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Weighted Arithmetic Indexing for Assessing Water Quality in Artificial Fish Ponds in Makurdi Metropolis Nigeria

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Abstract

This study assessed water quality from selected artificial ponds in Makurdi City, Nigeria using weighted arithmetic index. Water samples were collected from nine sampling sites; earthen pond, concrete and other fish pond. Standard procedures were adopted to analyze the selected physicochemical parameters of water. The analyzed results were subjected to WHO (2020) permissible limits for aquatic water quality. Physicochemical parameters of water in the study area were analyzed and the result showed average values as; Temperature: 29.60 ^{0}C, pH: 7.20, TDS: 0.25 mg/L, TSS: 0.11 mg/L, DO: 5.96 mg/L, BOD: 2.27 mg/L, COD: 0.24 mg/L, SO_4^{2-}: 9.31 mg/L, Cl^-:60.27 mg/L, NO_3^-: 0.19 mg/L and P: 0.09695 mg/L were blow WHO threshold in water while Turbidity: 175.35 NTU and Conductivity: 380.06 µscm^{-1} values were above the maximum limit in water by WHO. Water quality index calculated showed that only pond G (22.79) and H (18.52) were unpolluted, pond A (1096.93), B (141.72), C (330.28), D (115.27), E (123.84), F (83.46) and I (387.76) were polluted in varying degrees. The study recommends regular check on fish pond water in order to prevent pollution and indeed the quality of fish been reared

Key words: Fish, Pond, Water, Quality, weighted arithmetic index

Introduction

Water is one of the major abiotic factors that sustains all living things and for fish, it unarguably, the most important factor for its living. This is because fish life depends totally on water; to breathe, feed and grow, digest feeds, swim, excrete wastes, maintain a salt balance, and reproduce [1].

Artificial fish ponds involve rearing of fish in an enclosed water where all its life processes can be controlled. Since artificial ponds are restricted water bodies, they are particularly prone to pollution and contamination from both anthropogenic and natural sources with effects on the productivity and quality of the cultured fish [2].

Pollutants enter into the fish pond water through the water source, uptake by fish via feeds and sediments, runoffs, atmospheric depositions, geologic weathering and other farm management practices such as medicants, feed additives, antibiotics, fertilizers, disfectants, hormones, therapeutants and anesthetics, commonly applied during farm operations [3].

Many methods of evaluating water quality, normally called water quality index (WQI) developed by National and international organizations of different states are available, depending on their need to evaluate the level of water quality in a specific area of interest [4]. The Water Quality Index represents a numerical expression which has the purpose of establishing the ecological state of a body of water. For the general calculation of this index, it is usually necessary to determine the physical, chemical and biological parameters. According to the resulting value obtained by the calculation of the WQI index, the water samples to be studied could be framed in one of the following water quality categories: excellent, good, poor, very poor, undrinkable [4]. Among the methods, Weighted Arithmetic Water Quality Index Method (WAWQI), is more appropriate than other methods due to its factoring upon more quality parameters within one main mathematical equation, as well as to its possibility to describe the quality of surface and underground waters for human consumption [5].

Targuma *et al.* [6] reported acceptable limit of physicochemical parameters for fish pond water within Makurdi metropolis however, water quality index was not evaluated. In another work by Wuana *et al.* [7], it reported overall WQI value of 72.02 (grade C), which indicated for irrigation and industrial use but requires treatment before drinking. Therefore, this research aimed assessing water quality from selected artificial ponds in Makurdi metropolis, using weighted arithmetic index

Materials and Methods

Materials

In addition to routine materials in a standard chemical laboratory, the following were used: concentrated nitric acid (HNO_3,), concentrated perchloric acid ($HClO_4$), concentrated hydrochloric acid (HCl), concentrated sulfuric acid (H_2SO_4) and de-ionized water

Apparatus

Mortar and pestle (Porcelain), hot Plate, brown envelopes (A4-size), aluminium foil, 2.5-L Winchester bottle (amber) and laboratory test sieve (2 mm aperture)

Study area

The study is bound by latitude of 7° 44N and 7° 55N, and longitude 8° 20E and 8° 40E. It has two seasons, raining season and dry season. The raining season lasts from May to October and the dry season lasts from November to April. Makurdi is made up of two geopolitical division, North and South separated by the river Benue. Makurdi South has more land coverage than Makurdi North, hence sampling of the fish ponds will be carried out in the ratio of 2:1, therefore, 6 sampling sites at the south and 3 sampling sites at the north, making a total of nine sampling sites.

