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Comparative Analysis of Water Quality Assessment in the Basement Complex terrain of Central Nigeria: A Case Study of Ground and Surface Water Relations in the Agbadu - Bunu Community and it's Environ in Kabba/Bunu Local Government Area of Kogi State

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Abstract

Analysis of water resources around Agbadu - Bunu Community in Kogi State, Nigeria was carried out to assess the water quality by determining the concentrations of cations, anions, heavy metals, trace elements, pH, alkalinity, total dissolved solids and microbial loads in water samples. Ten water samples (one rainwater, two pond waters, one stream water, four hand-dug wells water, one hand pump water and one motorized borehole water) were systematically collected in the study area and analyzed using the atomic absorption spectrophotometer. Microbiological analysis for total bacteria count (TBC), total coliform (TC) and other intestinal bacteria were assessed using standard plate count Agar, Macconkey Agar, Macconkey broth and Brilliant Green Bile Agar. Multiple bottle methods were employed in the enumeration of Coliform. The physiochemical results were compared with the standard values recommended by the World Health Organization (WHO) and it showed that all the cations in water samples are within the WHO recommended limits. The water samples at locations B, E, F, G, H, J, and I have high alkalinity and $HC0^{3-}$ content. The heavy metals (Pb^{2+}, Ni^{2+} and Cd^{2+}) and trace elements (Fe and Cu) are dominantly high in the surface waters. The analysis of microbiological substances in the water samples revealed that most of the water in the area are not fit for human consumption due to the presence of indicator organisms higher than the WHO standard for drinking water. However, Samples obtained from locations G, I and J have TBC values of 40cfu/100mL, 10cfu/100mL and 05cfu/100mL, respectively. In addition, no E-Coli was recorded in these locations and they have the same TC values of 0cfu/100mL. The TBC and TC values fall within the WHO recommended limit, thus they are fit for human consumptions but needed to be treated due to their high MPN (Most Probable Number) index of <11/100 mL, <24/100 mL and <26/100 mL, respectively as against WHO standard of <10/100 mL. This study shows that the water resources in the study area are gradually been polluted and in the nearest future may not be good for drinking.

Keywords: *Water; Rainfall; Heavy metals; Anions; Microbes; Nigeria.*

1. Introduction

A large number of communities in Nigeria, especially those in the Eastern highland, Western highland and central parts depend largely on groundwater supply from the Basement Complex rocks through boreholes. The development of groundwater resources in these parts of Nigeria are carried out under severe budgetary constraints, with little opportunity for fundamental hydrogeological studies. Hard rock masses such as the basement-rock masses covering about two-third of the land surface of Nigeria in their under -formed state possess little or no primary inter-granular porosity or permeability and the hydro-geological properties are thus mainly determined by secondary storability and transmissivity. It is not possible to find absolutely pure water in nature even rainwater, when it drops, just emitting from the clouds, may be considered pure, but as the drops fall down, certain gasses get dissolved in it and make the rainwater impure [1]. Depending on the sources of the water, surface and groundwater may differ greatly in terms of purity and suitability for the purposes for which they are required [2]. Groundwater is the water, which is stored by nature, underground in the water bearing formations of Earth's crust. This could be natural springs, well and boreholes, infiltration galleria and radial collector wells [2]. The inorganic materials for which maximum contaminant levels have been established are generally toxic in one manner or the other. Lead, mercury, arsenic, barium, cadmium and chromium are poisonous and can exhibits chronic or acute toxicity depending on the concentration [3-7].

In the study area, groundwater occurrence is in the weathered basement or in the joint and fracture systems of the unweathered or partly weathered rocks. There are aquifers in the Basement Complex, hence, each site has to be treated as unique. The depths of aquifers are normally between 10 m and 60 m. Previous work by Omada *et al.* [5] on the physico-chemical characteristics of surface and ground water in central Nigeria shows that the concentration of cations and anions in the water resource of certain parts of central Nigeria conformed to the World Health Organization (WHO) for potable water. Omada *et al.* [5] collected fifty-five water samples for both cations and anions analysis using inductively coupled plasma-optical emission spectrometry (ICP-DES) and inductively coupled plasma-mass spectrometry (ICP-MS). They reported that that the area (central Nigeria) consist of two water types, namely, the earth-alkaline water and earth-alkaline waters. Furthermore, they documented that alkaline compounds with cations and anions concentrations are below WHO limit in some parts while other parts had their concentrations above WHO limits. As a result of the reported variations in the water types, in this study, we examine the quality of drinking water around Agbadu-Bunu in Kabba Local Government Area of Kogi State, central Nigeria (Figure 1).

