ASSESSMENT OF THE QUALITY OF SELECTED BOREHOLE WATER IN THE FEDERAL POLYTECHNIC, BIDA, NIGER STATE, NIGERIA

N. Keke Unique[1,2], M. Aliyu Babadoko[2], O. Arimoro Francis[1], Elizabeth Awe[2]

[1] Applied Hydrobiology Unit, Dept of Biological Sciences, Federal University of Technology, P.M.B. 65, Minna, Niger State.
[2]Science Laboratory Technology Department, The Federal Polytechnic, Bida, Niger State.

ABSTRACT

The concern over exposure to drinking water contaminants and the resultant adverse effects on human health has prompted several studies evaluating the quality of drinking water sources. This work, was, therefore, aimed at generating baseline data on the water quality status of borehole waters in the Federal Polytechnic, Bida, Northern Nigeria. The water samples were collected and analyzed for physicochemical and bacteriological parameters using standard methods by APHA. World Health Organization (WHO) and Federal Environmental Protection Agency (FEPA) acceptable limits for drinking water were used in their comparisons and evaluation. All physicochemical parameters in the borehole water samples were within WHO and FEPA recommended standards, except for the slightly elevated levels of nitrate. The concentration of total coliform and faecal coliform obtained from the water samples exceeds WHO standard of 10MPN/100ml and 0MPN/100ml respectively for drinking water. *Eschericha coli, Enterobacter, Klebsiella, Baccillus,* and *Klebsiella* were found in Small gate borehole, Sheraton hostel borehole, Hostel G borehole, Nicon hostel borehole, and Administrative block boreholes, respectively. However, the bacteriological characteristics of all these boreholes did not conform to WHO standards for drinking water, thereby making all the boreholes sampled unfit for drinking. Adequate treatment method is recommended before these water sources are consumed in order to avoid epidemic of water related diseases. Other implications of findings for theory development, practice, and further empirical studies are discussed.

KEYWORDS:
Physiochemical parameters, bacteriological parameters, water quality, water standard, coliform, borehole.

INTRODUCTION

Water is an essential element in the maintenance of all forms of life, and most living organisms can survive only for short periods without it. A significant proportion of the world's population use water for drinking, cooking, personal, and home hygiene [1]. Water can be obtained from a number of sources, among which are streams, lakes, rivers, ponds, rains, springs, and wells [2]. Water is the most known and most abundant of all known chemical substances, which occur naturally on the surface of the earth. It is fundamentally important to all plants, animals and man [3]. It is a prime solvent and its properties determine many natural phenomena. Water could be found in three states; solid as ice, liquid as water and gas as water vapour. It covers about three quarter of the total earth crust [4, 5]. Water can be obtained from a number of sources, among which are streams, lakes, rivers, ponds, rain, springs, ocean and wells [6,7].

Traditionally, the most important of the quality characteristics has been the concentration of dissolved salts because of the relationship between salt and land productivity. Later, health related characteristics such as presence of disease-causing microorganisms became important. More, recently, the introduction of anthropogenic chemicals, that have impact on health when present in trace amounts, has become a problem [4]. Of all the water sources on earth, only 3% are good (in terms of quality or freshness). These include: surface water (rivers, lakes, streams and reservoirs) and groundwater [4]. With the decline in the use of surface water for drinking water supply due to contamination, there is an increase in the reliance on ground water as drinking water source. Unfortunately, little attention is being paid to drinking water quality issues and quantity remains the priority focus during water supply projects. The need to define the quality of water has developed with the increasing demand for water which is suitable for specific uses and conforms to desired quality [8]. Although water quality and water quantity are inextricably linked, water quality deserves special attention because of its implications on public health and quality of life [9]. However, the increasing demand on water resources coupled with the deterioration of water quality has resulted in an increase of environmental pollution control studies [10].

Water quality may be defined as microbiological, physical and chemical properties of water that determine its fitness for different and specific use(s). If one of these properties is out of balance, the water quality is affected. ''Water Quality'' is a technical term that is based upon the characteristics of water in relation to guideline values of what is suitable for consumption and for all usual domestic purposes, including personal hygiene. These properties are determined by substances which are either dissolved in water or suspended in the water.

