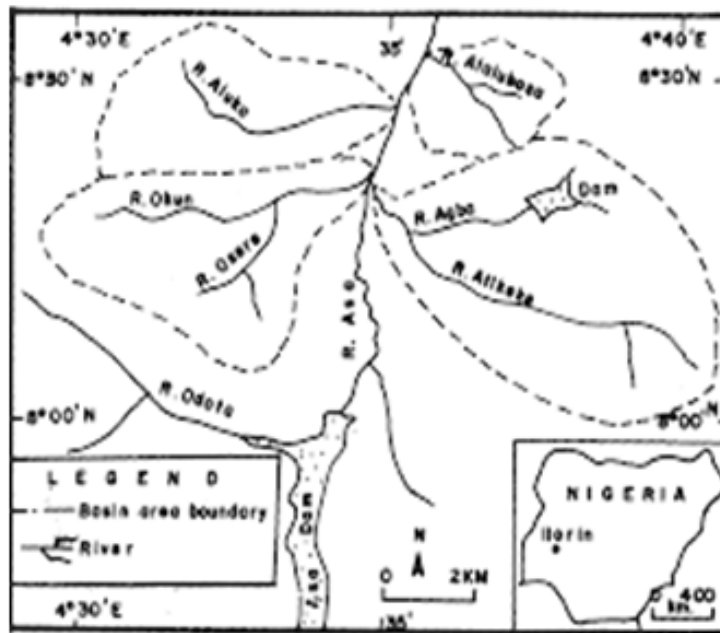


Fig. 2. Sketch map showing Ogunpa River and other streams
Source: Google images



Plate 1. Sampling locations A, B, C, D and E in Ogunpa River

2.3 Collection of Water Samples

The study was conducted over a period of 12 months which embrace the dry and wet seasons in Ibadan. Water samples were collected about 10cm below water surface using 2-litre plastic bottles which were previously washed with non-ionic detergent rinsed with tap water soaked in 10% HNO₃ and finally rinsed with distilled water. Collections were done monthly from five marked locations A, B, C, D and E that were stratified 1km apart along the Ogunpa River. All samples were stored in the refrigerator at 4°C to inactivate any bacteria and prevent change in volume due to evaporation.

2.4 Statistical Analyses

Data collected were evaluated using one-way analysis of variance. Results of the Laboratory analyses were subjected to data evaluation by use of one-way analysis of variance (F-statistic). Linear regression curves were plotted to determine slopes, gradients and correlation coefficients. Values from each parameter were compared with the WHO standard for decision making.

3. RESULTS AND DISCUSSION

3.1 Physical Characteristics of the Water Body

Table 1 gave mean values of TSS, TDS, Temperature pH and EC in the Ogunpa River. Basic analyses carried out on each of these parameters gave the following results.

3.1.1 Total suspended solids (TSS)

The mean TSS of the water was 219.39 mg/L. Mean value in the dry season was 211.964 mg/L while the mean value of TSS for the wet season was 226.81 mg/L. T-test statistic at 95% C.I showed no significant difference which implies no seasonal variation. At P<0.05 one-way analysis of variance (F-statistic) showed no significant differences in TSS at various locations which imply no gradient effect. A linear regression of TSS along the sample locations showed a weak negative correlation (eqn. 1).

$$\text{TSS. } Y = -0.9044X + 224.58 \quad (r^2 = 1.1\%) \quad (1)$$

Note: that all equations 1 to 4 to be presented

Y= Specific physical parameter (dependent variable)
 X= Distance from source in meters (independent variable)

3.1.2 Total Dissolved Solids (TDS)

The mean annual TDS of the water was 243.45 mg/L. Mean value in the dry and wet seasons was 208.764 mg/L and 278.14 mg/L respectively. T-test statistic at 95% C.I showed no significant difference between the two seasons. At P<0.05 one-way analysis of variance (F-statistic) showed no significant differences in TDS at the various locations which imply no gradient effect. A linear regression of TDS along the sample locations in Ogunpa River showed a weak positive correlation (Eqn. 2).