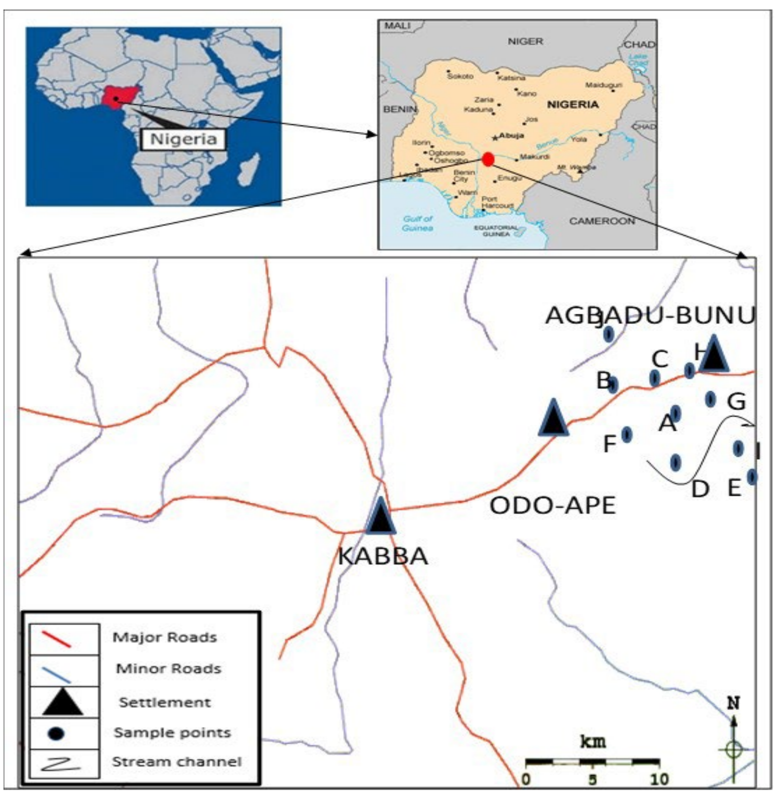

Figure 1. Map of Nigeria showing the study area and sample locations

The area has a fast growing population and increasing level of diverse socio-economic activities. Factors responsible for water contamination and the type of contaminants in water to determine its deviance from the normal were also investigated. The study area lies between latitude 7.91786^0 E and longitude 6.26911^0 N. The community experiences distinct dry and wet seasons. There is a fairly high amount of rainfall in the wet season and water is readily available during the wet season but may become dried or dry up during the dry season. This is particularly so in areas underlain by crystalline rocks of the Basement Complex where many rivers are intermittent and the underlain lithology does not favour large accumulation of groundwater [4].

2. Material and methods

A preliminary (reconnaissance) survey of the study area was carried out in order to study the various sources and kind of drinking water available in the area. This survey helped in the locations of various water sources and was marked out for random sample collection. Global positioning system (GPS) was used to measure the longitude and the latitude of the respective sample locations as well as the distance above sea level (Figure 1; Table 1). Two different types of containers were used for sample collection. Bottles for microbiological samples were first washed with detergent, rinsed with distilled water, dried and sterilized at 150℃ for 2 hours, while other plastic bottles were washed with detergent, rinsed with distilled water before used for water sampling. In the process of sampling, care was taken that the container used in fetching the water (fetcher) was thoroughly washed to make sure that there is no contamination during sampling or level of contamination is minimized. For the rainwater sources, early morning water from the rain was collected into a sample bottle. Boreholes water samples (hand pump water and motorized borehole) were collected after the mouth of the tap was first swabbed/sterilized with cotton wool soaked with alcohol (ethanol). Some quantities of the water were first pumped out to create room for fresh water from the source and also help in flushing out bacteria or other possible contaminants along the lining of the pipe. The water samples taken from both surface (stream, rain, pound) and ground (hand dug wells/boreholes) water were collected at random and labeled accordingly After collection, the samples were protected from reacting with air by tightening the cork properly, packed into a small cooler and transported immediately to the laboratory for analysis. The samples were analysed using the atomic absorption spectrophotometer (AAS). The different methods used were in accordance with the hydrological project technical assistance (HPTA) method for standard analytical procedure for water. The concentrations of cations, anions, heavy metals and trace elements were determined. The pH of the samples was determined using a pH meter (Mode: HP 2211 PWORP meter). 10 mL of each of the sample was poured in to a sterile beaker and the anode of the pH meter was inserted into it, allowed to stay till for about 5 minutes before the readings were taken and recorded one after the other. The stainless sensor was rinsed with distilled water after each reading.

