An Appraisal of Indices of Eutrophication of Surface Water of Some Parts of River Benue in Makurdi Metropolis, North-Central, Nigeria

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***Abstract*: Physical, chemical and biological parameters of surface water (river Benue) Makurdi, were evaluated to determine the eutrophication potential and make logical inference on the fate of surface water system. Sampling was from five (5) strategic sites along river Benue and standard methods were used for the measurement of nitrate, phosphate, biological oxygen demand, chemical oxygen demand, pH, conductivity, total dissolved oxygen (TDS), potassium and algae count as indices of eutrophication. The results showed low levels of nutrients and microbial activities. The values of some eutrophication parameters in the sites were as follows: BOD mg/L (Coca-Cola 0.30±0.00, Kyabis hotel 0.43±0.03, Wadata 0.88±0.03, Abattoir 0.90±0.10, BSU 0.62±0.03). Nitrate mg/L (Coca-Cola 1.86±0.13, Kyabis hotel 0.73±0.03, Wadata 0.68±0.05, Abattoir 0.40±0.03, BSU 0.89±0.04). Phosphate mg/L (Coca-Cola 0.04±0.00, Kyabis hotel 0.05±0.00, Wadata 0.05±0.00, Abattoir 0.08±0.00, BSU 0.05±0.00). Findings revealed that many of the eutrophication parameters studied were within threshold levels, as they were within permissible limits of the World Health Organization and Standard Organization of Nigeria, and therefore the river is not under immediate threat of accumulation of phytoplankton and nutrients. However, traditional practice of dumping of wastes into water bodies must be reversed to ensure the river does not become eutrophicated in the nearest future.**

***Keywords:* Eutrophication, River Benue, algal bloom, nitrate, phosphate.**

I. INTRODUCTION

Accumulation of large amounts of plant nutrients leading to excess algal growth is a common sight in many lakes and estuaries across the globe. In an aquatic ecosystem, algal productivity is necessary to support the food chain, however, excess growth under eutrophic conditions may eventually lead to severe deterioration of the water body (Manahan, 2001). This phenomenon referred to as eutrophication of water is a condition whereby an excess of nitrogen (N), phosphorus (P), and other inorganic nutrients enter a relatively closed and slow-flowing water body (such as lake, reservoir, river, embouchure, bay and freshwater wetland) stimulating the proliferation of algae and other plankton in the water, resulting in lower dissolved oxygen (DO), increased chlorophyll-a content and the deterioration of water quality (Fang *et al., 2004;* Liu *et al.*, 2009; Yan *et al.*, 2021). The cumulative effect of this is the excessive growth of phytoplankton leading to imbalanced primary and secondary productivity and a faster rate of succession from existence to higher serial stage, as caused by nutrient enrichment through runoffs that carry down overused fertilizers from agroecosystems and/or discharged human waste from settlements (Western, 2001; Khan and Ansari, 2005).

Makurdi is a sprawling capital city of Benue State in north central Nigeria located on latitudes 7.73 and 7.44 ºN and longitudes 8.56 and 8.32 ºE. Being a state capital, it plays host to many industrial and economic concerns. Additionally, it is a centre of network of vehicular movements crisscrossing to various parts of the country. The state derives its name from river Benue which bisects the capital city into North and South banks. Because water bodies such as River Benue which runs through the capital and commercial city of Makurdi, are generally prone to loading of nitrogen, phosphorus, and other nutrients from human and industrial activities, this work was designed to assess indices of eutrophication in water samples from the river.

II. MATERIALS AND METHODS

2.1 Sample collection and preservation

A 100 mL beaker was used to collect water samples from different areas within each sampling site and transferred into 1,000 cm^3 and 500 cm^3 containers to form composite samples of water. The samples were collected in clean plastic containers, acidified with HCl (conc.) and stored at temperatures less than 4°C to inhibit undesirable reactions that may interfere with the analytical accuracy of results (Ademoroti,1996). The samples for algae count were preserved using Lugol solution prepared by mixing 20 g of potassium iodide with 200 cm^3 distilled water then dissolving 10 g of pure iodine in this solution. 20 g of glacial acetic acid was added few days before usage and the solution was stored in dark glass bottle.