$$\text{TDS } Y= 1.454X + 250.85 \text{ (} r^2=0.8\% \text{)} \quad (2)$$

3.1.3 Temperature

The mean annual temperature of the water was 27.15°C. One-way analysis of variance (F-statistic) showed that temperature not significantly different between the locations, thus, no gradient effect. Linear regression of T°C along the sample locations showed a weak positive correlation (eqn. 3). In the dry season, the average temperature was 27.124°C and in the wet season, it was 27.18°C T-test statistic at 95% C.I showed no significant difference in temperature for the two seasons.

$$\text{T}^\circ\text{C } Y= 0.33X + 27.061 \text{ (} r^2 =2.36\% \text{)} \quad (3)$$

3.1.4 pH

The pH of Ogunpa River generally alkaline has a mean value of 7.56 Table 1. One-way analysis of variance (F-statistic) showed no significant difference in pH in all the sampling locations, which signifies no gradient effect. A linear regression analysis of pH along the sample locations showed a strong negative correlation (Eqn. 4). The mean pH value during the dry season was 7.546 (Tables 2 and 3). T-test statistics at 95% C.I. no significant difference in pH for the two seasons.

$$\text{pH } Y= -0.12552X + 7.9373 \text{ (} r^2 =68.44\% \text{)} \quad (4)$$

3.2 Chemical Characteristics of the Water Body

Mean values of SO₄²⁻, PO₄²⁻, NO₃⁻, Cl⁻, TH, Alk, DO, BOD and COD in Ogunpa River are presented in Table 1. Each of the parameters was subjected to further evaluation giving the following results.

3.2.1 Sulphate (SO₄²⁻)

The mean value of sulphate in the water body was 0.026 mg/L (Table 1). Mean value of sulphate during the dry season was 0.022 mg/L while in the wet season was 0.030mg/L (Tables 2 and 3) T-test statistic at 95% C.I. showed no significant difference in the two seasons. One-way analysis of variance (F-statistic) showed no

Table 1. Mean values of physico-chemical parameters in water samples from Ogunpa River along location (A to E)

Physico-chemical parameter	Locations					Mean	Who standards
	A	B	C	D	E		
TSS (mg/L)	165.72	262.10	229.07	243.44	196.63	219.39	-
TDS (mg/L)	247.89	235.32	251.57	225.00	257.51	243.45	500
Temp (°C)	26.56	27.63	26.88	27.67	27.03	27.15	25°C
pH	7.63	7.82	7.78	7.30	7.27	7.56	0.5-8.5
EC (µs/cm)	212.66	216.88	211.19	214.85	209.13	212.94	1000
SO ₄ ²⁻ (mg/L)	0.02	0.04	0.03	0.04	0.02	0.026	200
PO ₄ ³⁻ (mg/L)	0.03	0.02	0.04	0.05	0.04	0.032	280
NO ₃ ⁻ (mg/L)	0.03	0.02	0.03	0.02	0.02	0.022	10
Cl ⁻ (mg/L)	0.03	0.03	0.03	0.03	0.04	0.028	250
TH (mg/L)	213.20	247.29	178.32	161.30	176.98	195.42	100
Alk (mg/L)	220.96	187.24	194.89	219.70	201.64	204.88	400
DO (mg/L)	8.91	8.18	7.69	8.25	8.41	8.29	7
BOD (mg/L)	0.76	0.63	0.59	0.47	0.53	0.596	6
COD (mg/L)	105.57	118.82	92.94	100.82	97.29	101.68	10

Table 2. Physico-chemical parameters in waters along Ogunpa River during the dry Season

Physico-chemical Parameter	Locations					Mean
	A	B	C	D	E	
TSS (mg/L)	152.59	183.88	217.50	322.50	183.25	211.96
TDS (mg/L)	167.94	232.50	251.25	223.75	168.38	208.76
Temp (°C)	25.54	28.04	27.01	28.00	27.03	27.12
pH	7.46	7.75	8.13	7.30	7.09	7.55
EC (µs/cm)	230.63	255.63	231.75	213.75	241.25	234.60
SO ₄ ²⁻ (mg/L)	0.02	0.02	0.03	0.02	0.02	0.022
PO ₄ ³⁻ (mg/L)	0.03	0.03	0.03	0.05	0.03	0.034
NO ₃ ⁻ (mg/L)	0.02	0.02	0.04	0.02	0.02	0.024
Cl ⁻ (mg/L)	0.02	0.02	0.03	0.03	0.03	0.026
TH (mg/L)	238.13	280.39	159.33	146.88	200.88	205.12
Alk (mg/L)	230.00	199.45	226.00	263.76	228.89	229.62
DO (mg/L)	8.49	7.75	7.15	8.10	8.36	7.97
BOD (mg/L)	0.77	0.66	0.64	0.42	0.52	0.60
COD (mg/L)	91.75	96.75	94.63	87.38	96.88	93.48