Table 1. Sample points and their coordinates.

Sample ID			Coordinates	
ID	Label	Type of sample	Longitude	Latitude
A	RW	Rain Water	N 7°8′5.69″	E 6°2′5.65″
B	PW1	Pond Water	N 7°55.6′55″	E 6°1′5.75″
C	PW2	Pond Water	N 7°55.6′55″	E 6°1′5.75″
D	SW	Stream Water	N 7°55.4′77″	E 6°16′32″
E	HDW1	Hand Dug Well Water	N 7°55′25″	E 6°1.6′38″
F	HDW2	Hand Dug Well Water	N 7°55′51″	E 6°16.1′60″
G	HDW3	Hand Dug Well Water	N 7°55′55″	E 6°15.7′52″
H	HDW4	Hand Dug Well Water	N 7°55′087″	E 6°15.7′57″
I	HPW	Hand Pump Water	N 7°55′27″	E 6°1.6′14″
J	MPW	Motorized Pump Water	N 7°55′03″	E 6°1.6′13″

3. Results

The results of the total and average concentrations of cations, anions, heavy metal, trace elements, pH, alkalinity and total dissolved solids in the water resources (both surface and ground water) are presented in Tables 2 and 3. Table 4 shows the comparisons of the average concentrations of cations, anions, heavy metals, trace elements and pH, alkalinity and total dissolved solids of the water resources in the study area with the WHO standard for drinking water.

Table 2. Concentrations of cations, anions, heavy metals, trace elements, values of pH, alkalinity and total dissolved solids (TDS) in the water resources of the study area

Parameter (mg/L)	A (RW)	B (PW1)	C (PW2)	D (SW)	E (HDW1)	F (HDW2)	G (HDW3)	H (HDW4)	I (HPW)	J (MPW)
Ca^{2+}	4.38	4.22	4.21	3.64	4.12	4.101	2.90	2.64	2.11	1.48
Mg^{2+}	2.64	2.50	2.49	2.103	1.94	1.90	1.81	1.92	2.53	1.21
K^{+}	3.51	4.11	3.04	3.61	2.11	2.38	2.04	2.87	3.31	3.73
Na^{+}	0.13	0.782	0.63	0.67	0.37	0.13	0.48	0.38	3.41	4.76
$N0^{-}_{3}$	4.53	0.27	0.019	15.943	0.019	0.016	0.024	0.016	0.142	0.39
$HC0^{-}_{3}$	19.76	66.15	48.97	38.67	103.95	126.30	59.30	64.43	251.72	97.08
CL^{-}	29.78	6.62	8.51	17.02	16.54	17.02	25.53	25.52	19.85	23.16
$S0^{-}_{4}$	5.32	3.801	3.803	0.25	0.38	0.36	0.38	0.39	0.25	0.66
Pb^{2+}	0.031	0.071	0.07	0.30	0.044	0.043	0.046	0.05	0.034	0.031
Zn^{2+}	0.16	0.22	0.23	0.13	0.12	0.104	0.101	0.102	0.12	0.002
Ni^{2+}	0.071	0.06	0.051	0.35	0.03	0.03	0.039	0.03	0.045	0.02
Cd^{2+}	0.004	0.075	0.073	0.062	0.04	0.05	0.041	0.06	0.014	0.011
Fe	0.74	0.241	0.25	0.42	0.13	0.12	0.14	0.12	0.33	0.19
Mn	0.01	BDL	BDL	BDL	0.00	0.00	0.00	0.00	0.00	0.00
Cu	2.01	3.46	3.61	2.88	2.19	2.18	2.18	2.19	2.41	0.70
PH	6.95	7.18	6.96	7.06	7.22	7.01	6.82	6.76	7.21	7.66
Alkalinity	43.33	133.33	100.00	80.00	206.67	250.00	120.00	130.00	493.33	193.33
TDS	0.00	20.00	20.00	20.00	380.00	20.00	20.00	20.00	360.00	20.00

