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PHYSICO-CHEMICAL PARAMETERS OF IKERE-GORGE, ISEYIN, OYO STATE, NIGERIA

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ABSTRACT

Water quality determines the distribution of aquatic organisms within aquatic ecosystem. Deterioration of water quality is of a great concern in freshwater ecosystem because of its adverse effects on freshwater organisms. Therefore, the physico-chemical parameters of Ikere-gorge were examined in this study to determine its suitability for fish production. Air and water temperature, transparency, electrical conductivity and total dissolved solids were determined *in-situ*. Dissolved oxygen, alkalinity, hardness, phosphate and nitrate were determined with standard analytical methods. The selected parameters examined in this study were determined monthly between January 2017 and December 2018. The mean monthly values of physico-chemical parameters of Ikere-gorge obtained are as follows: air temperature (27.46±1.82 ºC), water temperature (28.14±1.57 ºC), pH (6.50±0.63), water transparency (1.34±0.12 m), dissolved oxygen (5.93±0.29 mg/L), electrical conductivity (130.59±7.59 µS/cm), total dissolved solids (67.67±4.37 mg/L), total hardness (56.70±15.76 mg/L), total alkalinity (58.97±9.53 mg/L), total phosphate (2.22±0.67 µg/L) and nitrate (2.90±1.23 µg/L). Likewise, it was observed that surface water temperature had negative significant relationship with dissolved oxygen at $P < 0.05$. Transparency has negative significant relationship with phytoplankton abundance at 0.05 ($P < 0.05$) and with phosphate and nitrate at 0.01 significant level. The annual mean of Trophic Status Index based on total phosphate is 15.04±1.63. This classified Ikere-gorge trophic status as mesotrophic at stage 2. The result of this study reveals the mesotrophic status of Ikere-gorge and water quality are within the ranges recommended for fish production and should be adequately managed for sustainable fish production.

Keywords: Aquatic organisms, Ecosystem, Freshwater, Trophic state, Abundance

INTRODUCTION

Aquatic ecosystems can generally be divided into three, namely marine, brackish and freshwater. Freshwater ecosystems include streams, rivers, ponds, lakes and dams. Freshwater ecosystem is the interactions and relationships between freshwater organisms and their natural and cultural environments (Naiman *et al.* 2006) Freshwater can be defined as the water that contains a relatively small amount of dissolved chemical compounds. It can also be defined as the water with low ionic content of sodium and chlorine ions. It makes up only 0.01% of the world's water and approximately 0.8% of the earth's surface (Sigee, 2005). However, this tiny fraction of global water supports at least 100,000 species out of approximately 1.8 million - almost 6% of all described species (Sigee, 2005; Dudgeon *et al.,* 2006).

Freshwater provides suitable habitats for freshwater fish and other aquatic organisms. But water quality determines the distribution of aquatic organisms within the ecosystem. Temperature plays a major role in the dynamics of water quality of freshwater ecosystem. Almost all biological and chemical processes in freshwater ecosystems are influenced by temperature. Changes in water temperature have subsequent impacts on almost every component of the ecology of freshwater fish and most of the aquatic organisms are poikilotherms. Therefore, action to

preserve water quality is a critical part of sustainable management of freshwater ecosystem. It affects the health of the hydrological system. A healthy system will provide better water quality and a more flexible ecosystem (Harrod *et al*., 2018; Gökçe**,** 2019).

Changes in physical and chemical properties of freshwater ecosystem lead to deterioration of its water quality (Gökçe**,** 2019). Often such changes could be negative due to the impacts of climate change and anthropogenic activities. Agricultural run-off, domestic wastes and loss of vegetation covers are some of the anthropogenic activities observed in Ikere-gorge. The result of this could be loss of species (Dudgeon *et al.,* 2006) because aquatic organisms exhibit habitat-specific distribution. Likewise there may be significant loss of freshwater ecological functions and related ecosystem services. Freshwater ecosystems provide numerous services upon which human activities depend. Such services include maintenance of variety of living organisms especially fish stocks, water purification for human consumption, energy supply, etc. Therefore, there is need for proper management of freshwater ecosystem for sustainable fish production. But, if freshwater ecosystem is not managed properly this may cause serious problems in availability of quality water to sustain life in and out of freshwater ecosystem (Amoo and Komolafe, 2018). In most cases, the deterioration of freshwaters ecosystem is a matter calling for urgent and serious attention, given the goods and services derived from them. The study of physicochemical parameters is a viable tool for monitoring pollution and managing water quality to protect and conserve the ecosystem (Dudgeon *et al.* 2006; Dirican, 2015; Gökçe, 2019). Therefore, this study aims to examine physico-chemical parameters of Ikere-gorge to determine the trophic status of the gorge.