significant difference in sulphate at all locations which imply no gradient effect. A linear regression of SO₄ along the sample locations showed a weak negative correlation (Eqn. 5)

$$\text{SO}_4: Y = -0.006X + 0.028 \quad (5)$$

Note: that in all equations 5 to 12

Y = Chemical parameter measured in mg/L (dependent variable)

X = Distance from source in meters (independent variable)

3.2.2 Phosphate (PO₄³⁻)

The mean value for phosphate was 0.032 mg/L (Table 1). Seasonally mean value of phosphate in the dry season was 0.034 mg/L while the mean concentration during the wet season was 0.030 mg/L (Tables 2 and 3). T-test statistic at 95% C.I. showed no significant difference between the two seasons. One-way analysis of variance (F-statistic) showed significantly different which between the locations at P<0.05 which implies gradient effect. A linear regression of PO₄ along the sample locations showed a weak positive correlation (Eqn. 6).

$$\text{PO}_4 Y = 0.0029X + 0.0247 (r^2 = 44\%) \quad (6)$$

3.2.3 Nitrate (NO₃⁻)

The mean value of Nitrate was 0.022mg/L (Table 1) for the experimental year. One-way analysis of variance (F-statistic) results showed no significant difference (P<0.05) in Nitrate at the

various locations which implies no gradient effect.

Mean values of Nitrate in the dry season was 0.024 mg/L while during the wet season the concentration was 0.02 mg/L. T-test statistic at 95% C.I. showed no significant difference between the two seasons. A linear regression of NO₃ along the sample locations showed a weak negative correlation (Eqn. 7).

$$\text{NO}_3^- Y = -0.0012X + 0.026 (r^2 = 49\%) \quad (7)$$

3.2.4 Chloride (Cl⁻)

The mean concentration of chloride in the water samples was 0.028 mg/L (Table 1). Chloride during the dry season was 0.026 mg/L while mean value during the wet season was 0.03mg/L (Tables 2 and 3). At P<0.05, one-way analysis of variance was no significant difference in chloride in all the locations, which implies no gradient effect (Table 4). T-test statistics at 95% C.I. showed significant seasonal variation (Table 4). A linear regression of chloride along the sample locations showed a resultant positive correlation (Eqn. 8).

$$\text{Cl}^- Y = 0.0021X + 0.0202 (r^2 = 62\%) \quad (8)$$

3.2.5 Total Hardness (TH)

Mean TH value in the waters for the test period was 195.42 mg/L (Table). TH during the dry season was 205.12 mg/L while mean during the wet season was 185.71mg/L (Tables 2 and 3). One way analysis of variance (F-statistic) at

P<0.05 showed there was no significant difference in TH in all the locations, which implies no gradient effect (Table 4). A linear regression of TH along the sample locations showed a weak negative correlation (Eqn. 9). T-test statistic at 95% C.I. showed significant seasonal variation traceable to higher carbonate and bicarbonate in the waters during the dry season.

$$\text{TH: } Y = -14.191X + 234.75 \quad (r^2 = 60\%) \quad (9)$$

3.2.6 Alkalinity (Alk)

Mean Alkalinity value averaged 204.88 mg/L in the test waters for the experimental year (Table 1). The mean values of Alkalinity during dry and wet seasons were 228.89 mg/L and 180.14 mg/L respectively (Tables 2 and 3). One-way analysis of variance (F-statistic) at P<0.05 showed no significant differences in Alkalinity at the various locations which imply no gradient effect (Table 4). A linear regression of Alk along the sample locations showed a weak negative correlation (Eqn. 10). T-test statistic at 95% C.I. showed significant seasonal variation in the two seasons (Table 4).

