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Physicochemical and Bacteriological Assessment of Ground Water in Selected Areas of Makurdi, Benue State, Nigeria

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ABSTRACT

Ground waters fill wells and urban water supplies as well as irrigating crops which are essential for man's survival. This research assessed groundwater quality in three selected locations in Makurdi, Benue State. Water samples were collected from three locations in replicates and analyzed for physicochemical and biological parameters using Atomic Absorption Spectroscopy (AAS), Iron Chromatographic, membrane filtration and Titrimetric methods. The result showed that almost all the physicochemical parameters for the water samples obtained from the three locations, such as pH, electrical conductivity, iron, chloride, Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD), and sulphate falls within the limits as recommended by World Health Organisation (WHO) and Nigeria Standard for Drinking Water Quality (NSDWQ); Total Hardness (TH) and temperature for the water samples from the three locations are not within the permissive level as recommended by WHO and NSDWQ. In Wurukum, Dissolved Oxygen (5.6), Chemical Oxygen Demand [COD (4.8)], turbidity (19.25), and coliform (194) do not fall within the permissible level of WHO and NSDWQ. Wadata water samples contain nitrate, which is within the permissive levels, while nitrate levels for High Levels and Wurukum water samples are not within the permissive level of WHO and NSDWQ as well as the turbidity of High Level and Wadata water samples are within the permissive level. Therefore, it is essential that residents within the studied locations be enlightened on the negative effect of drinking polluted water and the need for water treatment before consumption in order to avoid the adverse effects of drinking contaminated water.

KEYWORDS: Groundwater, physicochemical, pollution, coliform, drinking.

INTRODUCTION

Water is one of the most important and precious natural resources which is utilized by humanity. It is essential for the lives of human beings and lower animals, plants and microbes. Water is the most abundant compound on earth and occupies 70 % of the earth's surface. Good quality water is assessed to the reduction of bad health and poverty. So, water is a crucial factor for development and quality of life in many countries. People can survive for days, weeks, or even longer without food, but humans cannot survive even for four days without water (Akinbile and Yusoff, 2011).

Nigeria has suffered from lack of access to safe drinking water from improved sources and adequate sanitation services. World Health Organization (WHO) reported that 75 % of all diseases in the developing countries arise from polluted drinking water. Acceptable quality safe drinking water suggests that its physical, chemical, and biological parameters are acceptable. The international and local agencies have established parameters to determine the physicochemical qualities of drinking water (WHO, 2011). The problems associated with chemical constituents of drinking water arise primarily from their ability to cause adverse health effects after a prolonged period of exposure to contaminants with cumulative toxic properties such as heavy metals and carcinogenic substances (WHO, 2011).

It is stated that the most common household water may be unsafe due to hardness, iron, sulfides, sodium, chloride, alkalinity, acidity and pathogens such as bacteria and viruses. In addition to this, an external agency for cancer research reported that the use of chemical disinfectants in water treatment, usually results in chemical by-products some of which are potentially hazardous. This means water is a vehicle for disease transmission (Mahananda *et al.,* 2010).

About 97 % of water exists in oceans; this is not suitable for drinking. 3 % is freshwater; of this amount, 2.97 % makes up the glaciers and ice caps. The remaining tiny portion of 0.3 % is available as surface and groundwater for human use (Jain *et al.,* 2010).

Groundwater is an essential water source; it comes from rain, sleet, and hail permeating the ground. The water moves down into the ground because of gravity, passing between soil particles until it reaches a depth where the land is filled or saturated with water. Groundwater is contaminated when manufactured products such as gasoline, oil and chemicals get into the groundwater table and cause it to become unsafe for human use. Fertilizer can find their way into the ground over time. Toxic substances from mining sites and motor oil may also seep into the ground. In the next century, water will become limiting due to increasing population, urbanization, and climatic change (Brewer, 2009). More than 60 % of the Nigerian population depends on groundwater for domestic water supply (Omole, 2011; 2013). Nitrate concentration above 45 mg/L may prove harmful to human health causing methemoglobinaemia (blue babies) which generally affects bottle-fed infants (Jain *et al.*, 2010). A high concentration of sulfates may induce diarrhoea and intestinal disorders. Elevated concentrations of iron in natural water resources can lead to several serious health problems like cancer, diabetes, liver/heart diseases and neurodegenerative diseases (Azizullah *et al.*, 2011). Arsenic in drinking water is related to skin lesions (Leken *et al.*, 2019).