Samples for biological oxygen demand analysis were not acidified to keep the organisms alive for proper analysis. Glass containers were avoided because potassium can be adsorbed unto the surface thereby producing a lower concentration during analysis.

Composite samples were collected in triplicates from five different points (Wadata, Benue State University, Kyabiz hotel, Coca-Cola, and Abbatoir) along River Benue.

2.2 Measurement of physical parameters

2.2.1 Temperature

The temperatures of the samples were measured using electroanalytical instrument Jenway 3510 pH meter.

2.2.2 Measurement of total dissolved solid

A Hach Sension5 instrument was used to measure the total dissolved solid by measuring out 100 cm^3 of the sample into five conical flasks and allowed to attain equilibrium with the electroanalytical probe that was dipped into the solution. The solution/probe system was allowed to equilibrate for some time, after which the data obtained was read in the digital meter and recorded. The electronic probe was rinsed thoroughly with distilled water followed by rinsing with the solution whose parameter was next to be determined (Ademoroti, 1996).

2.2.3 Conductivity measurement

The Hach Sension5 instrument was used in the determination of conductivity of the sample. It is an analytical instrument with many analytical capabilities which includes the determination of conductivity. This was achieved by dipping the analytical probe into 100 cm^3 of the sample and allowed to stabilize after which the value was read and recorded. The probe was rinsed with distilled water after each determination followed by rinsing with the next sample to be determined to prevent the dilution of the measured sample from experimental error.

2.2.4 pH measurement

The pH mode of the instrument was turned on and allowed to equilibrate, and then calibrated before the pH readings of the sample was taken in accordance with instrument specifications.

2.3 Measurement of chemical parameters

2.3.1 Measurement of chemical oxygen demand (Titrimetric method)

Standard potassium heptaoxodichromate (VI) ($K_2Cr_2O_7$) solution (0.125 M) was made by dissolving 12.259 g of analytical grade $K_2Cr_2O_7$ (previously dried at 103°C for 2 hours) in distilled water and made up to the one-litre mark. Ag_2SO_4-H_2SO_4 solution was made by dissolving 11 g $AgSO_4$ crystals in 20 cm^3 concentrated tetraoxosulphate (VI) acid (H_2SO_4) (specific gravity 1.84 g/L and 98 percent purity) and allowed to stay 24 to 48 hours for complete dissolution. Mercury (II) sulphate powder (0.4 g) was used for each determination. 2 g of sulphamic acid was used to counter the effect of NO_2-N which could interfere with the determination. Standard iron (II) ammonium sulphate (0.05M) was prepared which contained 20 cm^3 concentrated H_2SO_4 added during preparation, cooled and diluted to the one-liter mark, shaken very well and standardized daily against standard $K_2Cr_2O_7$ solution. 0.4 g H_2SO_4 was placed in refluxing flask and 20 cm^3 sample was added followed by 2 g sulphamic acid (H_3NSO_3) to remove interference resulting from NO_2-N. 10 cm^3 standard $K_2Cr_2O_7$ was added with the aid of a pipette followed by several glass beads previously oven-dried at 35°C for an hour. Ag_2SO_4-H_2SO_4 solution (30 cm^3) was added slowly with swirling. The flask was then connected to a condenser and refluxed for 2 hours before cooling. A blank mixture was prepared after this reaction. The condenser was washed with distilled water into Erlenmeyer flask and diluted to 150 cm^3, cooled to room temperature and then titrated the excess $K_2Cr_2O_7$ with FAS using 2 drops of ferroin indicator.

The COD was calculated as follows:

$$\text{Mg/L COD} = \frac{(V_b - V_s) \times M \times 16{,}000}{\text{Sample mass}}$$

Where;

V_b = cm^3 of ferrous ammonium sulphate (FAS) used for blank
V_s = cm^3 FAS used for sample
M = Molarity of FAS

2.3.2 Measurement of potassium

Potassium was determined using flame emission spectrophotometric method which is the routine method suitable for alkaline and alkaline earth metals. The instrument was a direct reading digital machine designed for use in clinical, industrial and educational applications. Calibration curve was done by using 1 cm^3, 2 cm^3, 3 cm^3, 4 cm^3 and 5 cm^3 standard potassium chloride solution diluted to 50 cm^3 using distilled water and aspirated into the flame photometer where measurements were made and standard curve prepared. The percentage transmittance of the sample solutions was noted and read against concentrations on the calibration curve and results recorded.