MATERIALS AND METHODS

The Study Site

Ikere-gorge is a 565 million cubic meters (mcm) multipurpose dam located at Ikere village, about 28 km, North East of Iseyin in Oyo State. Ikere-gorge is located between longitude 8°10' and 8° 20'N and latitude 3° 40' and 3° 50'E. Ikere- gorge took its source from Sepeteri about 40 km to Ikere through Asamu and Alagbon. Ikere-gorge has Ogun River as its major tributary and River Amaka, River Oowe and River Owu as its minor tributaries. Ikere-gorge is open to fishing in all twelve villages surrounding the dam. Four fishing villages were randomly selected as four sampling sites. The selected sampling sites (fishing villages) were Site A - Asamu (N 8º 13' 54.828" E 3º 47' 00. 696"), Site B - Agatu (N 8º 09' 51. 972" E 3º 44' 57.642"), Site C -Spillway (N 8º 11' 53.760" E 3º 44' 51. 810") and Site D - Irawote (N 8º 14' 01. 170" E 3º 42' 47. 802"). They were sampled monthly for the examination of water quality parameters of the gorge.

Analysis of Water Quality Parameters

Water samples were collected with water sampling bottles and some parameters were determined *in-situ*. Air temperature was measured in degree Celsius (ºC) *in-situ* with mercury – in – glass thermometer. Water temperature (ºC), pH, electrical conductivity (µS/cm) and total dissolved solids (mg/L) were also measured *in-situ* with a combined probe (Hanna, Model HI 98129). Dissolved oxygen samples were fixed *in-situ* with 2 ml each of manganese sulfate, alkali-iodide azide and concentrated sulfuric acid. In the laboratory, Azide-Winkler titration method was used to analyze dissolved oxygen. Water transparency was determined by the use of a Secchi disc, with a method described by Michaud (1991) and Offem *et al.* (2011). Titrimetric method was used to analyse total alkalinity (APHA, 1989). Vanado-molybido-phosphoric acid colorimetric method was used to measure the concentration of phosphate (mg/L) while solution salicylate (colorimetric) method was used to measure the concentration of nitrates (mg/L) in the water samples (Odulate, 2010).

Determination of Trophic State of Ikere-Gorge

The trophic state of the gorge was determined using Carlson Trophic State Index (Carlson, 1977) and calculated as;

$$TSI(TP) = 14.49(In\,TP) + 4.20 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

TP is the total phosphorus concentration measured in the surface water in µg/L.

RESULTS

Water Quality Parameters

The spatial monthly mean values of water quality parameters of Ikere-gorge for a period of 24 months (January 2017 – December 2018) are presented in table 1. The monthly mean and standard deviation values of water quality parameters varied slightly among the sampling sites. The monthly mean value of air temperature during the period of study was 27.46±1.82 ºC. The lowest value (23.5 ºC) of air temperature was recorded in Site D in January and the highest air temperature value (31.0 ºC) was recorded in Site B in May. Likewise, the monthly mean surface water temperature was 28.14±1.57 ºC. The lowest value (25.0 ºC) of water temperature of the dam was recorded in October and the highest value (32.0 ºC) in the month of August both in Site A.

The monthly mean value of pH of Ikere-gorge was 6.50±0.63. The pH values of the dam varied between 5.5 in May (Site D) and 7.7 in February recorded in Site A. The gorge was slightly acidic between the months of May and August, but near neutral during the remaining months of the year. The monthly mean value of water transparency obtained in this study was 1.34±0.12 m. The lowest monthly value of water transparency (1.1 m) was recorded in Site C in May while double peak of water transparency, 1.6 m was recorded in Site A in the months of January and June.

The monthly mean value of dissolved oxygen was 5.93±0.29 mg/L. Site C had the lowest value of dissolved oxygen (5.2 mg/L) and Site B had the highest (6.6 mg/L) value of dissolved oxygen in September. The monthly mean value of electrical conductivity was 130.59±7.59 (µS/cm). Site A in January had the lowest value (102.5 µS/cm) of electrical conductivity while Site B in July had the highest value (158.0 µS/cm) of electrical conductivity. The monthly mean value of total dissolved solids was 67.67±4.37 mg/L. The lowest value (53.5 mg/L) of total dissolved solids was observed in Site C in March, while the highest value of 80 mg/L was observed in Site B in January.