The environment plays a vital role in health and human development. The acute effects from exposure to environmental contaminants are linked to specific environmental hazards and health effect such as leukemia (Temilola *et al.*, 2011).

Therefore, this study is aimed at assessing the quality of groundwater at different locations in Makurdi, Benue State, Nigeria.

MATERIALS AND METHODS

Sample collection

All the samples were collected in March, 2021. The water samples were collected from wells in High Level, Wurukum and Wadata. All samples were collected in sterilized bottles, stored and transported in a cold box kept below 4 ºC to the laboratory. Analyses were performed within 24 hours of collection. Samples for metal analysis were preserved by adding 3 mL conc. nitric acid per liter of water, while those for dissolved oxygen were treated (as soon as collected) with 2 mL of manganese sulfate and 2 mL of alkaline-iodide-azide solutions.

Physicochemical analyses

All samples were analyzed for Taste, Odour, Temperature, Colour, Suspended Solid, pH, Electrical Conductivity (EC), Turbidity, Total Hardness (THD), Calcium Hardness (CHD), Magnesium Hardness (MHD), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Nitrate ($NO3^-$), Iron (Fe), Sulphate ($SO4^{2-}$), Phosphate ($PO4^3$), Nitrite, Chloride (Cl^-), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD) using standard procedures (ALPHA, 1998).

Microbiological analysis

Total and faecal coliform bacteria counts were determined by membrane filtration (MF) technique as described by APHA (1998). The analysis was carried out at the Ministry of Water Resources, Benue State, Nigeria.

The results obtained were compared with standard values provided by the Nigeria Standard for Drinking Water Quality (NSDWQ, 2015) and World Health Organisation (WHO, 2011).

Statistical analysis

Statistical analyses were performed on the data using PAST (Paleontological Statistics Software Package for Education and Data Analysis) software for windows.

RESULT

The analyses of the samples of groundwater obtained from selected locations in Makurdi are shown in Tables 1 to 4 below. The same results are represented in graphical forms in Figure 1—5 for ease of understanding and comparison.

Table 1. Physical characteristics for the samples got from three locations

Physical parameters	**High Level**	**Wurukum**	**Wadata**	**Maximum standard by NSDWQ**	**WHO standard (2011)**
Taste (mg/L)	3.8	4.6	2.2	5	__
Odour (mg/L)	2.6	1.5	2.1	5	__
Temperature (˚C)	32.5	32.7	30.6	Ambient	25
Turbidity (NTU)	3.70	19.25	3.98	5	5
Colour (ptco)	22	38	3	15	__
Suspended Solid	10	43	19	__	__
Total Suspended Solid [TSS] (mg/L)	411	288	236	__	__
Total Dissolved Solid [TDS] (ppm)	401	245	217	500	500
Electrical Conductivity (µS/cm)	642	580	498	1000	1000

Water samples from the three locations were analyzed for physical characteristics such as taste, odour, temperature etc and their values presented in table 1.

Table 2. Chemical characteristics for the samples got from three locations

Chemical parameters	**High Level**	**Wurukum**	**Wadata**	**Maximum standard by NSDWQ**	**WHO standard (2011)**
pH	6.45	7.00	6.77	6.5—8.5	6.5—8.5
Total Hardness	280	540	240	150	200
Calcium Hardness	220	380	180	__	__
Magnesium Hardness	60	160	60	__	__
Nitrate (mg/L)	62	88	30.0	50	45
Iron (mg/L)	0.29	0.27	0.20	0.3	0.3
Sulphate (mg/L)	43	105	195	100	200
Chloride (mg/L)	107.46	159.2	91.54	250	250
Nitrite (mg/L)	0.14	0.30	0.02	0.2	__
Phosphate (mg/L)	0.146	1.50	0.158	__	5

Table 3. Biological characteristics for the samples got from three locations

Biological parameters	**High Level**	**Wurukum**	**Wadata**	**Maximum standard by NSDWQ**	**WHO standard (2011)**
D_1O_1—DO_2	03.6—02.8	05.6—03.2	03.8—04.2	5	2
Biological Oxygen Demand (BOD)	0.8	02.4	0.4	__	10
COD	1.6	4.8	0.8	__	2.5
Total Coliform (CFU's)	160	194	130	0	10
Faecal Coliform	70	85	50	0	__

Water samples from the three locations were analyzed for their biological characteristics such as Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) etc and their values presented in table 3.