2.3.3 Determination of nitrate (photometer method)

Nitrate was first reduced to nitrite; the resulting nitrite was then determined by a diazonium reaction to form a reddish dye. The reduction stage was carried out using the unique zinc-based Nitratest powder, and Nitratest tablet which aid rapid flocculation after one-minute contact period. The test was conducted in a special Nitratest tube - a graduated sample container with hopper bottom to facilitate settlement and decanting of the sample. After flocculation, the clear solution was carefully decanted into a round test tube, filled to the 10 mL mark in which one nitricol tablet was added, and allowed to stand for ten minutes for full colour development and nitrate was measured using a 7100 Palintest Wagtech photometer.

2.3.4 Determination of phosphate

For spectroscopic analysis of each of the water samples, a 7100 Palintest Photometer was employed. The principle of this technique is based on the adsorption of scattering of a measured intensity of incident light compared to the light intensity reaching the detector array. The light intensity is determined as Transmittance (%T) or Absorbance (A) and compared to calibration tables stored within the Photometer 7100. The stored calibration tables convert the transmittance or absorbance to results in a variety of units, (mg/L, ppm, etc.), (Ademoroti, 1996).

Using the Palintest phosphate LR method, one phosphate No 1 LR tablet and one phosphate No 2 LR tablet were crushed and added and dissolved in 10 mL of the sample. The sample was left to stand for ten minutes for colour development and phosphate was measured using a 7100 Palintest Wagtech photometer.

2.4 Biological parameters

2.4.1 Determination of biological oxygen demand

Ultra-pure quality distilled water obtained from all-glass distiller was used. Phosphate buffer solution was prepared by dissolving 8.5 g KH_2PO_4, 21.75 g K_2HPO_4, 33.4 g $Na_2HPO_4 .7H_2O$ and 1.7 g NH_4Cl in 500 cm^3 distilled water and diluted to one liter and preserved in stock bottles. Magnesium sulphate solution was prepared by dissolving 22.5 g $MgSO_4 .7H_2O$ in one-liter distilled water. Calcium chloride solution was prepared by dissolving 27.5 g anhydrous $CaCl_2$ in one-liter distilled water. Iron (III) chloride solution was prepared by dissolving 0.25 g $FeCl_3 .6H_2O$ in one-liter distilled water. 0.5 M H_2SO_4 and 1M NaOH were prepared to neutralize basic and acidic solutions respectively. Water used for dilution was prepared by storing distilled water in a large aspirator with mouth plugged with clean cotton wool to permit saturation with dissolved oxygen (DO). 1 cm^3 each of the following reagents were added to the distilled water: Phosphate buffer, magnesium sulphate, calcium chloride and iron (II) chloride solution. The phosphate was not added until the dilution water was about to be used. Several dilutions of the prepared samples were made to obtain adequate drop in oxygen content and suitable amounts of sample measured into BOD bottles in duplicates by the aid of large-tip volumetric pipette. Dissolved oxygen was determined immediately and the blank and other sets were left in the dark for 5days at 20 degrees Celsius cooled in an incubator.

The biochemical oxygen demand was determined as follows:

BOD mg/L	=	$(DO_o - DO_d) \div$ Percent dilution
Where :		
DO_o	= Dissolved oxygen found in the sample on the initial day.	
DO_d	= Dissolved oxygen found in the dilutions of the sample after titration on the	
Final day		

2.4.2 Determination of algae concentration

The preserved sample for algal count was later decanted carefully and sub-sample examined under a BDM12 O-TEACHERS (20x) Microscope and systematically algal units were identified and counted.

III. RESULTS AND DISCUSSION

3.1 Results

Table 1 displays the physical and chemical parameters of the surface water from the five strategic points (Coca-cola, Kyabis hotel, Benue State University Wadata and Abattoir) across river Benue and graphically presented in Fig. 1. Table 2 and Fig. 2 show the algae concentration in the five strategic points.