The quality of groundwater is a function of natural processes as well as anthropogenic activities. Nitrate compounds, heavy metals, pesticides, etc that are contained in our drinking water can also constitute undesirable pollutants when they are not within World Health Organization (WHO) guidelines for drinking water [11]. Regular control of water intakes by distribution network operators guarantees the desired effectiveness of the water treatment process [12]. This work was, therefore, aimed at generating baseline data on the water quality status of borehole waters in the Polytechnic.

MATERIALS AND METHODS

The study sites. The study was carried out in Federal Polytechnic Campus Bida local government area of Niger State, Nigeria. Bida is the second largest in Niger State with the population of 178,840 (2007). It is located southwest of Minna, capital of Niger State, and is a dry arid town. The vegetation is basically savanna rain and grass lands. The main occupation of the people of Bida is predominantly farming that is crop production and animal husbandry. A good number of occupants are also in the civil service and private organization.The climate for Bida is characterized by rainfall during raining seasons and comparatively hot during dry seasons. The temperature of Bida is between 23℃ to31℃. The indigenous language spoken by inhabitants of Bida local government is Nupe. (The world gazetter, 2007).

Sample collection. Borehole water from five (5) different locations (Small gate borehole, Sheraton hostel borehole, Hostel G borehole, Nicon hostel borehole, and Admin block borehole) within the Federal Polytechnic, Bida, Northern Nigeria, was collected. All plastic and glass wares utilized were pre-treated by washing with dilute HCl (0.05M) and later rinsed with distilled water. They were then air-dried in a dust-free environment. At the collection points, containers were rinsed with relevant samples twice and filled with samples and then corked tightly. A total of fifteen (15) samples were collected aseptically and the samples were collected three (3) times each from the boreholes.

Physiochemical parameters determination. Odour, taste, and color were determined by the use of the sensory evaluation panel as described by the method of APHA [13]. pH, temperature, and conductivity were determined *in situ* using Jenway (model type HANNAH 1910) multi-purpose tester. Total Alkalinity and Total Hardness were determined using the titrimetric methods as clearly described by APHA [14]. Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) were done using the titrimetric method (Wrinkler) as clearly described by [15]. Turbidity, Total dissolved solids, Nitrate, and Phosphates were determined as described by FAO [16].

Determination of bacteriological quality. The determination of the bacteriological quality of the water samples was carried out using Membrane Filtration and Most Probable Number (MPN) methods as described by [5, 17]

Membrane filtration techniques. The membrane filtration unit was set up and a sterile disk (membrane filter) was placed in filtration unit, 100ml of the water sample to be tested was poured into the funnel, and passed through the Millipore filter by the aid of the vacuum pump, the funnel was removed and the filter disk, handle with sterile forceps, was placed on the pad previously impregnated with medium (Mac Conkey Agar). The plates were incubated inverted at 37℃ for 24hours, at which the number of coliform can be determined. The experiment was carried out on the remaining water samples; the experiment was repeated after 48hours for accuracy.

Most probable number/Examination of total and feacal coliform. Presumptive test: Total coliform and faecal coliform were enumerated by multiple tube fermentation tests as described by APHA (2005). Coliform count was obtained using the three tube assay of the Most Probable Number (MPN) technique. Presumptive coliform test was carried out using MacConkey broth (Oxoid). The first set of the five tubes had sterile 10ml double strength broth and the second and third sets had 10ml single strength broth. All the tubes contained Durham tube before sterilization. The three sets of the tubes received 10ml, 1ml and 0.1ml of water samples using sterile pipettes. They were carefully labeled and incubated at 37ºC for 24-48 hours for estimation of total coliforms and at 44.5ºC for faecal coliforms for 24-48 hours and examined for acid and gas production. Acid production was determined by colour change in the broth from reddish purple to yellow and gas production was checked for by entrapment of gas in the Durham tube. The MPN was then determined from the MPN table for the three set of tube.

Confirmed test: Confirmed test was carried out by transferring a loopful of culture from a positive tube from presumptive test into a tube of Brilliant Green Lactose Bile (BGLB) broth (oxoid) with Durham tubes. The tubes were incubated at 37ºC for 24-48 hours for total coliform and 44.5ºC for faecal coliforms and observed for gas production.