DISCUSSION

Water samples were analyzed to determine the degree of groundwater pollution**.** Results were compared with Nigeria Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) to determine suitability for human consumption.

Water samples in High Level and Wadata were slightly acidic and the water sample for Wurukum is neutral with pH values within the WHO and NSDWQ acceptable range (table 2). Results from the study area reveal that temperature for all sampling locations exceeded the permissible limit of 25 °C for domestic water (table 1), which indicated the presence of foreign bodies like an active micro-organism (Akinbile and Yusoff, 2011; Nta *et al.,* 2020).

The concentrations of iron in the results obtained were 0.29, 0.27, and 0.20 for all locations, which is within the permissible limit of 0.3 mg/L as specified by WHO as shown in table 2. Concentration above the allowable range may result from weathering of minerals, rocks of iron in the soil and dissolution of natural iron deposit in groundwater bodies through leaching. Consumption of water containing a high concentration of iron can cause diabetes mellitus, liver damage, arteriosclerosis and other diseases (Akinbile and Yusoff, 2011), and it's dangerous even at a lower concentration.

Electrical Conductivity (EC) is the capacity of a substance to conduct electric current. This ability depends on their total concentration mobility, ion, relative concentration and temperature. Pure water is not a good conductor of electric current; an increase in ion concentration enhances the electrical conductivity of water. The result indicated the EC value was 642 µ/cm, 580 µ/cm, and 498 µ/cm for the three locations respectively as shown in table 1. This result means that water in the study area was moderately ionized with moderate level of ionic concentration activities.

Nitrate is one of the disease-causing substances of water quality. The sources of nitrate are nitrogen cycle, waste from industries, nitrogenous fertilizer, among others. The maximum WHO drinking water limit for nitrate is 45 mg\L. The results from the study areas reveal that nitrate concentration is 62 mg/L, 88 mg/L and 30 mg/L for High Level, Wurukum and Wadata, respectively (table 2). These values indicated that the nitrate concentration is above the WHO permissive range for High Level and Wurukum, but nitrate concentration is within the permissive range for Wadata.

A high concentration of chloride can damage metallic materials as well as causes harm to plant through irrigation. Chloride values are 107.46 mg/L, 159.2 mg/L, and 91.54 mg/L, indicating that chloride concentration is within the WHO and NSDWQ acceptable range (table 2).

The total hardness of water is determined by the presence of soluble salts of magnesium, calcium, and other heavy metals dissolved in it. Values obtained are 280 mg/L, 540 mg/L and 240 mg/L found in table 2. These values are not within the WHO permissive range of 200 mg/L.

Turbidity in drinking water is caused by materials and substances that may be present in water sources as a result of infiltration or from the re-suspension of sediment in the water channels. The study revealed that turbidity values of High Level and Wadata are within the permissible range of drinking water standard, but that of Wurukum (19.25 mg/L) is not within the allowable drinking water standard given by WHO and NSDWQ.

The presence of Total Dissolved Solid (TDS) indicates the salinity of the water, which can be as a result of industrial discharge which causes soil contamination and leaching effect. Values obtained showed that TDS in all locations are 401 mg/L, 245 mg/L, and 217 mg/L (table 1), which indicated that TDS values are within the WHO and NSDWQ acceptable range of 500 mg/L.

Biological Oxygen Demand (BOD) gives a measure of oxygen required for the biological degradation of carbonaceous matter in water sample. The BOD values for all samples point are within the acceptable range of 10 mg/L (table 3).

The concentration of phosphate in all samples is within the permissible range (table 2). Natural water contains sulfate ions, and most of these ions are water-soluble. Sulphate concentration in all samples lies within the acceptable limit of 5 recommended by WHO.