Table 1: Physical and chemical properties of water samples (River Benue) in Makurdi metropolis, Benue State Nigeria

Parameters/	pH	Temp.	TDS	Electrical	COD	BOD	Turbidity	K	Phosphate	$NO3^-$
Sites		(^{0}C)	(mg/L)	Conductivity	(mg/L)	(mg/L)	(NTU)	(mg/L)	(mg/L)	(mg/L)
				(µS/cm)						
A	7.82 ± 0.17^{c}	31.70 ± 0.17^{b}	23.90 ± 0.10^{e}	47.73 ± 0.50^{e}	0.60 ± 0.00^{a}	0.30 ± 0.00^{a}	60.63 ± 0.47^{b}	2.33 ± 0.06^{b}	0.04 ± 0.00^{a}	1.86 ± 0.13^{d}
B	6.83 ± 0.15^{a}	31.20 ± 0.35^{ab}	17.67 ± 0.21^{c}	35.37 ± 0.25^{c}	0.83 ± 0.06^{b}	0.43 ± 0.03^{b}	40.77 ± 0.25^{a}	1.82 ± 0.13^{a}	0.05 ± 0.00^{c}	0.73 ± 0.03^{b}
C	7.31 ± 0.25^{b}	31.53 ± 0.23^{ab}	21.47 ± 0.47^{d}	42.93 ± 1.12^{d}	1.23 ± 0.06^{c}	0.62 ± 0.03^{c}	77.43 ± 0.21^{c}	2.37 ± 0.21^{b}	0.05 ± 0.00^{b}	0.89 ± 0.04
D	7.32 ± 0.19^{b}	31.23 ± 0.15^{ab}	15.83 ± 0.38^{b}	32.20 ± 1.39^{b}	1.77 ± 0.06^{d}	0.88 ± 0.03^{d}	81.60 ± 0.40^{d}	2.97 ± 0.25^{c}	0.05 ± 0.00^{b}	0.68 ± 0.05^{b}
E	7.05 ± 0.04^{ab}	31.10 ± 0.36^{a}	14.47 ± 0.29^{a}	30.03 ± 1.34^{a}	1.87 ± 0.12^{d}	0.90 ± 0.10^{d}	94.13 ± 0.21^{e}	2.30 ± 0.27^{b}	0.08 ± 0.00^{d}	0.40 ± 0.03^{a}

Results are expressed as mean ± standard deviation. Mean values followed by different superscript letter within a column are significantly different (*P*≤0.05).

Temp.: Temperature, TDS: Total dissolved solids, COD: Chemical oxygen demand, BOD: Biological oxygen demand, K: Potassium, $NO3^-$: Nitrate.

A: Coca-cola; B: Kyabis hotel; C: Benue State University; D: Wadata; E: Abattoir.

Table 2: Algae concentration (%) of water samples (River Benue) in Makurdi metropolis, Benue State, Nigeria

Phytoplankton/ Sampling period	Desmid (Closterium sp.)	Diatom (Gyrosigma balticum sp.)	Diatom (Flagilaria crotonensis sp.)	Cyanobacteria (Leptolyngbya sp.)	Green Algae (Volvox sp.)
			SITE 1: COCA COLA		
Week 1	3.50±0.71[ab]	2.50±0.71[a]	ND	1.00±0.00[a]	ND
Week 2	5.50±0.73[b]	1.00±0.00[a]	ND	1.50±0.71[a]	ND
Week 3	2.50±0.71[a]	2.50±0.73[a]	ND	1.50±0.71[a]	ND
			SITE 2: KYABIS HOTEL		
Week 1	4.00±0.28[b]	4.00±0.14[a]	4.00±0.14[b]	3.00±0.14[b]	1.00±0.14[a]
Week 2	3.00±0.14[a]	6.00±0.71[b]	2.00±0.14[a]	1.00±0.14[a]	1.00±0.28[a]
Week 3	5.00±0.14[c]	3.00±0.28[a]	2.00±0.28[a]	4.00±0.14[c]	1.00±0.00[a]
			SITE 3: BENUE STATE	UNIVERSITY	
Week 1	8.50±0.71[b]	2.50±1.72[a]	ND	5.50±1.73[b]	ND
Week 2	5.00±0.00[a]	3.00±0.00[a]	ND	4.50±1.71[ab]	ND
Week 3	5.50±0.73[a]	2.50±1.71[a]	ND	3.00±0.00[a]	ND
			SITE 4: WADATA		
Week 1	6.50±0.71[b]	3.50±0.71[a]	1.00±0.00[a]	ND	ND
Week 2	3.50±0.73[a]	2.0±1.41[a]	3.50±0.71[b]	ND	ND
Week 3	2.50±0.71[a]	2.0±0.00[a]	2.50±0.71[ab]	ND	ND
			SITE 5: ABATTOIR		
Week 1	8.50±0.71[b]	4.50±0.71[ab]	5.00±0.00[ab]	ND	1.00±0.00[a]
Week 2	5.50±0.72[a]	3.00±0.00[a]	5.50±0.71[b]	ND	2.50±0.73[a]
Week 3	7.00±0.00[ab]	5.50±0.71[b]	3.50±0.71[a]	ND	1.50±0.71[a]