Completed test: Completed test was carried out by streaking a loopful of broth from a positive tube onto Eosine Methylene Blue (EMB) agar plate for pure colonies. The plates were incubated at 37ºC for 24-48 hours. Colonies developing on EMB agar were further identified as faecal coliforms (*Escherichia coli*). Colonies with green metallic sheen were confirmed to be faecal coliform bacteria with rods shape.

Data Analysis and Presentation. The range, mean and standard deviation for each parameter and station were calculated. Community attributes (metrics), physical and chemical features of stations were compared using one way ANOVA on log (x + 1) transformed data. Significant ANOVAs (P < 0.05) were followed by post hoc {Tukey Honest (HSD)} tests to identify differences between station means.

RESULTS AND DISCUSSION

Physicochemical Characteristics of Borehole Water. A summary of the results of physico-chemical analyses is presented in Tables 1. These values were placed alongside Federal Environmental Protection Agency (FEPA) limits and World Health Organization (WHO) guideline values [18,19]. ANOVA indicated significantly calculated F values in all the Physicochemical parameters sampled for the five boreholes, except the minerals. However, significant differences (P< 0.05) among the five boreholes were indicated by Turkey's HSD significant difference tests.

The colour, odour, and taste of these water samples are unobjectionable. These fall within the standard that is acceptable to international bodies like W.H.O, FEPA, and EPA. Odour in water is usually caused by volatile substances associated with organic and inorganic chemical materials such as algae and hydrogen, respectively [20]

The pH values in the study areas (5.11-7.21) indicated slightly acidic and to slightly alkaline (near neutral) nature of the ground waters and are well within the limits prescribed by [19] for various uses, including drinking, and that of pH of most natural waters [21]. It is, therefore, desirable since low pH corrodes the pipe and causes acidosis (which results in peptic ulcer) while high pH may cause incrustation and also affects the mucous membrane.

Dissolved Oxygen (DO) is the amount of oxygen dissolved in water. It takes the advantage of the fact that the heavier the organic matter content of the water, the greater the expected growth of aerobic organisms in it and the less the oxygen content of it after growth. The DO in this study ranges from 5.22 to 6.77 mg/L. This range did not show any organic pollution or thermal pollution as the values were within the permissible limit of WHO and FEPA standards. A higher DO indicates better water quality. This showed that the boreholes were not densely organic matter packed; otherwise, it would have been consumed to an extent during microbial decomposition. Adequate dissolved oxygen is necessary for good water quality as oxygen is a necessary element to all forms of life; the lower the concentration, the greater the stress. Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills.

Biological oxygen demand (BOD) fell within the recommended guideline of [1]. According to [8] BOD classification of 1-2mg/l as very good, with less organic matter present; 3-5mg/l as moderately clean; 6-9mg/l as poor, somewhat Polluted (indicates organic matter is present and bacteria are decomposing this waste); etc, the water samples were moderately clean and safe for drinking. When organic matter such as dead plants, leaves, grass clippings, manure, sewage, or even food waste is present in a water supply, the bacteria will begin the process of breaking down this waste. When this happens, much of the available dissolved oxygen is consumed by aerobic bacteria. BOD is a measure of the oxygen used by microorganisms to decompose this waste. If there is a large quantity of organic waste in the water supply, there will also be a lot of bacteria present working to decompose this waste.

Electrical conductivity is the normalized measure of the water's ability to conduct electric current. This is mostly influenced by dissolved salts such as sodium chloride and potassium chloride. The sources of conductivity may be an abundance of dissolved salts due to poor irrigation, minerals from rain water run-offs, or other discharges. Electrical conductivity is a measure of the Total dissolved solids (TDS) of a water body. TDS and conductivity are closely related in the sense that the more salts are dissolved in the water, the higher the value of the conductivity. In this study, the highest mean TDS value of 36.43 mg/l had the corresponding highest mean conductivity of 54.67μs/cm. The low conductivity values of the samples implied that the dissolved salts were minimal. Total dissolved solids affect the taste of our water. The low level of conductivity could be attributed to the low level of total dissolved solids. The two parameters (TDS and conductivity) fell within the limits of [11, 18] recommendations.

Turbidity is the material in water that affects the transparency or light-scattering capacity of the water. It is the reflection of the total suspended solids or particles contained in water. The low level of turbidity could account for the reason why the entire appearance of the water samples were very clear and having no odour.