The number of coliforms indicates the presence of pathogenic organisms and should not be present in drinking water. Total Coliform (TC) is 160 mg/L, 194 mg/L, and 130 mg/L for High Level, Wurukum and Wadata respectively (table 3). The very high TC values observed in Wurukum were probably due to defecation/refuse sites and open-pit latrines in these areas, mostly inhabited by low-income earners or poor people in that community

Chemical Oxygen Demand (COD) measures the amount of dissolved oxidizable organic matter including the non-biological degradable matters. The microorganisms using the organic matter as an energy source will readily deplete available dissolved oxygen (dissolved oxygen produces the most energy per mole) in the system (McMahon and Chapelle, 2007). High Level and Wadata had COD values of 1.6 mg/L and 0.8 mg/L, below the 2.5 mg/L required of good drinking water (table 3). On the contrary, Wurukum had a far greater value than 2.5 mg/L; hence groundwater in Wurukum can be regarded as poor.

CONCLUSION AND RECOMMENDATION

The study showed that the samples are not within the permissible level of a drinking water due to contamination problems, particularly those of anthropogenic sources and such water should not be consumed by humans and animals. The health implications of continuous exposure to excessive levels of contaminants in drinking water are enormous. The prompt realization of these negative impacts of continuous contamination by humans will help to curb these problems. It is recommended that tests of private wells, boreholes and streams which tap into both deep and shallow aquifers should be carried out regularly and measures for the treatment of contaminated water sources be effected within the study areas.