Results are expressed as mean ± standard deviation. Mean values followed by different superscript letter within a column are significantly different ($P \leq 0.05$).

ND: Not detected

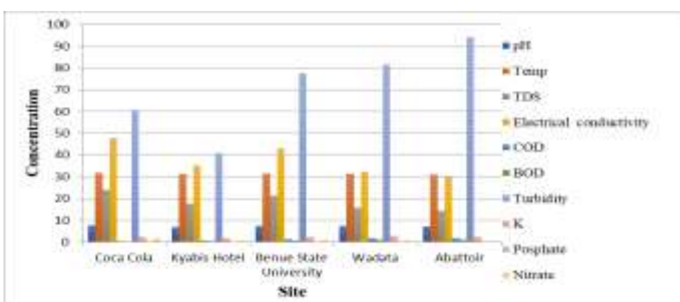
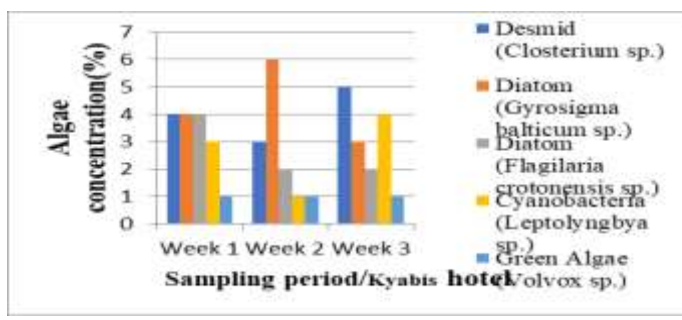
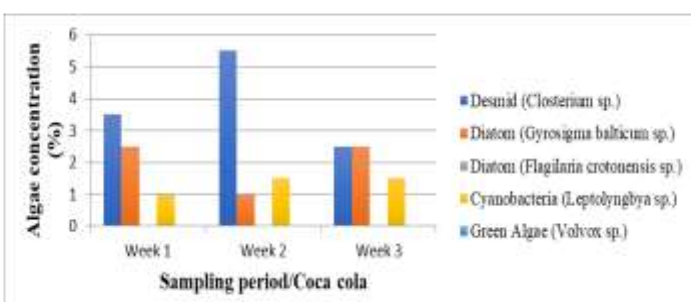
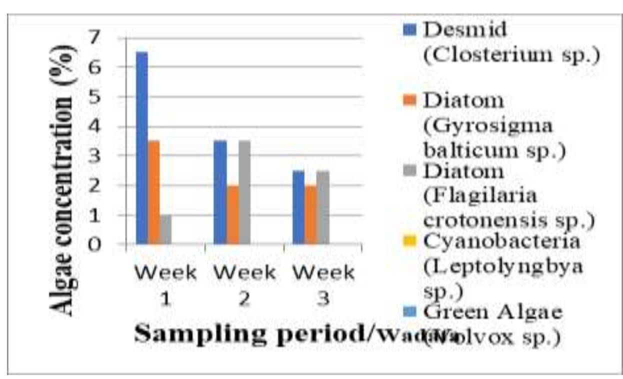


Fig.1: Bar chart showing physical and chemical properties of water samples (River Benue) in Makurdi Metropolis