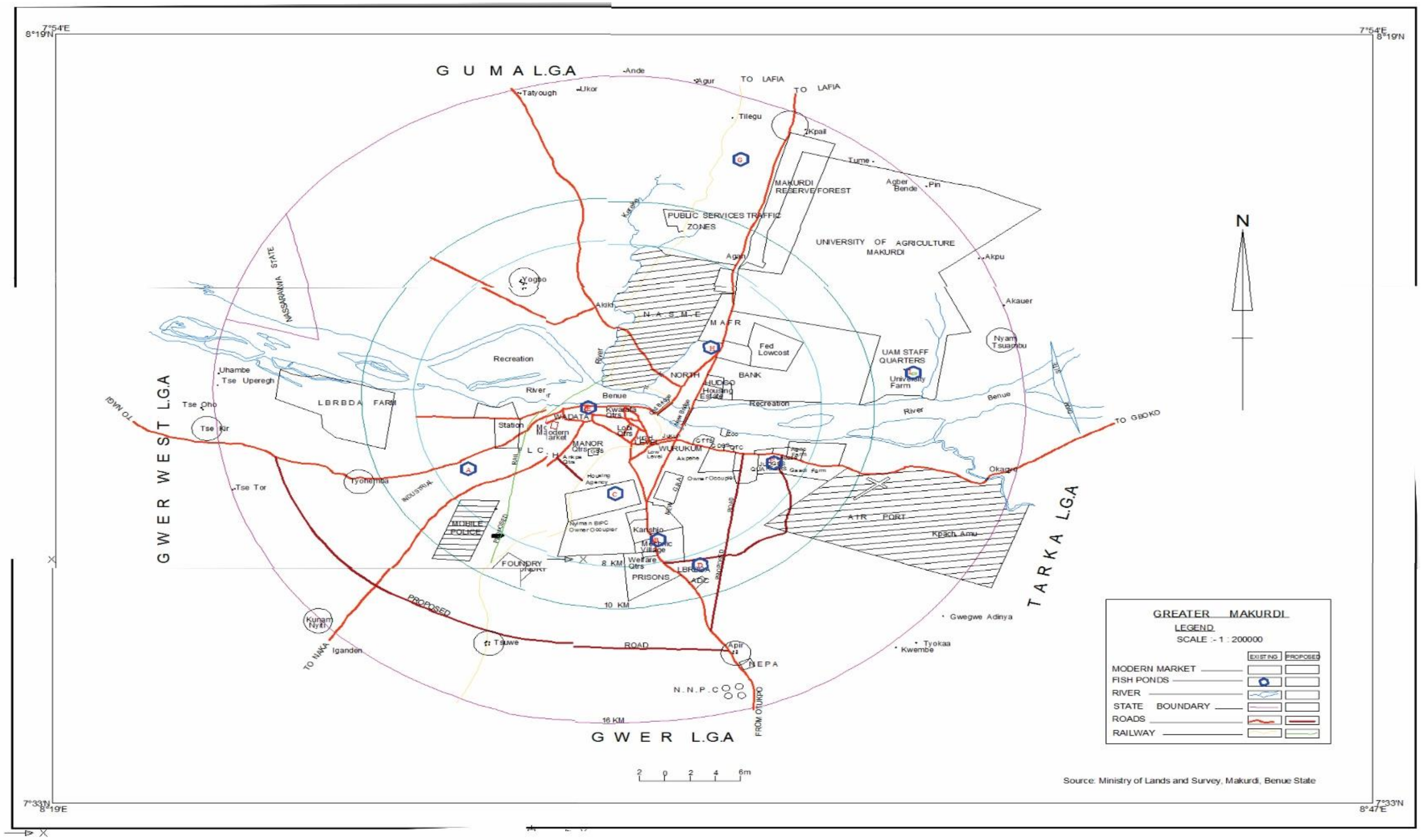

Fig. 1: Map showing 9 fish ponds areas in Makurdi Metropolis used for the analysis

Methods

Water sample collection

Water samples in each of the nine ponds were drawn randomly and homogenized in sterile 500 mL bottles and labeled; A_w, B_w, C_w, D_w, E_w, F_w for ponds from Makurdi South and G_w, H_w, and I_w for ponds at Makurdi North. The water samples collected were then be filtered through 0.45-µm filters to remove particulate matter and transported to laboratory for physiochemical analysis, noting the type of fish pond, the source of water and the type of fish in each of the ponds [8]

Physicochemical Analyses of Water

The physicochemical properties of the water samples were determined according to standard methods [9]. All measurements were carried out in triplicates.