No amount of phosphate in water is believed to have effects on human health [22]. However, too much amounts of phosphate in water could cause eutrophication. The level of phosphate in all the water samples is low. Therefore, they are good both for drinking and other purposes. Nitrate can reach both surface water and groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), from wastewater disposal and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks (Where latrines and septic tanks are poorly sited, these can lead to contamination of drinking-water sources with nitrate). The guideline value (50 mg/litre) for nitrate is based on the occurrence of methaemoglobinaemia, or blue-baby syndrome, in bottle-fed infants caused by excess nitrate/nitrite exposure of infants up to approximately 3–6 months of age [23]. All the boreholes sampled recorded values higher than the recommended values of both WHO and FEPA. The high level of Nitrate gave an indication that the groundwater must have been contaminated with nitrate, either by agricultural run-offs, dumping of refuse or from waste water.

TABLE 1
Physicochemical parameters of selected Borehole water in the Federal Polytechnic, Bida.

	Sampled Stations[1,2]				
Parameters[3]	SGB	SHB	HGB	NHB	ABB
Odour	UO	UO	UO	UO	UO
Taste	TL	TL	TL	TL	TL
Colour	UO	UO	UO	UO	UO
Temp (°C)	28.67±0.333a	26.33±0.333b	26.67±0.333b	25.33±0.333b	25.67±0.333b
	(28.00-29.00)	(26.00-27.00)	(26.00-27.00)	(25.00-26.00)	(25 - 26.00)
pH	5.11± 0.003a	6.41±0.006d	7.21±0.003e	6.29± 0.003c	6.21± 0.006b
	(5.11-5.12)	(6.40-6.42)	(7.20-7.21)	(6.29-6.30)	(6.20-6.22)
DO (mg/L)	5.22 ±0.04a	4.94±0.086a	6.10±0.058b	6.33±0.285b	6.70±0.055b
	(5.16-5.30)	(4.81-5.10)	(6.00-6.20)	(6.00-6.90)	(6.61-6.80)
BOD (mg/L)	1.95±0.029a	1.61±0.018c	1.72±0.012b	1.67±0.012bc	1.30±0.015d
	(1.90-2.00)	(1.58-1.64)	(1.70-1.74)	(1.65-1.69)	(1.28-1.33)
Turbidity (NTU)	1.49±0.00a	0.003±0.003d	0.003±0.003d	0.29±0.007b	0.18±0.010c
	(1.48-1.50)	(0.00-0.01)	(0.00-0.01)	(0.28-0.30)	(0.17-0.20)
TA (mg/L)	4.77±0.037a	5.21±0.010c	4.77±0.033a	5.23±0.033c	5.03±0.0333b
	(4.70-4.82)	(5.20-5.23)	(4.70-4.80)	(5.20-5.30)	(5.00-5.10)
TH (mg/L)	5.03±0.033a	9.57±0.033b	15.27±0.007d	10.33±0.033c	5.07±0.067a
	(5.00-5.10)	(9.50-9.60)	(15.20-15.40)	(10.30-10.40)	(5.00-5.20)
Phosphate(mg/L)	8.60±0.012a	9.21±0.00b	10.27±0.001c	8.39±0.003d	7.14±0.030e
	(8.58-8.62)	(9.21-9.21)	(10.26-10.28)	(8.39-8.40)	(7.10-7.20)
Nitrate (mg/L)	58.98±0.012a	63.20±0.009c	72.28±0.009e	70.00-0.003d	60.49±0.007b
	(58.96-59.00)	(63.18-63.21)	(72.27-72.30)	(70.00-70.01)	(60.48-60.50)
Cond (µs/cm)	21.33±0.333a	28.67±0.333c	54.67±0.667d	24.67±0.333b	21.00±0.577a
	(21.00-22.00)	(28.00-29.00)	(54.00-56.00)	(24.00-25.00)	(20.00-22.00)
TDS (mg/L)	14.23±0.233a	19.07±0.233c	36.43±0.433d	16.47±0.233b	14.01±0.398a
	(4.00-14.70)	(18.60-19.30)	(36.00-37.30)	(16.00-16.70)	(13.32-14.70)
Copper (mg/L)	0.007±0.003a	0.010±0.000a	0.01±0.006a	0.00±0.00a	0.00±0.00a
	(0.00-0.01)	(0.01-0.01)	(0.00-0.002)	(0.00-0.00)	(0.00-0.00)
Iron (mg/L)	0.007±0.003a	0.00±0.00a	0.007±0.003a	0.007±0.003a	0.007±0.003a
	(0.00-0.01)	(0.00-0.00)	(0.00-0.01)	(0.00-0.01)	(0.00-0.01)
Mang (mg/L)	0.01±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	(0.01-0.01)	(0.00-0.00)	(0.00-0.00)	(0.00-0.00)	(0.00-0.00)
Lead (mg/L)	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
	(0.00-0.00)	(0.00-0.00)	(0.00-0.00)	(0.00-0.00)	(0.00-0.00)