The mean monthly value of total hardness was 56.70±15.76 mg/L. The lowest value (31.7 mg/L) of total hardness was recorded in Site B in December, while the highest value of 85.9 mg/L was recorded in Site C in September. The mean monthly value of total alkalinity was 58.97±9.53 (mg/L). The lowest value (42.0 mg/L) of total alkalinity was recorded in Site B in April, while the highest value of 79.75 (mg/L) was recorded in Site A in September. The mean monthly value of total phosphate was 2.22±0.67 µg/L. The lowest value (1.1 µg/L) of total phosphate was recorded in Site B in December while the highest value of 3.7 µg/L was recorded in Site C in September. The mean monthly value of nitrate was 2.90±1.23 µg/L. The lowest value of nitrate was recorded in Site C while the highest value of 5.3 µg/L was recorded in Site D in September

Table 1: Mean Monthly Water Quality Parameters of Ikere-Gorge, Iseyin, Oyo State, Nigeria (Jan. 2017 – Dec. 2018)

Water Quality	Site A	Site B	Site C	Site D	Pooled Mean
Air Temp	27.46±1.96	27.54±2.05	27.67±1.99	27.17±1.87	27.46±1.82
Water temp	28.21±2.15	28.13±1.69	28.08±1.61	28.13±1.54	28.14±1.57
pH	6.60±0.64	6.42±0.61	6.40±0.52	6.55±0.83	6.50±0.63
Trans (m)	1.39±0.13	1.30±0.15	1.34±0.13	1.35±0.15	1.34±0.12
DO (mg/L)	5.90±0.33	5.95±0.45	5.92±0.46	5.94±0.37	5.93±0.29
Cond (µS/cm)	127.88±12.13	138.79±14.18	124.46±12.0	131.25±6.68	130.59±7.59
TDS (mg/L)	67.38±5.54	70.92±7.38	64.92±7.17	67.46±3.33	67.67±4.37
T.Hard (mg/L)	56.77±16.27	54.30±15.22	59.01±16.28	56.74±16.02	56.70±15.76
T.Alka (mg/L)	60.26±10.55	58.17±10.18	59.01±9.40	58.44±8.95	58.97±9.53
Phos (mg/L)	2.20±0.62	2.13±0.71	2.50±0.69	2.05±0.71	2.22±0.67
Nitrat (mg/L)	2.77±1.26	2.83±1.13	2.95±1.29	3.08±1.27	2.90±1.23

Air Temp- Air temperature (ºC), Water Temp – Water temperature (ºC), Trans – Transparency (m), DO – Dissolved oxygen (mg/L), Cond – Conductivity(µS/cm), TDS – Total dissolved solids (mg/L), THard– Total hardness (mg/L), TAlka – Alkalinity (mg/L), Phos – Phosphate (µg/L), Nitrate (µg/L).

Correlation Analysis of Water Quality Parameters and Plankton Abundance

Table 2 shows two-tailed Pearson correlation matrix of water quality parameter and plankton abundance of Ikere-gorge. Air temperature had a negative relationship with surface water temperature and transparency but a positive relationship with phosphate. Surface water temperature had a negative relationship with dissolved oxygen at P<0.05 significant level. Also, pH had a negative relationship with phytoplankton abundance at P< 0.05 significant level. Transparency had a negative relationship with total hardness and phytoplankton abundance at P< 0.05 significant level. Transparency also had a negative relationship with phosphate and nitrate but at P< 0.01 significant level. Dissolved oxygen had a positive relationship with phosphate at P< 0.05 significant level.

Conductivity had a positive relationship with total dissolved solids, total hardness and zooplankton abundance at 0.01 significant level. Conductivity also had a positive relationship with total alkalinity and phytoplankton but at 0.05 significant level. Total dissolved solids had a positive relationship with total hardness, total alkalinity and zooplankton abundance at 0.01 significant level. Total hardness had a positive relationship with total alkalinity and nitrate at 0.01 significant level. Total alkalinity had a positive relationship with nitrate and zooplankton abundance at 0.05 significant level. Phosphate had positive relationship with nitrate at 0.05 significant level. Nitrate had a positive relationship with both phytoplankton and zooplankton abundance at 0.05 significant level. Phytoplankton abundance had a positive relationship with zooplankton abundance at 0.05 significant level.

Analysis of Trophic State Index (TSI)

Table 3 shows mean monthly variation of Carlson trophic index. The annual trophic state index of Ikere-gorge was the average of the monthly values. As shown in the table, the lowest TSI (7.62±1.91) was recorded in the month of December. The highest TSI (21.58±1.12) was recorded in the month of September. The annual mean of TSI based on total phosphate was 15.04±1.63. This classified Ikere-gorge trophic status as mesotrophic at stage 2.