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APPENDIXES

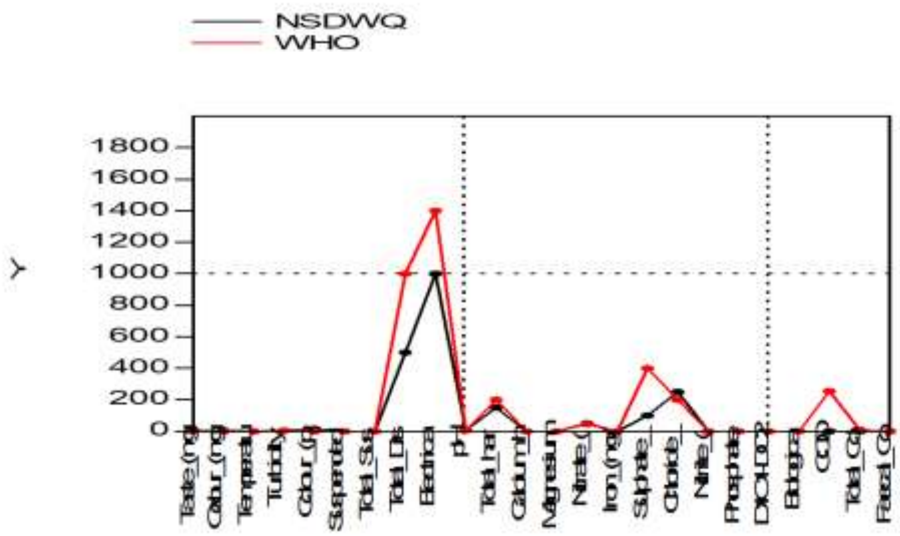

Figure 1. Deviation of water sample parameters from WHO and NSDWQ standards

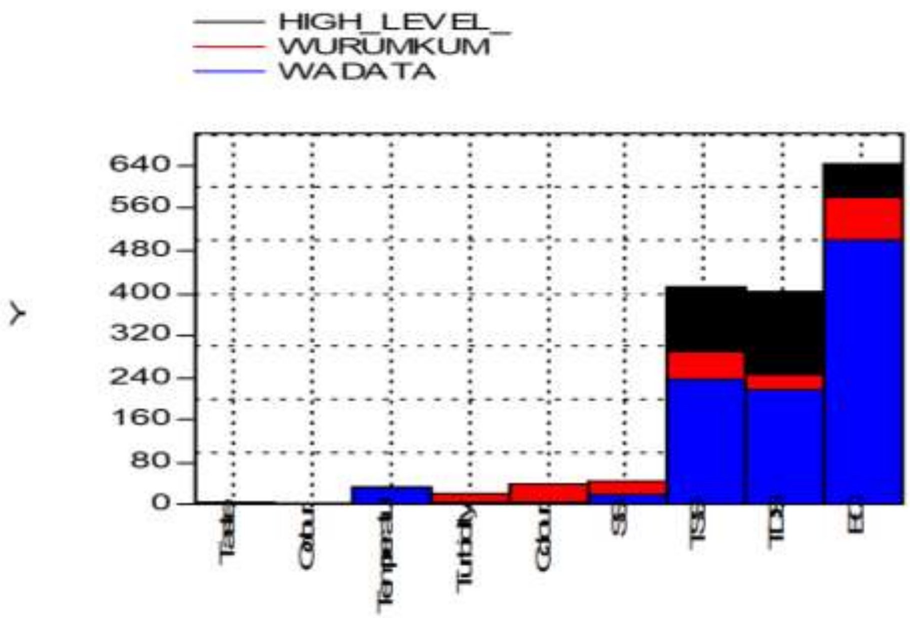

Figure 2. Histogram showing the result of physical characteristics obtained from the three locations

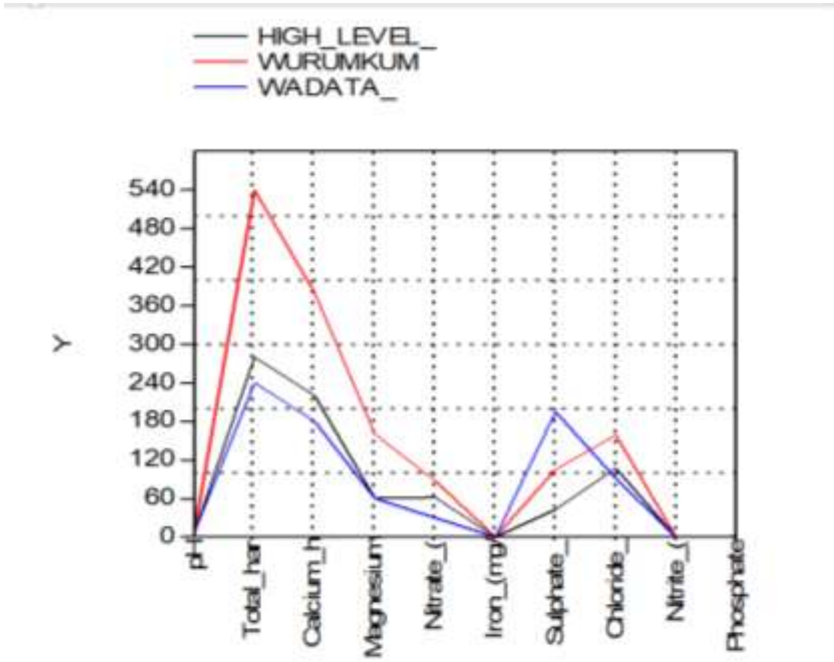

Figure 3. Line chart showing the result of chemical characteristics obtained from the three locations