Table 1 Continued

Parameters[3]	F ANOVA	P value	FEPA	WHO
Odour			UO	UO
Taste			UO	UO
Colour			UO	UO
Temp (°C)	15.3[a]	2.59E-17	30	27
pH	2.786E04[a]	3.49E-20	6-9	6.5-9
DO (mg/L)	29.2[a]	1.71E-05	4-6	14
BOD (mg/L)	166.40[a]	4.21E-09	30	<4
Turbidity (NTU)	9294.29[a]	8.435E- 18	-	5
TA (mg/L)	53.372[a]	1.036E- 06	100	500
TH (mg/L)	7421.05 [a]	2.598E-17	100	500
Phosphate(mg/L)	5541.56[a]	1.175E-06	NL	NL
Nitrate (mg/L)	5.006E05[a]	1.864E-26	20	50
Cond (µs/cm)	894.100[a]	1.009E-12		100
TDS (mg/L)	864.46[a]	1.193E-12	2000	1000
Copper (mg/L)	2.875	0.080		1.5
Iron (mg/L)	1.000	0.452		0.30
Mang (mg/L)	-	-		0.05
Lead (mg/L)	-	-		0.05

[1]SGB = Small gate borehole; SHB=Sheraton hostel borehole; HGB=Hostel G borehole; NHB=Nicon hostel borehole; ABB= Admin block borehole

[2]Data are the means ± SE of triplicate determinations with minimum and maximum values in parenthesis. Different lowercase letters in a row show significant differences (P< 0.05) indicated by Turkey's HSD significant difference tests. [a] indicates significantly calculated F value detected by ANOVA

[3]Temp = Temperature; Mang = Manganese; DO = Dissolved Oxygen; BOD =Biological Oxygen Demand; TA = Total Alkalinity; TH = Total Hardness; Cond = Conductivity; TDS = Total dissolved solids; UO = Unobjectionable; NTU = Nephelometric turbidity units; NL= No limits

Total alkalinity (mg/l) for all the borehole sources sampled in this study was very low and acidic according to the tabulation of total alkalinity and its cultural significance [21], where- 0-9 is strongly acidic; 10-50 is very low alkalinity; 50-200 is high alkalinity; 211-500 is optimum. The total alkalinity values which conferred acidity status on the boreholes is also in conformity with the pH values which also indicated that the boreholes are acidic, though slightly. This low values agree with Holden and Green's [24] view that alkaline waters are not typical of Africa. Large amount of alkalinity imparts bitter taste to water. Hardness of water is due to the presence of dissolved salts of metals (except the salts of alkali earth metals, such as sodium and potassium), notably those of calcium, magnesium and iron, in water. The low level of hardness corresponded with the low level of total dissolved solids, indicating little or no dissolved metals. Hard water requires more soap and synthetic detergents for home laundry and washing, and contributes to incrustation and scaling in boilers and industrial equipment. [25] suggested that 0-60mg/l is soft; 61-120mg/l as moderately hard; 121-180mg/l as hard; and 180mg/l as very hard ($CaCO_3$). The Total alkalinity and Total hardness of the water samples agreed with the standards of [18, 19] for drinking water.

The concentrations of heavy metals and minerals (iron, lead, manganese and copper) in the water samples were generally low compared with the WHO and FEPA standards. This result did not show any evidence of the heavy metal pollution as their concentrations were very low.