N.B. Sample A = Rainwater (RW); Samples B and C = pond water (PW1 and PW2); Sample D = Stream water (SW); Samples E, F, G, and H= Hand dug well water (HDW1 – 4); Samples I and J = Boreholes (Hand pump well water (HPW) and motorized borehole water (MPW))

Table 3. Average concentrations of cations, anions, heavy metals, trace elements, values of pH, alkalinity and total dissolved solids (TDS) in the surface water resources of the study area

Parameters	Average concentrations in surface water (mg/L)	Average concentrations in ground water (mg/L)
Ca^{2+}	4.113	2.892
Mg^{2+}	2.433	1.885
K^{+}	3.568	2.743
Na^{+}	0.553	1.588
$N0_{3}^{-}$	5.188	0.101
$HC0_{3}^{-}$	43.388	116.13
Cl^{-}	15.483	21.268
$S0_{4}^{2-}$	3.293	0.403
Pb^{2+}	0.118	0.041
Zn^{2+}	0.054	0.036
Ni^{2+}	0.185	0.92
Cd^{2+}	0.133	0.398
Fe	0.213	0.172
Mn	0.003	0.00
Cu	2.99	1.975
P^{H}	7.04	7.113
Alkalinity	89.165	232.22
TDS	15.00	136.67

Table 4. Comparison of average concentrations of cations, anions, heavy metals, trace elements, values of pH, alkalinity and total dissolved solids (TDS) in the water resources of the study area with WHO standards

Cations	WHO,2011 guideline maximum value mg/L	Guideline value mg/L	Maximum admissible concentration mg/L	Average value of study area mg/L (This study)
Calcium (Ca^{2+})	-	100.00	-	3.503
Sodium (Na^{+})	200.00	20.000	150.000	1.071
Potassium (K^{+})	-	10.000	12.000	3.156
Magnesium (Mg^{2+})	-	30.000	50.000	2.159
Chloride ion (Cl^{-})	250	-	-	18.376
Sulphate ion ($S0_4^{2-}$)	250	-	-	1.848
Nitrate ion ($N0_3^{-}$)	50	-	-	2.645
Hydrogen trioxocarbonate ion ($HC0_3^{-}$)	50	-	-	80.209
Lead (Pb^{2+})	0.010	-	0.005	0.080
Cadmium (Cd^{2+})	0.003	-	0.005	0.045
Zinc (Zn^{2+})	3.000	0.100	-	0.139
Nickel (Ni^{2+})	0.020	-	-	0.266
Iron (Fe)	0.300	0.050	0.200	0.193
Manganese (Mn)	0.050	-	-	0.002
Copper (Cu)	0.05	-	-	2.483
Ph	8.500	6.5-8.5	6.5-8.5	7.082
Alkalinity	100.000	-	-	174.999
TDS	500.000	-	-	88.000

Total Bacterial Count (TBC) value of the water samples analyzed has the mean value of 199.75×10^3 cfu/100 mL and 50×10^3 cfu/100 mL for surface and ground water of the area respectively. The highest values ranging from 2.35×10^2 cfu/100 mL to 1.38×10^2 cfu/100 mL for surface and ground water respectively against the 100 cfu/mL for WHO standard for potable water. Total Coliform Count of the water samples has mean values of 2.0×10^1 cfu/100 mL and 0.717×10^1 cfu/100 mL for surface and ground water respectively. The highest values ranging from 0.23×10^2 cfu/100 mL to 0.30×10^2 cfu/100 ml for surface and ground water, respectively against zero (0) cfu/100 mL for WHO standard for potable water (Table 5). E. Coli Count for the water samples analyzed is absent in most of the samples and only present in very minute amount in some of the samples. Though no particular amount was recorded, this mostly conformed with the zero (0) cfu/100 mL for WHO standard for potable water.