$$\text{Alk } Y = -2.8959X + 205.32 \quad (r^2 = 10\%) \quad (10)$$

3.2.7 Dissolved Oxygen (DO)

The mean concentration of DO in sampled waters was 8.29 mg/L (Table 1). The mean values of DO in the dry and wet seasons were

7.97 mg/L, 8.45 mg/L respectively (Tables 2 and 3). The T-test statistics at 95% C.I. showed no significant difference in the two seasons (Table 4). One-way analysis of variance (F-statistics) showed no significant difference between the locations implying no gradient effect (Table 4). A linear regression of DO along the sample locations showed a negative correlation (Eqn. 11).

$$\text{DO: } Y = 0.1281X + 8.773 \quad (r^2 = 23\%) \quad (11)$$

3.2.8 Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand of the water body averaged 0.60 mg/L (Table 1) in the experimental year. One-way analysis of variance (F-statistic) at P<0.05 showed a significant difference in values obtained from all the locations which imply gradient effect. BOD value of dry season was 0.60 mg/L and mean value during the wet season was 0.59 mg/L (Tables 2 and 3). T-test statistics at 95% C.I. showed no significant difference in the two seasons (Table 4). A linear regression of BOD along with the sample location a negative correlation (Eqn. 12).

$$\text{BOD: } Y = -06X + 0.772 \quad (r^2 = 78\%) \quad (12)$$

3.2.9 Chemical Oxygen Demand (COD)

The chemical oxygen demand of the water body averaged 101.68 mg/L (Table 1) in the experimental year. At P<0.05 one-way analysis

Table 3. Physico-chemical parameters in waters along Ogunpa River during the wet Season

Physico-chemical parameter	Locations					Mean
	A	B	C	D	E	
TSS (mg/L)	178.75	340.31	240.63	164.38	210.00	226.81
TDS (mg/L)	327.81	238.13	251.88	226.25	346.63	278.14
Temp (°C)	27.57	27.21	26.75	27.34	27.02	27.18
Ph	7.79	7.89	7.43	7.29	7.45	7.57
EC (µs/cm)	194.69	178.13	190.63	215.94	177.00	191.28
SO ₄ ²⁻ (mg/L)	0.02	0.03	0.03	0.03	0.02	0.03
PO ₄ ³⁻ (mg/L)	0.03	0.02	0.04	0.04	0.04	0.03
NO ₃ ⁻ (mg/L)	0.03	0.02	0.02	0.02	0.02	0.02
Cl ⁻ (mg/L)	0.03	0.03	0.02	0.03	0.04	0.03
TH (mg/L)	188.26	214.19	197.31	175.72	153.07	185.71
Alk (mg/L)	211.91	175.03	163.75	175.63	174.38	180.14
DO (mg/L)	9.33	8.60	8.22	8.40	8.45	8.60
BOD (mg/L)	0.75	0.60	0.54	0.51	0.54	0.59
COD (mg/L)	119.38	126.88	91.25	114.25	97.69	109.89

Table 4. Physico-chemical analyses, gradient effect and seasonal variation

Physical	Gradient along last locations on ogunpa river (A-E)			Seasonal variation ogunpa river (F & H) T-statistics AT <0.05
	*Slope	r ²	Gradient effect (dy/dx), ANOVA at R<0.05	
TSS	-ve	0.001	0	0
TDS	+ve	0.01	0	1
Temp	+ve	0.02	0	0
pH	-ve	0.68	0	0
EC	-ve	0.02	0	0
Chemical				
SO ₄ ²⁻	-ve	0.09	0	0
PO ₄ ³⁻	+ve	0.44	1	0
NO ₃ ⁻	-ve	0.49	0	0
Cl ⁻	+ve	0.62	0	1
TH	-ve	0.60	0	1
Alk	-ve	0.10	0	1
DO	-ve	0.23	0	0
BOD	-ve	0.78	1	0
COD	-ve	0.36	0	1

Note: For gradient (dy/dx) and Seasonal variation:
(1) = significantly established (0) = Not significantly established
* Slope is slanting course from horizontal

of variance (F-statistic) showed no significant difference in values obtained from all the locations which imply no gradient effect. The mean COD during the dry season was 93.48 mg/L while the mean COD during the wet season was 109.89 mg/L (Tables 2 and 3). A linear regression of COD along the sample locations showed a negative correlation (Eqn. 13). C.I. also showed no significant difference which implies no seasonal variation in the two seasons.