Table 2: Correlation Matrix of Water Quality Parameters of Ikere-gorge, Iseyin, Oyo State, Nigeria (Jan. 2017 – Dec. 2018)

	AirT	WaterT	pH	Transp	DO	Cond	TDS	T.Hard	T.Alk	Phosp	Nitrat	NP	NZ
AirTemp	1												
Water.T	-0.64*	1											
pH	-0.36	-0.11	1										
Transp	-0.73**	0.34	0.41	1									
DO	0.43	-0.58*	0.40	-0.42	1								
Cond	-0.33	0.23	0.37	0.40	-0.47	1							
TDS	-0.19	0.46	0.26	-0.31	-0.47	0.94**	1						
T.Hard	0.072	-0.09	-0.25	-0.66*	0.07	0.73**	0.724**	1					
T.Alk	-0.33	0.37	-0.18	-0.30	-0.09	0.64*	0.729**	0.81**	1				
Phosph	0.65*	-0.30	-0.27	-0.87**	0.59*	0.04	0.06	0.54	0.25	1			
Nitrate	0.49	-0.24	-0.30	-0.74**	0.27	0.49	0.45	0.76**	0.61*	0.67*	1		
NP	0.51	0.06	-0.68*	-0.69*	-0.10	0.61*	0.55	0.48	0.31	0.45	0.59*	1	
NZ	0.22	0.12	-0.45	-0.53	-0.21	0.80**	0.82**	0.71*	0.60*	0.34	0.64*	0 .71**	1

AirT- Air temperature (°C), WaterT – Water temperature (°C), Transp – Transparency (m), DO – Dissolved oxygen (mg/L), Cond – Conductivity(mg/L), TDS – Total dissolved solids (mg/L), THard– Total hardness (mg/L), TAlk – Alkalinity (mg/L), Phosp – Phosphate (mg/L), Nitrate (mg/L), NP – Number of Phytoplankton /ml, NZ – Number of Zooplankton/ml. * = 0.05; ** = 0.01

Table 3: Mean Monthly Variation of Trophic State Index (TSI) of Ikere-Gorge, Iseyin, Oyo State, Nigeria (Jan. 2017 – Dec. 2018)

Month	TSI TP
January	8.98±1.90
February	11.76±2.23
March	15.93±0.83
April	16.59±2.34
May	21.38±0.75
June	16.35±1.74
July	17.43±1.41
August	16.23±1.15
September	21.58±1.12
October	17.26±1.61
November	9.41±2.58
December	7.62±1.91
Average	**15.04±1.63**

TSI TP – Trophic State Index by Total Phosphate

DISCUSSION

The mean surface water temperature of Ikere-gorge was 28.14±1.57 ºC. This is in agreement with the findings of Olorunpomi *et al*. (2019), but higher than the value obtained earlier by Aiwerioghene and Ayoade (2016) for Ikere-gorge. This could be an indication of climate change over Ikere-gorge. This observation is consistent with the report of Harrod *et al*. (2018) that an increase in water temperature is expected in freshwater due to link between air and water temperature. Also, the recent variation in the water temperature could be attributed to loss of vegetation covers around Ikere-gorge. This is in agreement with the report of Lawani and Dirisu (2019) that climate change, loss of vegetation cover and water depth are factors responsible for changes in temperature of a water body. It must be borne in mind that almost all biological and chemical processes in freshwater ecosystems are influenced by temperature. Changes in water temperature have subsequent impacts on almost every component of the ecology of freshwater fish including sub-organismal, individual, population, species, community and ecosystem levels.

It was observed that the mean pH value was 6.50±0.63; this implies that Ikere-gorge water was near-neutral. This is in agreement with the findings of Olorunpomi *et al*. (2019) but lower than the value reported by Adeosun *et al*. (2009) for Ikere-gorge. Amoo and Komolafe (2018) also reported higher value of pH for Strabag Lake in Adegbayi, Ibadan. However, the pH value obtained in this study is within the tolerance range for fish production; since most fish can tolerate pH values of about 5.0 to 9.0; outside that range can create problems for reproduction and survival (Uttah *et al*. 2008). The mean water transparency obtained in this study was 1.34±0.12 m. This is lower than the value reported earlier by Aiwerioghene and Ayoade (2016) for Ikere-gorge and the value Dan-kishiya and Chiaha (2012) reported for Lower Usuma Reservoir Bwari, Nigeria. The difference observed in the values may be due to sampling period or anthropogenic activities. Fishermen of Ikere-gorge identified water clarity as a major factor that determines the quantity, quality and type of catch. They reported that when there is high clarity, they tend to have low catch and vice versa.