Temperature: Surface water temperature was determined on site using the temperature sensor of a dissolved oxygen probe. The probe was immersed in the reservoir water to a depth of 0.3 m and allowed to stabilize before temperature readings were taken in ^{0}C.

pH: The pH of the water was measured on site using a portable pH meter. The pH probe was lowered to a depth of about 0.3 m, allowed to stabilize and the pH value, read.

Electrical conductivity: A multi-range conductivity meter was used to measure electrical conductivity (EC) of surface water at the sampling site. The meter probe was lowered into the reservoir water to a depth of 0.3 m and allowed to stabilize before taking the conductivity readings in µS cm-1.

Turbidity: The turbidity of water in the site was determined by use of a turbidity meter. The measurement was read in Nephelometric Turbidity Units (NTU).

Dissolved Oxygen (DO): Dissolved oxygen (DO) was measured on site using a JENWAY 970231B Oxygen meter. The DO probe was immersed into the reservoir water at a depth of approximately 0.3 m. While gently stirring the water with the DO probe, the readings were allowed to stabilize and DO read in mg L-1.

Biochemical Oxygen Demand (BOD): BOD in water was measured using dissolved oxygen values taken initially at sample collection and the dissolved oxygen value after five (5) days of incubation. The difference (in mg/L) represents the amount of oxygen consumed by microorganisms to break down the organic matter present in the sample during the incubation period.

Chemical Oxygen Demand (COD): Titrimetric method was employed in the determination of COD. A 10 ml of 0.125 M $K_2Cr_2O_7$ was added to 20 ml of the water sample using a pipette in a refluxing flask. Glass beads or anti – bumping chips was added. Then 30 mL of concentrated H_2SO_4 was added slowly and with gentle swirling. The flask was then being connected to the condenser and refluxed for 2 hours. After that, the flask was cooled and the condenser washed with distilled water into the flask and diluted to about 150 mL. The excess dichromate was titrated with 0.05 M ferrous ammonium sulphate (FAS) using 2 drops of ferroin as indicator. A blank mixture was prepared and treated using the same procedure.

$$\text{mg/L COD} = \frac{(Vb - Vs) \times M \times 16000}{\text{mL sample}} \quad (1)$$

where: V_b = mL FAS used for blank, V_s = mL FAS used for sample, m= molarity of FAS.

Total dissolved solids (TDS): TDS was measured using the probe of a conductivity multi-meter. The value was recorded in mg/L.

Determination of total suspended solids (TSS): Total suspended solids = total solid — total dissolved solids (2)

Nitrates: Nitrate concentration was determined using a HACH 5000 UV-Vis spectrophotometer. The value was recorded in mg/L.

Phosphates: Phosphate concentration was determined using a HACH 5000 UV-Vis spectrophotometer. The value was recorded in mg/L.

Sulphates: Sulphate concentration was determined using a HACH 5000 UV-Vis spectrophotometer. The value was recorded in mg/L.

Chlorides (Cl^-): In 100 mL of sample, 1 mL of K_2CrO_4 indicator was added and titrated against 0.02mol $AgNO_3$ till brick red precipitates were formed. The formula used to calculate mg. of Cl^-/L is as follows: Mg of Cl^-/L=

$$\frac{B.R \times m \times 35.45 \times 1000}{\text{Amount of sample taken (ml)}} \quad (3)$$

where, B.R. = Burette reading (Amount of titrant used), m = molarity of Silver Nitrate, 35.45 = Equivalent weight of Chloride

Total hardness (Mg): Hardness in the water was measured by titrating the water samples in triplicate using EDTA solution with a K10 buffer, and Erichrome Black T indicator. The result was recorded in mg/L. Results from the analyses above were used to determine the water quality index (WQI) using the weighted arithmetic method.

Evaluation of WQI (Weighted Arithmetic method) Tyagi et al., [10]. In this model, different water quality components are multiplied by a weighting factor and are then aggregated using simple arithmetic mean. For assessing the quality of water in this study, firstly, the quality rating scale (Qi) for each parameter is calculated by using the following;

$$Qi = \frac{\{(V_{actual} - V_{ideal}) * 100\}}{(V_{standard} - V_{ideal})} \quad (4)$$

where, Qi = Quality rating of ith parameter for a total of n water quality parameters; V_{actual} = Actual value of the water quality parameter obtained from laboratory analysis; V_{ideal} = Ideal value of that water quality parameter can be obtained from the standard Tables. Videal for pH = 7 and for other parameters it is equaling to zero, but for DO Videal = 14.6 mg/L, Vstandard = Recommended WHO standard of the water quality parameter.