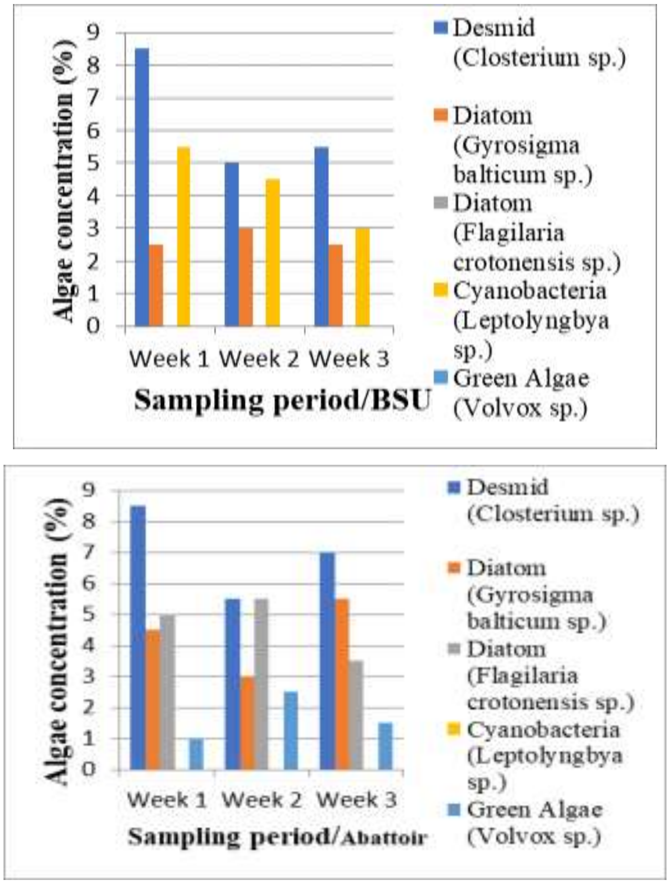


Fig.2: Bar chart showing Algae concentration (%) with sampling period across the stations

IV. DISCUSSION

Table 1 shows that there is no significant difference in temperature across the sites during this research. All the sites showed almost the same temperature, did not exceed the acceptable limits of >40 set by WHO but exceeded the limit of >26 set by FEPA and the little differences could be due to differences in biological activities and instrumental error.

Highest value of chemical oxygen demand (COD) in all the sites was recorded in Abattoir with a value of 1.87±0.12 mg/L and the lowest value of 0.60±0.00 mg/L was recorded in Coca-Cola. Table 1 showed irregular trends in all the sites suggesting that the major sources of waste may be due to anthropogenic activities with irregular discharges of waste with time. Eutrophication is more severe in pools of stagnant water bodies but most of the sites used in this research were flowing at various water volumes throughout the duration of the research. The values of COD recorded in this research were low in comparison with that of Lagos state due to lack of intense industrial activities in Makurdi metropolis (Taiwo *et al., 2012*).

Turbidity in water is due to the presence of suspended particulate matter such as clay, silt, microscopic organisms and colloidal organic particles. High values of turbidity were recorded across the various sites as shown in Table 1 with the highest value of 94.13±0.21 NTU recorded in Abattoir and lowest value of 40.77±0.25 NTU recorded in Kyabis hotel. All the sites exceeded the acceptable limits of 5 NTU,10 NTU and 15 NTU set by WHO, FEPA and SON respectively. Turbidity itself is not a major health concern, but high value of turbidity can provide a medium for microbial growth and increase in these growths could facilitate eutrophication.

The conductivity of an aqueous solution depends on the quantity of the total dissolved salts present and it is approximately proportional to the amount of the total dissolved solids. All the conductivity values recorded in this research, ranging from 30.03±1.34 to 47.73±0.50 µS/cm with the highest value recorded at Coca-Cola are within the acceptable limit of 1,000 µS/cm set by SON. Conductivity is often used as a surrogate for TDS and a conductivity of 1,400 µs/cm is equivalent to 1,000 µg/L of dissolved solid (Anake *et al., 2013*). Higher conductivity records ranging from 80.40 µs/cm-178.80 µs/cm were observed during rainy season in Kwara State of Nigeria and was attributed to increase in the concentration of cations such as magnesium and sulphate while utilization of these salts by planktons and macrophytes produce reduction in conductivity (Moshood, 2008). TDS in Kwara State showed a positive correlation with conductivity and a similar trend was observed in this research.