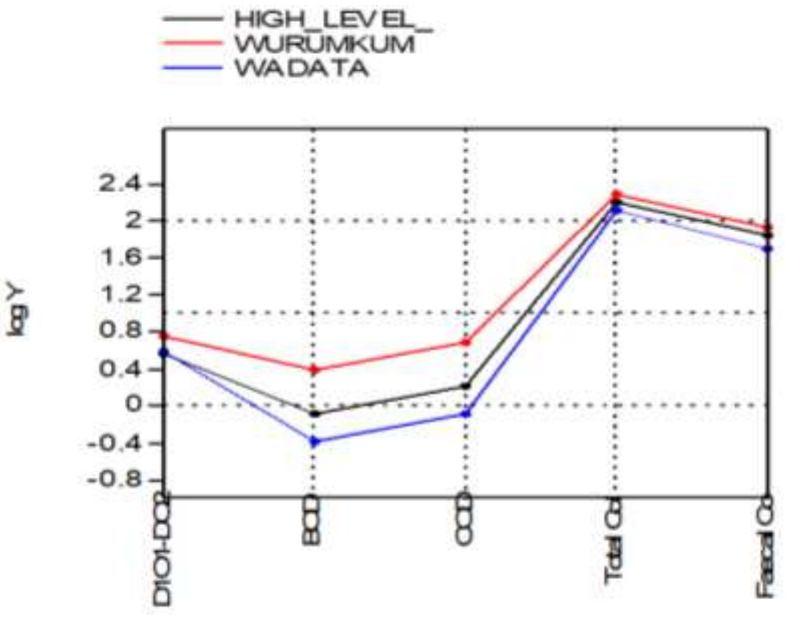

Figure 4. Line chart showing the result of biological characteristics obtained from the three locations

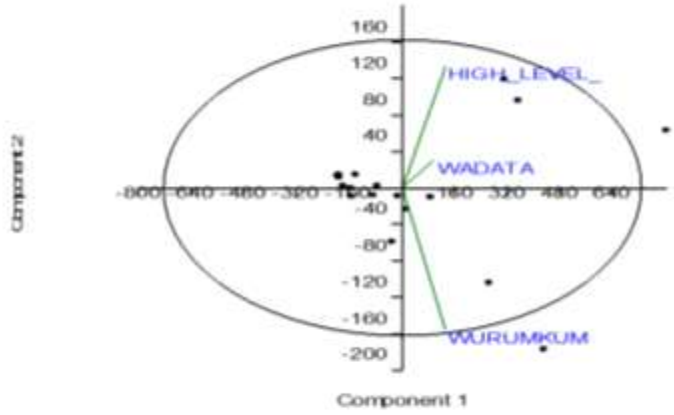

Figure 5. Principal Component Analysis (PCA) for the three locations

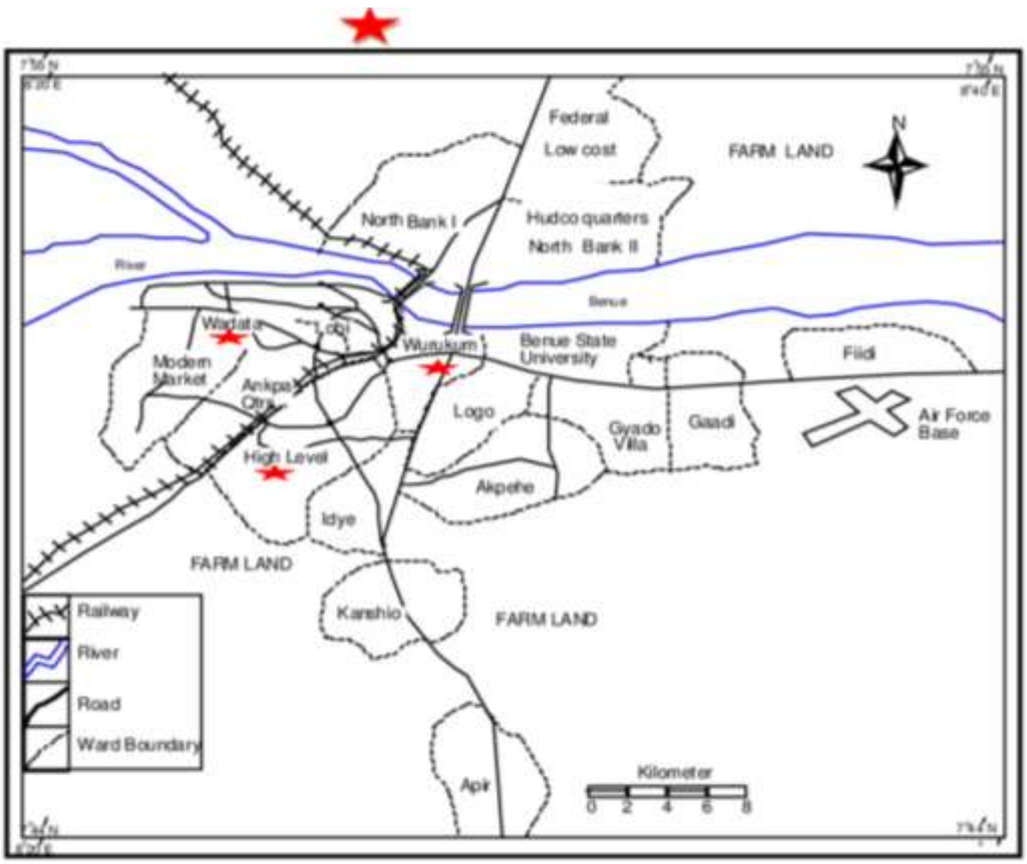

Figure 6. Sketched map of Makurdi, Benue State showing the sampling locations indicated by