Table 5. Microbiological analysis of water samples in the study area

Microbiological/Samples factors	A RW	B PW1	C PW2	D SW	E HDW1	F HDW2	G HDW3	H HDW4	I HPW	J MBW
Protozoan (count/mL)	0	12	0	0	0	0	0	0	0	0
Total plate count(cfu/mL)	5	110	129	235	50	138	40	57	10	05
Total coliforms (cfu/100mL)	10	30	17	23	30	03	0	10	0	0
Salmonella typhi	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Shigella SP	Present	Absent	Absent	Absent	Absent	Present	Absent	Present	Absent	Absent
E. coli	Absent	Present	Present	Present	Present	Present	Absent	Present	Absent	Absent
Streptococcus faecalis	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
MPN Index<10/100 mL	2400	2400	94	8	2400	920	11	2	2400	26
	Accept	Not acceptable	Not acceptable	Not acceptable	Not acceptable	Not acceptable	Accept	Not acceptable	Accept	accept

4. Discussion

The quality of water is most often a function of the mineralogical and geochemical characteristics of the rocks underlying the area [8]. Most minerals in rocks are soluble under appropriate geochemical condition. The quality of groundwater therefore, in some parts of the country, particularly shallow ground changed as a result of human activities. Groundwater is less susceptible to bacterial pollution than surface water because the soil and rocks through which groundwater flows screens out most bacteria [9]. Bacteria however occasionally find their way into groundwater sometimes in high concentrations. But, freedom from bacteria's pollution alone does not mean that the water is fit for drinking. Many unseen dissolved minerals and organic constituents are present in groundwater in various concentrations. Most of which are harmless or even beneficial, while others are harmful and a few may be highly toxic. Water typically is not considered desirable for drinking if the quantity of dissolved minerals exceeds 1000 mg/L [9]. Water with a few thousands mg/L of dissolved minerals is classified as lightly saline, but is sometimes used in area where less mineralized water is available [9]. Water from some wells and springs can contain very large concentrations of dissolved minerals and waste, which are harmful or dangerous to humans, animals and plants. The quality of water resources in the study area can be degraded by excessive waste disposal and dissolved minerals which can upsets the balance that exist between plants and animals with severe effects on all forms of life.

Carbonate ($HC0_3^-$)

The WHO standard has given the guideline maximum concentration of carbonate to be 50 mg/L[10]. The determined concentration of the carbonate in the surface water range between 19.76 mg/L and 66.15 mg/L, averaging 43.388 mg/L. However, the results of the groundwater (hand dug wells and boreholes) concentration range from 59.30 mg/L to 251.72 mg/L, averaging 116.13 mg/L. The analysis of surface water concentration shows that three of the four water samples analyzed are within the WHO standard limit and is therefore safe, while the ground water concentration for $HC0_3^-$ is higher than the WHO standard limit. This is perhaps hard water, which is not safe or suitable for drinking, except by boiling.

Nitrate ($N0_3^-$) and sulphates

The WHO standard has shown that the guideline maximum concentration for nitrate is 50 mg/L[10]. The result of the analysis shows that the concentration of nitrate in the surface water is vary from 0.02 mg/L up to 15.94 mg/L, with an average concentration of about 5.19 mg/L. On the other hand, the results of the ground water shows concentration ranging between, 0.016 mg/L and 0.39 mg/L, averaging 0.10 mg/L. The surface and ground water concentrations fall below the WHO standard limit and are therefore safe for drinking. The low concentration of nitrate in the water samples might be that the water contains less or no organic matter [2]. The WHO standard for the guideline maximum concentration of sulphate ion is 250 mg/L [10]. The concentrations of sulphate in surface water varies from 0.25 mg/L up to 5.32 mg/L, averaging 3.30 mg/L. Conversely, the concentration of sulphates in the ground water ranges from 0.25 mg/L to 0.66 mg/L. The surface and ground water concentration fall below the WHO standard limit and is therefore safe for drinking.