Bacteriological Characteristics of Borehole Water. The summary of the results of the bacteriological analyses of the selected boreholes in the Federal Polytechnic, Bida is shown in Table 2. The concentration of total coliform and faecal coliform obtained from the water samples exceeds WHO standard of 10MPN/100ml and 0MPN/100ml respectively for drinking water. [1] specified that potable drinking water should be devoid of total coliform in any given sample. This indicates that none of the boreholes is safe for drinking. This result corroborates the finding of [26] that the MPN coliform index per 100ml of water samples collected from selected boreholes in Ilorin metropolis ranged from 0 to 16MPN/100ml. [27] in a related study isolated some members of coliform in some sources of water for domestic uses in Calabar metropolis. [28] also obtained high faecal coliform from wells and boreholes water in some peri-urban communities in Kumasi, Ghana.

The high plate counts observed in borehole water indicated the presence of organic matters and related nutrient sources. The primary sources of bacterial contamination might include the surface run-off, sewage treatment facilities, natural soil/plants bacteria, the use of fertilizer on farm lands and improper management activities of the inhabitation like washing, refuse dump, feacal droppings, dipping of different materials inside the water sources [22]. These sources are also responsible for high values of nitrates and therefore, suggested direct correlation between the high values of nitrates and high bacterial/coliform values obtained in this study. The sample collected from Nicon Hostel had the highest number of coliform.

Various groups of bacteria were isolated and identified during the study. They include *Escherichia coli*, *Enterobacter sp.*, *klebsiella sp.* and *Baccillus sp.* Small gate borehole, Sheraton hostel borehole, Hostel G borehole, Nicon hostel borehole, and Administrative block boreholes had *Eschericha coli, Enterobacter, Klebsiella, Baccillus,* and *Klebsiella* found in them, respectively. These organisms are important human pathogens associated with a variety of infectious diseases such as gastroenteritis, typhoid fever, dysentery, cholera, urinary tract infections etc [29, 30]. Their presence raises serious public health concern because they are known causative agents of many water borne diseases and indicates that these water sources are not potable. Their entry into water sources could be attributed to seepages from nearby septic tanks, as opined by [27] or through deliberate and indiscriminate deposition of animal waste and human faeces into streams as commonly observed in some riverine areas.

TABLE 2
Bacterial Count Through Membrane Filtration (MF) and Most Probable Number (MPN) Methods.

Sample Locations	MF (Cfu/ml)	MPN (Cfu/ml)
Small Gate Borehole	18	28
Sheraton Hostel Borehole	7	9
Hostel G Borehole	6	15
Nicon Hostel Borehole	Numerous	93
Administration Block Borehole	7	20

CONCLUSION AND RECOMMENDATIONS

Underground water is believed to be the purest form of water because of the purification properties of the soil. However, source of contamination could be due to improper design and construction of boreholes, shallowness, and proximity to toilet, refuse dump sites, and various human activities which can serve as source of contamination.

Concerns by student and non-student members of Federal Polytechnic, Bida community over the quality of their drinking water sources necessitated this study. This quest was factored by the observed proximity of these boreholes to potential sources of water pollution along with the activities that take place around these water sources.

The physicochemical parameters of all the sampled boreholes conformed to WHO and FEPA standards for drinking water. However, the bacteriological characteristics of all these boreholes did not conform to WHO and FEPA standards for drinking water, thereby making all the boreholes sampled unfit for drinking. Adequate treatment method is recommended before these water sources are consumed in order to avoid epidemic of water related diseases. This will involve adequate treatment through chlorination or ozonization before the water is made available to students and other consumers.

The geologist drilling boreholes have to be educated on the importance of ensuring that dump sites are not used for drilling of boreholes. Moreover, the populace needs to be educated on the importance of maintaining clean and hygienic environment around the borehole to ensure the safety of water from such boreholes.

In addition, there should be consistent surveillance and monitoring of the borehole water supplies within the university campus for a possible detection of any adverse changes in quality.

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CORRESPONDING AUTHOR

Keke, Ndubuisi Unique
Applied Hydrobiology Unit, Department of Biological Sciences, Federal University of Technology, P.M.B. 65, Minna, Niger State, Nigeria.

e-mail: uniquekkn@gmail.com