The mean dissolved oxygen of Ikere-gorge was 5.93±0.29 mg/L. This is in agreement with the findings of Aiwerioghene and Ayoade (2016). The value is however lower than the value reported by Olorunpomi *et al*. (2019) for Ikere-gorge. Also, this value is lower than the values reported by Ayoade *et al*. (2006) for Asejire dam and Oyan dam. The dissolved oxygen value obtained in this study is quite adequate for fish production; since 5 mg/L of dissolved oxygen concentration is the benchmark for most commercial fish species (Uttah *et al*. 2008).

Geological features, temperature and rainfall of an area are factors affecting electrical conductivity (Lawani and Dirisu, 2019). The electrical conductivity range of 102.5 µS/cm and 158.0 µS/cm recorded for Ikere-gorge is lower than the values reported for Awba Dam, University of Ibadan, but higher than the ranges reported for River Niger at Onitsha (Anago *et al*. 2013; Arazu and Ogbeibu, 2017). The total dissolved solids range of 53.5 mg/L and 80 mg/L is within the range reported by Dimowo (2013) for River Ogun, Abeokuta, Ogun state, Nigeria. Ikere-gorge water is moderately hard with its total hardness which ranged from 31.7 mg/L to 85.9 mg/L (EPA, 2001). But, this range is lower than the ranges reported for Çamlıgöze dam water in Sivas, Turkey and Ona River, Apata, Ibadan, Oyo State, Nigeria (Andem *et al*. 2012; Dirican, 2015).

The total alkalinity of Ikere-gorge varied between 42.0 mg/L and 79.75 mg/L. These values are higher than the values Arazu and Ogbeibu (2017) reported for River Niger at Onitsha stretch, Nigeria and the value reported by Imoobe (2011) for Okhuo River, Edo State, Nigeria. But it is lower than the values reported by Andem *et al*. (2012) for Ona River, Oyo State, Nigeria. Total phosphate of Ikere-gorge was observed to vary between 1.1 mg/L and 3.7 mg/L. This range is higher than that reported by Arazu and Ogbeibu (2017) for River Niger at Onitsha stretch, Nigeria. The mean monthly value of nitrate observed in this study was 2.90±1.23 mg/L. But, this value is higher than the value of 0.35±0.12 mg/L reported by Aiwerioghene and Ayoade (2016) for the same water body. However, United State Environmental Protection Agency recommended

a threshold of 4 mg/L. Ikere-gorge is classified based on trophic status as mesotrophic at stage 2. This shows that the water is moderately clear, but there is probability of decreasing dissolved oxygen concentration in the lower layer of the gorge (Lu, 2012).

There is negative significant relationship between water temperature and oxygen. This show the inverse relationship between the two variables; when there is increase in water temperature, then there will be decrease in dissolved oxygen. This observation is in agreement with the report of Portinho *et al.* (2016); Odulate *et al.* (2017) and Valenti *et al.* (2017). Likewise, there is negative significant relationship between water transparency and water nutrients (phosphate and nitrate). This shows that as the nutrient increases, there will be corresponding increase in primary productivity of plankton, and then water transparency will be decreasing. Arazu and Ogbeibu (2017) also observed that water transparency is highly related to productivity and strongly affected by suspended and dissolved materials in water.

CONCLUSION

Water quality parameters of Ikere-gorge were analysed in this study. It was observed that water temperature of Ikere-gorge had increased above the value that was earlier reported. This is attributed to the impacts of climate change on Ikere-gorge. The water pH of Ikere-gorge showed that the gorge is near neutral. All water quality parameters analysed were found to be suitable for fish production and within World Health Organisation (WHO) limits. Correlation analysis showed that there was an inverse relationship between Ikere-gorge water temperature and dissolved oxygen. Furthermore there was a direct relationship between the nutrients (phosphate and nitrate) and the primary productivity (phytoplankton and zooplankton); such that as the nutrient increased, there was a corresponding increase in primary productivity. There was an inverse relationship between the primary productivity and water transparency; such that as the primary productivity increased there was a corresponding decrease in water transparency. Ikere-gorge could be classified based on trophic status as mesotrophic at stage 2. This showed that the water was moderately clear, but there is increasing probability of decreasing dissolved oxygen concentration in lower layer of the gorge. Therefore, management of Ikere-gorge must be holistic to incorporate water and pollution management to improve and sustain fish production.

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