$$\text{COD: } Y = -3.704X + 11553(r^2 = 36\%) \quad (13)$$

4. DISCUSSION

TSS which is a measure of solids and an indicator of water quality. Incidentally, we could not lay hand on any legal permissible concentration for TSS in this study. Thus, after Moris [12], any value of TSS below 30 mg/L is regarded as low while values above 100mg/L are considered high. The high concentration of TSS can lower water quality by absorbing light. This has adverse effects on aquatic plants which receive less light, which decreases photosynthesis and resultant less oxygen is produced, suspended solids have the ability to along fish gills, decrease both growth rate, resistance to diseases and prevent egg and larval development [4]. Suspended solid is often affected by the stream flow and anthropogenic activities which disturbs land activities. In this study higher value of TSS was recorded in the

wet season than the dry season which is traceable to rise in TSS after heavy rainfall.

The total dissolved solids test is used as an indicator test to determine the general quality of the water. The sources of total solids can include all of the dissolved cations and anions. The mean TDS value of the water body was below the recommended maximum concentration level of 500 mg/L for drinking water set by World Health Organization [13]. Ela [14] classified water according to the concentration of TDS per litre; fresh water <1500 mg/L, TDS, brackish water 1500 to 5000 mg/L and saline water 5000 mg/L. This is an indication that the water in the Ogunpa River can be regarded as freshwater. Most of the aquatic environments including mixed fish fauna have tolerance for TDS level of 1000 mg/L [15]. The high concentration of TDS has an undesirable taste which could be salty, bitter or metallic which be as a result of the presence of toxic heavy metals in the water.

Water temperature affects water quality parameters and plays an important role in aquatic life. Water temperature affects the Dissolved oxygen in the water. The solubility of oxygen reduces water temperature rises. The mean annual temperature was above 25°C the WHO recommended a value for water [13]. However, the mean annual temperature recorded was adequate for the survival, metabolism, and physiology of aquatic organisms. The mean temperature of 27.15°C recorded is in agreement

with other African water bodies recorded by Mustapha [16]. The pH of pure water is 7. The pH of water from Ogunpa River is considered satisfactory, it is within the recommended of 6.5-8.5 for drinking water set by World Health Organization [13]. The survival, metabolism, and growth of the aquatic organism is affected by the pH of the water in the ecosystem [17]. The photosynthesis and growth of the aquatic plant is affected by the pH [18] indicated that pH higher than 7 but lower than 8 is adequate for biological activity, but pH less than 4 is harmful to aquatic life. The presence of carbonate and bicarbonate in water can be the cause of high pH [19]. The low pH in the water of most aquatic ecosystem can be caused by decaying vegetation [20]. The run-off from surrounding rocks and water discharged, alkalinity and acidity can affect the pH.

The mean Electrical conductivity for Ogunpa River was lower than the recommended standard of 1,000 $\mu\text{s}/\text{cm}$ for drinking water by World Health Organization [13]. Electrical conductivity increases when salts are dissolved in water. The mean sulphate concentration in the water body was below 200 mg/L recommended for drinking water by World Health Organization [13]. Sulphate can occur naturally in freshwater which is leached from the soil.

The sources of PO_4^{3-} in the water body could be due to anthropogenic activities from fertilizers pesticides, industry and cleaning compounds. Natural sources of pH include phosphate containing rocks and solid or liquid wastes. The WHO safe limit of phosphate in drinking water is 250 mg/L [13], hence the value obtained in this study does not exceed the permissible level. The mean value of PO_4^{3-} is low, it should not give any serious threat to human and aquatic habitat.

High chloride concentration gives salty taste to water and beverages. The WHO recommended a level of chloride in drinking water is 250 mg/L, hence the value does not exceed the permissible level. However, it was reported that Cl^- higher than 20 mg/L are advantageous in thorough freshwater fish culture [21].