The highest value of total dissolved solids (TDS) was recorded at Coca- Cola with a value of 23.90±0.10 mg/L and the lowest value was recorded at Abattoir with a value of 14.47±0.29 mg/L and hence its low conductivity value. All the values of TDS observed in this research were within the acceptable limits of 500 mg/L set by WHO and SON.

Almost all the sites showed pH values within the neutral range with Coca-Cola having a value of 7.82±0.17, Wadata 7.32±0.19, Abattoir 7.05±0.04, BSU 7.31±0.25 and Kyabis hotel showed a value of 6.83±0.15 which is slightly acidic. Most synthetic fertilizers used in irrigation have pH in the acid range and sometimes are neutralized by farmers using slaked lime for optimum crop yield. Low levels of pH could be attributed to presence of excess CO_2 and SO_2 caused by microbial activities (Anake *et al., 2013*) which could be the reason for the acidic pH recorded at Kyabis hotel. The pH value of all the sites were within the permissible limit of 6.5-8.5 set by WHO and SON.

Biological oxygen demand is the amount of oxygen required by microorganisms to break down organic matter present in a water sample, waste water or treated effluent under aerobic conditions within a specific time at certain temperature. High BOD value is proportional to high eutrophication (Taiwo *et al.*,2012). All the sites recorded very low values of BOD ranging from 0.30±0.00 to 0.90±0.10 mg/L as shown in table 1 with Abattoir recording the highest value. These low values recorded could be attributed to minimal discharge of organic and synthetic waste, reduced farming activities around these sites, reduced human activities and fast transportation of biodegradable waste from the immediate vicinity when water volumes are high. Samples of water with BOD values greater or equal to 10 mg/L are said to be very bad with heavy biodegradable waste deposits (Taiwo *et al.*,2012). Eutrophication research should not be limited to water assessment for consumption but also in relation to its agricultural, industrial, recreational, commercial uses and its ability to sustain aquatic life (Taiwo *et al.*,2012). High BOD values were recorded as high as 534 mg/L and 1352.3 mg/L in two different sites in Lagos, 4,374 mg/L in Port Harcourt and 300 mg/L in Kaduna (Taiwo *et al.*,2012). This is an indication that eutrophication tends to be higher in densely populated areas with concentration of industry. The values of BOD in this research were very low which may be deduced to the absence of concentration of chemical industries and relatively low population density compared to Lagos and Port Harcourt.

The highest level of nitrate was recorded at Coca-Cola with a value of 1.86±0.13 mg/L which is attributed to industrial activities from the brewery and lots of irrigation farming around the area. The lowest value was recorded in Abattoir with a value of 0.40±0.03 mg/L. All the sites showed nitrate values ranging from 0.40±0.03 to 1.86±0.13 mg/L and did not exceed the acceptable limits set by WHO. All the sites showed low levels of nitrate in respect to eutrophication indices which could be due to lack of industrial activities and low population density in Makurdi, Benue State. Eutrophication profile in Makurdi metropolis with respect to nitrate concentration, is therefore similar to that of Ibadan in the Western part of Nigeria.

Phosphorus is an essential nutrient for living organisms and exist in water bodies as dissolved and particulate species. Phosphorus is rarely found in high concentrations in surface waters as it is actively taken up by plants. It is generally the limiting nutrient for algae growth and controls the primary productivity of water bodies. All the sites showed relative low levels of phosphate ranging from 0.04±0.00 to 0.08±0.00 mg/L, some of which exceeded the limits of 0.05 mg/L set by US EPA. This may be due to irregular release of phosphate from sediments or bacteria oxidation of phosphorous compounds and perturbation from human activities through waste disposal.

The highest value of potassium was recorded at Wadata with a value of 2.97±0.25 mg/L and the lowest recorded at Kyabis hotel with a value of 1.82±0.13. all the sites showed low levels of potassium which did not exceed the WHO permissible limit of potassium which is 12 mg/L. These low levels of potassium could be possibly due to reduction in the use of NPK fertilizers and reduced farming and cultivation activities from October to January when cultivation activities are almost brought to a standstill which was the sampling period of this research and possible depletion in effluent flow and plant metabolism.