Then, after calculating the quality rating scale (Qi), the Relative (unit) weight (Wi) is calculated by a value inversely proportional to the recommended standard (Si) for the corresponding parameter using the following expression;

$$Wi = \frac{1}{Si} \quad (5)$$

where, Wi = Relative (unit) weight for nth parameter, Si= Standard permissible value for nth parameter. I = Proportionality constant. That means, the Relative (unit) weight (WI) to various water Quality parameters is inversely proportional to the recommended standards for the corresponding parameter. Finally, the overall WQI is calculated by aggregating the quality rating with the unit weight linearly by using the following equation:

$$WQi = \frac{\Sigma QiWi}{\Sigma Wi} \quad (6)$$

where, Qi = Quality rating, Wi = Relative weight. In general, WQI is defined for a specific and intended use of water. In this study the WQI was considered for human consumption or uses and the maximum permissible WQI for the drinking water was taken as 100 score. The suitability of WQI values for human consumption according to [10] are rated as follows.

Table 1: Recommended Values of Physicochemical parameters of Water [20]

Parameter	V_{ideal}	$S_{standard}$
Temperature	0	30
pH	7	8.5
TS	0	1000
TDS	0	500
TSS	0	500
Turbidity	0	5
Conductivity	0	250
DO (mg/L)	14.6	10
BOD (mg/L)	0	5
COD (mg/L)	0	5
SO^{2-}_4	0	200
Cl^-	0	250
NO^-_3	0	50
P (mg/L)	0	0.5
Mg (mg/L)	0	50

Where V_{ideal} = Ideal value of water quality parameter

$V_{standard}$ = Recommended WHO standard of the water quality parameter

Table 2: Rating for Water Quality for Weighted Arithmetic Index [11]

Range	Rating
0-25	Excellent
26-50	Good
51-75	Bad
76-100	Very bad
100 and above	Unfit

Correlation

The results obtained from the water parameters were used to assess the quality of water index using Pearson Correlation Coefficient.

Results and Discussion

Table 3A: Physicochemical Parameters in Ponds Water

Ponds Sample Identity	Parameters					
	Temperature °C	pH	TDS mg/L	TSS mg/L	Turbidity (NTU)	Conductivity µscm^{-1}
A_w	31.80 ±0.06	5.90 ± 0.07	0.31 ±0.0028	0.27 ±0.00	793.50±0.71	830.00 ±0.00
B_w	28.60±0.02	7.60 ± 0.07	0.30 ±0.0042	0.08 ±0.00	84.20 ±0.71	843.50 ±2.12
C_w	28.90±0.02	7.00 ± 0.14	0.19 ±0.0311	0.22 ±0.03	232.00±1.41	203.50 ±0.71
D_w	29.50±0.01	6.80 ± 0.00	0.28 ±0.0014	0.03 ±0.00	76.50 ±0.42	305.00 ±0.00
E_w	29.00±0.05	7.80 ± 0.07	0.26 ±0.0042	0.06 ±0.01	69.90 ±0.14	288.50 ±0.71
F_w	30.50±0.02	8.00 ± 0.00	0.29 ±0.0014	0.04 ±0.00	40.15 ±0.07	369.00 ±0.00
G_w	29.10±0.06	8.50±0.006	0.24 ±0.0028	0.06 ±0.00	8.88 ±1.15	193.00 ±1.41
H_w	27.50±0.03	6.70±0.007	0.23 ±0.0028	0.02 ±0.00	6.01 ±0.78	226.50 ±0.71
I_w	31.70±0.91	6.70±0.006	0.17 ±0.0000	0.20 ±0.00	267.00±0.00	161.50 ±0.71
Range	27.50-31.80	5.90-8.50	0.17-0.31	0.02-0.27	6.01-793.50	161.50-843.50
Mean	29.60±0.01	7.20± 0.07	0.25±0.0042	0.11±0.00	175.35±0.71	380.06 ±0.00
WHO	25-30 °C	6.5-8.5	500	500	5 NTU	250

Note; A_w, B_w, C_w, D_w, E_w, F_w for water in ponds from Makurdi South and G_w, H_w, and I_w for ponds at Makurdi North