Nitrogen plays a very important role at a high level of eutrophication in the aquatic ecosystem. In such a situation like this, nitrogen-fixing cyanobacteria can cause more problem than any other types of algae [22]. Rast and Thornton [23] reported that eutrophication-related problems begin to increase at N concentrations of the order of 0.34 – 0.70 mg N/L. The NO_3^- N mean

concentration of Ogunpa River did not exceed the threshold value of 0.70 mg/L and would thus not contribute to eutrophication in the water body. The mean concentration of Nitrate was below 10.00 mg/L level stipulated by the WHO for drinking water [13]. Nitrate concentrations above 10 mg/L are harmless but the water may contain toxic substance and pollutant from industrial or agricultural sources [24].

Total Hardness in water constitutes the measurement of calcium and magnesium natural present in rock formations which is often responsible for hardness concentrations in water bodies. The WHO maximum allowable concentration of TH in drinking water is 100 mg/L [13]. It was, however observed that Ogunpa River contained concentrations higher than the above stated World Health Organization limit. The high concentration of TH recorded might be due to natural sources due to weathering of rocks when comprises calcium and magnesium carbonates and addition of calcium and magnesium through run-off from agricultural and other catchment zones during raining season. Total hardness greater than 15 mg/L CaCO_3 is reported adequate for fish growth while less concentration causes retarded growth of fish and will require liming for increased fish production [25,26].

The alkalinity of water deal with the quality and types of components present such as bicarbonate, carbonate, and hydroxide. Removal of CO_2 from the bicarbonates for the process of photosynthesis by algae may expand total alkalinity [27]. The World Health Organization maximum allowable concentration of alkalinity in drinking water is 400 mg/L [13]. Ogunpa River contained concentrations of alkalinity lower than the above WHO limit. The mean value obtained was lower compared with the report of Saliu and Ekpo [7] who recorded the value of >250 mg/L Ogbe creek, Lagos.

Dissolved oxygen concentration in water is of great significance to all aquatic organisms and is considered to be component which revolves on physical and biological process occurring in a water body. It is significant in the production and support of life. It regulates the nature of the entire aquatic ecosystem to a high extent. Supplies of oxygen in a water body are mainly from two sources directly from the atmosphere and during the process of photosynthesis by aquatic plants that possess chlorophyll. The concentration of DO relies on surface agitation due to temperature respiration rate of the living

organisms and the decomposition rate of dead organic matters. Dissolved oxygen concentration in unpolluted water is normally about 8 to 10 mg/L (at 25°C) [27] and concentration below 5 mg/L can adversely affect aquatic organisms [28,29]. Water samples from Ogunpa River have to DO within the limits 8 to 10 mg/L stated for unpolluted water at 25°C [28] which can be regarded as unpolluted can, therefore, support the functioning and survival of the biological ecosystem.

The biochemical oxygen demand of the water body is below 6 mg/L of BOD stipulated by WHO for portable water WHO [13]. Vannote *et al.* [30] stated that rivers with high BOD have high levels of nutrients in the water. The low BOD value of the body could be as a result of low levels of nutrients in the water. Chemical oxygen demand measures the quantity of oxygen required for chemical oxidation of most organic matter and oxidizable inorganic substances with the aid of strong chemical oxidant. The WHO maximum allowable concentration of COD in drinking water is 10 mg/L [13].

It was, however, observed that the COD in water in Ogunpa River contained concentrations higher than the above stated WHO limit. Emmanuel and Ogunwemimo [31] reported the lowest COD value of 35 mg/L in January and the highest value of 51mg/L at Abule Agege creek of Lagos. High levels of COD indicated that there was the decomposition of organic and inorganic compounds in the water that requires high levels of oxygen in the water. The high value of COD analyzed may pose a danger for the safety of the water for drinking purposes.

5. CONCLUSION AND RECOMMENDATIONS

In this work, the water quality of Ogunpa River, in terms of physico-chemical parameters, was determined. The results of TDS, pH, EC, SO_4^{2-} , PO_4^{3-} , NO_3^- , Cl^- and BOD fall within the recommended limits of WHO and could support healthy survival of flora and fauna constituents in the aquatic system.

However, increase in anthropogenic activities from industrialization, population growth, and urbanization along the Ogunpa River could upset the water quality. Proper measures must therefore be put in place for sustainability and to discourage users from polluting the water. Appropriate education on human behaviors such as direct unhygienic defecation and dumping of

untreated wastes and also monitoring and control to prevent source of pollution and improve health of the water body are essential.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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