Table 4. Result of physiochemical and biological parameters in replicates for the samples

PHYSICAL PARAMETERS	HIGH LEVEL				WURUKUM				WADATA			MAXIMUMSTANDARD		
	BH1	BH2	BH3	Averge	H/A	H/B	H/C	Avearge	XX	XY	XZ	Average	NSDWQ	WHO
TASTE	3.6	4.1	3.7	3.8	4.2	4.9	4.7	4.6	2.3	2.1	2.2	2.2	5	0
Odour	2.9	2.4	2.5	2.6	1.45	1.55	1.5	1.5	2.2	2.1	2	2.1	5.1	0
Temperature	32.6	32.1	32.8	32.5	33.1	32	33	32.7	30.4	31.1	30.3	30.6	Ambient	25
Turbidity(NTU)	3.66	3.85	3.59	3.7	22.26	16.24	19.25	19.25	4.25	4.29	3.4	3.98	5	5
colour	23	21	22	22	36.4	37.9	39.7	38	3	3	3	3	15	0
SS	12	7	11	10	42.7	42.3	44	43	21	17	19	19	0	0
TSS	300	350	388	411	285	299	280	288	250	230	228	236	0	0
TDS	108	950	145	401	250	237	248	245	214	220	217	217	500	0
EC	750	600	576	642	590	570	580	580	48.2	53	45.5	48.9	1000	1000

CHEMICAL PARAMETERS	HIGH LEVEL				WURUKUM				WADATA			MAXIMUMSTANDARD		
	BH1	BH2	BH3	Averge	H/A	H/B	H/C	Avearge	XX	XY	XZ	Average	NSDWQ	WHO
PH	6.2	6.57	6.57	6.45	7	8	6	7	6.32	7.4	6.59	6.77	6.5-8.5	6.5-8.5
Total Hardness	230	300	310	280	543	538	539	540	250	230	240	240	150	
Calcium hardness	250	205	205	220	383	375	382	380	200	161	179	180		
Magnesium hardness	58	55	67	60	159	165	156	160	58	75	47	60		
Nitrate	62	64	60	62	92	82	90	88	27	34	29	30	50	45
Iron	0.31	0.27	0.29	0.29	0.27	0.25	0.29	0.27	0.22	0.18	0.2	0.2	0.3	0.3
Sulphate	46	40	43	43	105	103	107	105	193	192	200	195	100	200
chloride	111.12	101.15	110.11	107.46	14.9	16.94	15.92	15.92	9204	9194	9064	9154	250	250
Nitrite	0.12	0.16	0.14	0.14	0.31	0.27	0.31	0.3	0.02	0.02	0.02	0.02	0.2	
Phosphate	0.143	0.147	0.148	0.146	1.5	1.5	1.5	1.5	0.145	0.155	0.174	0.158		5

BIOLOGICAL PARAMETERS	HIGH LEVEL				WURUKUM				WADATA			MAXIMUMSTANDARD		
	BH1	BH2	BH3	Averge	H/A	H/B	H/C	Avearge	XX	XY	XZ	Average	NSDWQ	WHO
D1 O1-D O2				03.6-02.8				05.6-03.2				03.8-0.42	5	2
Biological oxygen demand (BOD)	0.7	0.8	0.9	0.8	2.37	2.44	2.39	2.4	0.4	0.39	0.41	0.4		10
Chemical oxygen demand(COD)	1.5	1.6	1.7	1.6	46	48	50	48	0.82	0.77	0.81	0.8		225
Total coliform	165	160	155	160	182	200	200	194	131	128	131	130	0	10
Faecal coliform	11	69	70	70	83	82	90	85	150	148	152	150	0	