Table 3B: Mean Concentration of Physicochemical Parameters in Ponds Water

Ponds Sample Identity	Parameters		
	DO (mg/L)	BOD (mg/L)	COD (mg/L)
A_w	6.03 ±0.04	2.56 ±0.04	0.25 ±0.0007
B_w	5.61 ±0.00	2.47 ±0.13	0.21 ±0.0007
C_w	5.85 ±0.00	2.16 ±0.01	0.24 ±0.0141
D_w	6.07 ±0.04	2.01 ±0.07	0.25 ±0.0007
E_w	5.76 ±0.04	1.78 ±0.26	0.24 ±0.0141
F_w	6.46 ±0.00	3.08 ±0.00	0.29 ±0.0007
G_w	6.43 ±0.00	2.21 ±0.00	0.23 ±0.0007
H_w	5.33 ±0.01	2.64 ±0.10	0.22 ±0.0000
I_w	6.12 ±0.01	1.40 ±0.08	0.24 ±0.0141
Range	5.33-6.46	1.40-3.08	0.21-0.29
Mean	5.96±0.00	2.27±0.00	0.24±0.0141
WHO	5	5	5

Note; A_w, B_w, C_w, D_w, E_w, F_w for water in ponds from Makurdi South and G_w, H_w, and I_w for ponds at Makurdi North

Table 3C: Mean Concentrations (mg/L) of Physicochemical Parameters in Ponds Water

Ponds Sample Identity	Chemical Parameters				
	SO_4^{2-}	Cl-	NO_3^-	P	Mg
A_w	10.43 ±0.03	120.53 ±0.00	0.20 ±0.0064	ND	ND
B_w	10.69 ±0.00	76.22 ±2.51	0.15 ±0.0028	0.1148 ±0.002	ND
C_w	9.50 ±0.44	69.13 ±2.51	0.20 ±0.0064	0.0930 ±0.000	ND
D_w	8.57 ±0.12	99.26 ±0.00	0.15 ±0.0021	0.0673 ±0.000	ND
E_w	8.70 ±0.07	51.40 ±2.51	0.23 ±0.0007	0.1080 ±0.003	ND
F_w	9.29 ±0.29	47.86 ±2.51	0.20 ±0.0064	0.1269 ±0.002	ND
G_w	8.89 ±0.07	19.50 ±2.51	0.14 ±0.0021	ND	ND
H_w	9.09 ±0.39	44.31 ±2.51	0.20 ±0.0007	ND	ND
I_w	8.67 ±0.03	14.18 ±0.00	0.27 ±0.0028	0.0717 ±0.002	ND
Range	8.57-10.69	14.18-120.53	0.14-0.27	0.0673-0.1269	
Mean	9.31 ±0.29	60.27±2.51	0.19±0.0064	0.09695±0.000	
WHO	200	250	7	0.5	

Note; A_w, B_w, C_w, D_w, E_w, F_w for water in ponds from Makurdi South and G_w, H_w, and I_w for ponds at Makurdi North

Table 4: Water Quality Index for all the Ponds and their Status

Ponds Sample Identity	WQI level	Remark
A_w	1096.9264	Unfit
B_w	141.7175	Unfit
C_w	330.2790	Unfit
D_w	115.2721	Unfit
E_w	123.8371	Unfit
F_w	83.4621	Unfit
G_w	22.7908	Good
H_w	18.5208	Excellent
I_w	387.7552	unfit

Note; A_w, B_w, C_w, D_w, E_w, F_w for water in ponds from Makurdi South and G_w, H_w, and I_w for ponds at Makurdi North, WQI= Water Quality IndeX

Table 5: Pearson Correlation Coefficient for Water Analysis

		DO	BOD	COD	TDS	TSS	Turb	SO_4^{2-}	Cl^-	Cond	NO_3^-	Temp	pH
DO	Pearson Correlation	1											
BOD	Pearson Correlation	.023	1										
COD	Pearson Correlation	.645**	.307	1									
TDS	Pearson Correlation	.092	.610**	.244	1								
TSS	Pearson Correlation	.102	-.265	.080	-.254	1							
Turb	Pearson Correlation	.072	-.013	.210	.172	.865**	1						
SO4	Pearson Correlation	-.237	.493*	-.231	.466	.378	.489*	1					
Cl	Pearson Correlation	-.187	.283	.131	.636**	.326	.578*	.537*	1				
Conduct	Pearson Correlation	-.169	.409	-.118	.735**	.253	.529*	.876**	.685**	1			
NO3	Pearson Correlation	-.063	-.355	.303	-.471*	.381	.287	-.234	-.283	-.250	1		
Temp	Pearson Correlation	.601**	-.174	.573*	.055	.633**	.693**	.079	.144	.214	.477*	1	
pH	Pearson Correlation	.279	.278	-.055	.217	-.630**	-.673**	-.096	-.349	-.143	-.499*	-.481*	1