All the sites in this research had phytoplankton composition less than 100 count. Certain groups of algae such as the desmids, chrysophytes and diatoms are referred to as oligotrophic species while cyanobacteria and euglenoids are classified as eutrophic species (Voinov and Svirezhew *et al.*,2016). Most of the species identified in this study belongs to the classes diatom and desmid indicating that eutrophication was still at its rudimentary stage. Desmids and diatoms are small algae which usually predominate in oligotrophic waters due to their higher surface area to volume ratio and hence benefit from more efficient nutrient uptake rates per unit biovolume but larger species become more abundant in eutrophic conditions (Neustupa, 2013).

In site 1, *Closterium sp.* in the class desmid had the highest count of algae in week 2 with a total count of 5.50±0.73 as shown in table 2. 2.50±0.73 count of the class diatom (*Gyrosigma balticum sp.)* and 1.50±0.71 count of cyanobacteria was also recorded at site 1. Thus, giving an oligotrophic water with eutrophication at its rudimentary stage due to the presence of cyanobacteria. The distribution of algae at site 2 is such that Diatom had two species (*Gyrosigma balticum* and *Flagilaria crotonensis sp.)* which showed the highest count of algae of 6.00±0.71 and 4.00±0.14 respectively and desmid had a total count of 4.00±0.28 which are oligotrophic species. Two classes of eutrophic species cyanobacteria and green algae (*Volvox sp.)* were also recorded at site 2 with 4.00±0.14 and 1.00±0.00 counts respectively.

The presence of these eutrophic species could be attributed to the presence of offensive odour associated with the dumping wastes in site 2 giving a eutrophication water at its early stage. Oligotrophic species had higher counts of 8.50±0.71 of the class desmid and higher counts of eutrophic species ranging from 3.00±0.00 to 5.50±1.73 which was a class of cyanobacteria in site 3. In site 4, there was no record of eutrophic species giving an oligotrophic water with two classes of diatom as shown in Table 2 and desmid which had the highest count of algae (6.50±0.71). Site 5 had higher counts of algae compared to the others sites which is attributed to high value of phosphate that was recorded in this site as shown in Table 1. In site 5 desmid had the highest count of algae ranging from 5.50±0.72 to 8.50±0.71 and the two classes of diatom was also observed in this site. Eutrophic species (green algae) was also observed in this site with 2.50±0.73 count which is higher than counts in site 1. This could be attributed to the fact that the surface water in site 5 was aesthetically offensive with organic waste from decomposing refuse dump and animal dungs. A study on eutrophication showed that heterotrophic zooplanktons and metazoans in addition to phytoplankton showed positive correlation between total phosphorous and microscopic animals (Pinto-Coelho,1998).

The dominant presence of desmids and diatoms is an indication that the surface water of river Benue in Makurdi metropolis is an oligotrophic water due to low population and lack of intense industrialization in the state and the presence of few eutrophic species like cyanobacteria and green algae is an indication that the state is at the early stage of eutrophication. However, this alga is likely to be succeeded by eutrophic species if measures are not taken.

V. CONCLUSION

Physical, chemical and biochemical parameters were measured in five strategic points of river Benue in Makurdi to evaluate the indices of eutrophication in the water body. After comparison of analytical results obtained from the five strategic points with standards, most of the parameters measured and observed were within the acceptable limits set by WHO, NAFDAC, FEPA and SON except for turbidity and phosphate which could be attributed to the human activities around these areas.

Although BOD and COD were low indicating low eutrophication potential, the tendency of eutrophication being blown into frightening proportion by human activities, if no appropriate measures are undertaken to curtail these human activities should not be overlooked. Phosphate levels exceeded the acceptable limits set by US EPA which also indicates onset of eutrophication. The algae counts were also low in comparison with other studies and this could be attributed to low population density and industrialization in the state. The major pollution of the river Benue is from dumping of refuse and animal dungs as well as run offs from gutters and farming activities, all these could lead to high levels of eutrophication in the water in the nearest future if proper measures are not undertaken.

Conflict of interest

The authors declare that there is no conflict of interest of any sort with regards to this research and its subsequent article for publication.

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