**Correlation is significant at the 0.01 level (2-tailed)., *Correlation is significant at the 0.05 level (2-tailed)

Temperature

Temperature is an essential water factor with great influence on the chemical and biological characteristics of aquatic lives [12]. As could be seen from Table 3A, the temperature recorded in this study ranged from 27.50-31.80 ^{0}C with a mean of 29.60±0.01^{0}C which is within the permissible limit for pond water set by WHO. Targuma *et al.* [6] in a comparative Analysis of metal levels in Clarias gariepinus and water from River Benue and commercial fish Ponds in Makurdi also reported a similar water temperature for fish pond of 29.1 ^{O}C ± 0.24. However, the temperature of pond A, 31.80 ^{0}C and that of pond I, 31.70 ^{o}C were slightly more than the required limit for fish pond. This could be because, they were the only earthen fish ponds recorded in these studies with large surface area, thereby absorbing more heat from the surrounding. Across the ponds in the study area, the trend of temperature was A>I>F >D >G >E >C >B >H. There was a positive correlation between temperature, DO, turbidity and sulphate at 0.01 level of significant and a correction with COD at 0.05 level of significant.

pH

The value of pH of water samples is an indicator of its acidic or alkaline nature. It is reported that fish have an average blood pH of 7.4 [13]; hence pond water with pH value close to the above-mentioned pH value is accepted as favorable for fish cultivation. On-site analyses of pH were carried out in the study area as seen from Table 3A and ranged from 5.90-8.50 with a mean value of of 7.20± 0.07 which was within the permissible limit of 6.5-8.5. pH variations may be as a result of the initial pH of the water bodies before introduction into the pond [14]. Njoku *et al.* [15] reported a similar pH value. Ponds F, 8.00 and Pond G, 8.50 however, have higher pH than others. This could be attributed to the type of soil or sediment composition containing Ca_2CO_3 and $MgCO_3$ in its structure therefore playing a key role in this high pH values recorded in water or from high feeding regime [16]. The pH of water in pond, A (5.90) appeared slightly acidic. The slight acidity may have occurred from the effects of respiration as a result of overstocking of the fish in the pond, decomposition between plankton, macrophytes, fish and the feed could also be the cause of acidic pH in pond water [17]. Across the ponds, the trend of pH decreased in this order, G>F>E>B>C>D>H=I>A. pH had a positive correlation with TSS and turbidity at 0.01 and nitrate and temperature at 0.05 level of significant.

Total Suspended Solid

As contained from Table 3A, TSS in this work ranged from 0.02-0.27 mg/L with a mean value of 0.11±0.00mg/L which is below WHO permissible limit in pond water. Variations in the fish meals may have been responsible for the difference in the solid contents of the ponds [6]. The trend of TSS across the ponds is A>C >I >B >E=G >F >D >H. There was a strong positive correlation between TSS, pH and turbidity at 0.01 level of significant.

Total Dissolved Solid

The TDS is a measure of the dissolved organics and inorganics in the given water sample. As seen from Table 3A, the obtained ponds TDS varies in this other, A (0.31) **>** B (0.30) **>** F (0.29) > D (0.28) > E(0.26) > G(0.24) > H(0.23) > C (0.19) > I (0.17).The TDS investigated in this work ranges from 0.17-0.31 mg/L with a mean of 0.25±0.0042mg/L which is within the acceptable limit set by WHO. There was a correlation between TDS with BOD at 0.01 level of significant.

Turbidity

Turbidity in water refers to the intensity of the cloudiness of the sample due to the suspended particles, [18]. The trend observed of Turbidity (NTU) across the sampling points was in the order of A (793.50) > I (267.00) > C (232.00) > B(84.20) > D(76.50) > E(69.90) > F(40.15) > G(8.88) > H(6.01) NTU which ranged from 6.01-793.50 NTU and a mean of 175.35±0.71NTU as seen from Table 3A. The turbidity values in all the sampling points were found to be above the WHO permissible limit of 5 NTU. The high turbidity of some of the samples may be due to poor housekeeping. Turbidity may also be as a result of over-stocking, infrequent change of water, over feeding and metabolic activities of fishes in the pond such as excretion contribute to the turbidity of fish pond water. Iwar *et al.* [19] reported Mean values of turbidity to be higher than the WHO, FAO and NSDWQ Standards for drinking water in river Benue, Makurdi. There was a correlation between turbidity TSS and pH at 0.01 level of significant.

Conductivity

Electrical conductivity gives information on all dissolved ions in the solution. Low numbers of ions are required in water solution in fish ponds for osmotic balance in fish species. The EC investigated in this study ranged from 161.50-843.50 µscm^{-1} with an average of 380.06 ±0.00 µscm^{-1} which is above WHO acceptable limit of 250 µscm^{-1} **[20].** The wide variations across the ponds suggest that considerable amount of dissolved ionic substances enter the ponds. The trend of EC across the nine ponds investigate in decreasing order is B>A >F >D >E >H >C >G >I. There was a strong positive correlation between conductivity, TDS, sulphate and chloride at 0.01 level of significant. Conductivity also correlated with turbidity at 0.05 level of significant.

BOD

BOD is the measurement of the amount of dissolved oxygen needed by organisms to break down the organic matter present in a given water sample under aerobic conditions at a specific temperature over a certain period [21]. The BOD investigated here ranged from 1.40-3.08 mg/L with a mean of 2.27±0.00 mg/L as seen from Table 3B. All the ponds analyses show similar BOD and are within the permissible limit of WHO. This could be as a result of overstocking of fish in the pond causing a shortage of oxygen. The result obtained here corroborated with an earlier result reported by Uwah *et al* [22] in Ismailia Canal, Egypt and Atabong River, Nigeria, respectively.

BOD has a strong positive correlation with TDS and negative Cu at 0.01 level. There was also a negative correlation with Zn at 0.05 level of significant.

DO

DO is a measure of the amount of dissolved oxygen in the aquatic ecosystem [23]. The trend of DO (mg/L) values across the sampling points was in the order of F>G >I >D >A >C >B >E >H which ranged from 5.33-6.46 mg/L with a mean of 5.96±0.00 mg/L as seen from Table

3B. The different in the values of dissolved oxygen recorded in study could be attributed to different temperature, microbial and organic loads and resultant increase in metabolic activity [24]. These results showed that the levels of dissolved oxygen across all the sampling points analyzed were below the WHO [8] and corroborated similar research work by Ogbeibu *et al.* [25]. There was a positive correlation with COD and temperature in water at 0.05 level.

COD

Chemical oxygen demand determines the amount of oxygen required for chemical oxidation of organic and inorganic matter. The COD (mg/L) value along the 9 sampling sites was in the order of F **>** A= D **>** C= E=I **>** G **>** H **>** B respectively. The investigated COD ranged from 0.21-0.29 mg/L with a mean of 0.24±0.0141 mg/L as seen from Table 3B. All the COD measured are below WHO permissible limit. This is similar to Targuma *et al.,* [6] reported COD of 2.35 mg/L while working on some fish ponds in Makurdi. A Pearson correlation coefficient for water analysis in the study area showed a positive correlation with OD at 0.01 level and positive correlation with temperature at 0.05 level.

Phosphate

Phosphates are introduced into the aquatic environment in the form of phosphorus, which is a vital nutrient required for growth and proper functions of cells and tissues to support aquatic lives [26]. The result for the investigation of phosphorus in these studies shows an average of 0.09695±0.000 mg/L ranging from 0.0673-0.1269 mg/L which is below the WHO standard of 250 mg/L for pond water which is similar to the work reported by Uwah *et al.* [22]. However, the result at ponds A, 0.1148 mg/L, E, 0.1080 mg/L and F, 0.1269 mg/L are comparatively higher than the other ponds, though within the acceptable limits. The low phosphate in the water sample as seen from Table 3C could be attributed minimal feeds in the ponds and low use of chemicals in the ponds [27].

Nitrate

The average value of the nitrate investigated is 0.19±0.0064 mg/L which ranged from 0.14-0.27 mg/L as seen from Table 3C. The values are all within the acceptable limits of WHO (50 mg/L). Similar work by Mgbemena *et al.* [14] revealed nitrate concentration between 0.42±0.02 – 1.17±0.01 mg/L in Lagos. Ehiagbonare and Ogunrinde [28] report where nitrate level was revealed in the range of 2.21 - 4.91 mg/l contrast of result. There was a positive correlation between nitrates with TDS at 0.005 level of significant.

Sulphate

As seen from Table 3C, the investigated sulphate in this work ranged from 8.57-10.69 mg/L with an average of 9.31 ±0.29 mg/L which is within WHO permissible limit for pond water. Among the nine fish pond, the trend was thus, B**>**A>C>F>H>G>E>I>D. Similar results have been reported by Ehiagbonare and Ogunrinde [28] where the concentration of sulphate in the ponds varied from 0.66 - 1.09 mg/L. There was a correlation between sulphate with BOD and turbidity at 0.05 level of significant.

Chloride

One of the most vital inorganic ions in water is chloride. It is also regarded as an indicator of sewage pollution [29]. As seen from Table 3C, the concentration of chlorine recorded here ranged from 14.18- 120.53 with mean value of 60.27±2.51 mg/ L which is lower than the permissible limit of 250 mg/L. The highest concentration of Cl was found at pond A while the lowest was at pond I. across the ponds, the trend in descending order is A >D>B >C >E >F >H >G >I. chloride had a strong correlation with TDS at 0.01 level of significant and a correlation with turbidity and sulphate at 0.05 level of significant.

Water Quality Index for the Ponds under Study

WQI in pond A

From Table 4 using equation (6) the calculated WQI from pond A was 1096.9264 which implied that the quality of water is unsuitable because it exceeds the value of > 100 as recommended by [30]. This corroborated an early report by Mbachu *et al.* [31] in Water Quality Assessment on Physicochemical and Biological Parameters of Selected Lentic Ecosystem in Aboh Mbaise Local Government Area, Imo State, Nigeria.

WQI in pond B

From Table 4, the overall calculated WQI from pond B was 141.7175 which is far less than the WQI reported for pond A (1096.9264), though still unsuitable because it exceeds the value of > 100. This corroborated an early report by Iyiola *et al.* [32] in Owalla Reservoir in South-western Nigeria.

WQI in pond C

From Table 4, the overall calculated WQI from pond C was 330.2790 which is more than the calculated WQI for pond B (141.7175) but far less than the WQI reported for pond A (1096.9264), though still unsuitable because it exceeds the value of > 100. This corroborated an early report by Iyiola *et al.* [32] in Owalla Reservoir in South-western Nigeria: Assessment of Fish Distribution, Biological Diversity, and Water Quality Index. Indonesian.

WQI in pond D

From Table 4, the overall calculated WQI from this pond was 115.3413 which is less than the calculated WQI for pond A (1096.9264), B (141.7175) and C (330.2790), though still unsuitable because it exceeds the value of > 100. This corroborated an early report by Mbachu *et al.* [31] in Water Quality Assessment on Physicochemical and Biological Parameters of Selected Lentic Ecosystem in Aboh Mbaise Local Government Area, Imo State, Nigeria.

WQI in pond E

From Table 4, the overall calculated WQI from this pond was 123.9114 which is less than the calculated WQI for pond A (1096.9264), B (141.7175) and C (330.2790) but higher than pond D (115.2721), though still unsuitable because it exceeds the value of > 100. This corroborated an early report by Mbachu *et al.* [31] in Water Quality Assessment on Physicochemical and Biological Parameters of Selected Lentic Ecosystem in Aboh Mbaise Local Government Area, Imo State, Nigeria.

WQI in pond F

From Table 4, the overall calculated WQI from this pond was 83.5121which is less than the calculated WQI for pond A, B (141.7175) and C (330.2790), D (115.2721) and E (123.8371), though still unsuitable because it exceeds the value of > 100.

WQI in pond G
From Table 4, the overall calculated WQI from this pond was 22.8045 which is less than the calculated WQI for pond A, B (141.7175) and C (330.2790), D (115.2721), E (123.8371) and F (83.4621). The water quality measured in this pond is suitable for domestic and aquatic use because it is less than the value of < 100.

WQI in pond H
From Table 4, the overall calculated WQI from this pond was 18.5319which is less than the calculated WQI for pond A, B (141.7175) and C (330.2790), D (115.2721), E (123.8371), F (83.4621) and G (22.7908). The water quality measured in this pond is suitable and rated "excellent" for domestic and aquatic use because it is less than the value of < 100

WQI in pond I
From Table 4, the overall calculated WQI from this pond was 387.9879 which is less than the calculated WQI for pond A, but more than the calculated WQI for ponds B (141.7175) and C (330.2790), D (115.2721), E (123.8371), F (83.4621), G (22.7908) and H (18.5208). The water quality measured in this pond is unsuitable and rated "unfit" for domestic and aquatic use because it is less than the value of < 100.

Conclusion
Water quality parameters such as temperature, pH, TDS, TSS, BOD, COD, DO, SO_4^{2-}, Cl^-, $NO_3^-$and P determined in the study area complied with the recommended levels for aquaculture production. However, turbidity and EC were found to be above threshold recommendation by WHO while Mg was not detected in any of the fish pond analysed. Water quality index for the ponds in the study area showed that the waters of pond A, B, C, D, E, F, and I were not good for fish rearing except pond H and G which are described based on WQI as 'good water' and 'excellent water' respectively for domestic use. The high values of turbidity recorded for the fish ponds A, B, C, D, E, F, and I were responsible for the result of poor water quality of the pond. Farmers of these ponds therefore need proper sensitization, orientation and education on pond management especially feeds application which could cause high values of turbidity and by implication poor water quality.

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