Chloride (Cl^-)

The WHO standard has shown the guideline maximum concentration for chloride as 250 mg/L [10]. The results of the analysis show that the concentrations of chloride ion in the surface water range between 6.62 mg/L, and 29.78 mg/L with an average concentration of about 15.48 mg/L. Alternatively, the concentration of chloride in the ground water varies from 16.54 mg/L to 25.52 mg/L, averaging 21.27 mg/L, which falls below the WHO standard limit and are therefore is safe for drinking.

Calcium (Ca^{2+})

The WHO standard showed that the guideline maximum concentration for calcium is 100 mg/L [10]. The results of the analysis carried out on the samples collected from the surface water resources shows that the concentrations of calcium to be 4.38 mg/L, 4.21 mg/L and 3.64 mg/L in rain water, pond water and stream water, respectively. This concentration is below the maximum concentration guideline of the WHO [10] standard for drinking water, meaning that the surface water is safe for drinking. Similarly, the concentration of calcium in ground water ranges from 1.48mg/L to 4.120 mg/L, averaging 2.89 mg/L. These values are below the WHO standard limit and thus are consider to be safe for drinking.

Magnesium (Mg^{2+})

The WHO standard showed that the guideline maximum concentration for magnesium (Mg) is 50 mg/L [10]. The results of the analysis on the surface water samples show magnesium concentrations to 2.64 mg/L, 2.50 mg/L, 2.49 mg/L and 2.10 mg/L in RW, PW1, PW2 and SW, respectively. These concentrations are below the maximum concentration guideline of the WHO [10] standards for drinking water, meaning that the surface water are safe for drinking. However, the results for the ground water (hand dug wells and boreholes) concentrations ranges from 1.21 mg/L to 2.53 mg/L, which are the below the WHO standard limit and is said to be safe for drinking.

Potassium (K^{+})

The WHO standard for the guidelines maximum concentration for potassium is 12.00 mg/L [10]. The concentrations of potassium in the varies between 3.04 mg/L and 4.11mg/L for the surface, and between 2.04 mg/L and 3.73 mg/L for the groundwater. These values are below the WHO [10] recommended permissible limit of the concentration of potassium in drinking water. Therefore, the water are considered safe for drinking.

Sodium (Na^{+})

The WHO standard for the guidelines maximum concentration for sodium is 200.00 mg/L [10]. The concentrations of sodium in the range from 0.13 mg/L to 0.78 mg/L for the surface, and varies between 0.13 mg/L and 4.76 mg/L for the groundwater. These values are below the WHO [10] standard limit and are therefore safe for drinking.

Lead (Pb^{2+})

The WHO shows that the standard guideline maximum concentration for lead is 0.010 mg/L and the maximum admissible concentration is to be 0.005 mg/L [10]. The results of the analysis carried out on samples collected from the surface water shows that the concentrations of lead varies between 0.031mg/L and 0.30 mg/L, averaging 0.12 mg/L. These values concentration are above the WHO standard limit for drinking water, hence it is suitable for drinking. On the other hand, the concentration of lead (Pb) in the groundwater ranges from 0.031mg/L up to 0.046mg/L, which is also higher than the WHO recommended value. This shows that both the surface and ground water may not be safe or suitable for drinking.

Cadmium (Cd^{2+})

The WHO standard showed that the guideline maximum concentration for cadmium (Cd) is 0.003 mg/L and the maximum admissible concentration to be 0.005 mg/L. The concentrations of cadmium range between 0.004 mg/L and 0.075 mg/L, averaging 0.054 mg/L for the surface water. Likewise, the concentrations of cadmium (Cd) in the ground water varies from 0.011mg/l to 0.06mg/l, averaging 0.036 mg/L. The concentration of cadmium (Cd) in both surface and ground water resources are higher than the WHO permissible limit. This showed that the surface water and the ground water in the study area may not be safe for drinking.

Zinc (Zn^{2+})

The WHO standard for the guidelines maximum concentration for sodium is 3.00 mg/L [10]. The concentrations of sodium in the range from 0.13 mg/L to 0.22 mg/L for the surface, and varies between 0.10 mg/L and 0.12 mg/L for the groundwater. These values are below the WHO[10] standard limit and are therefore safe for drinking.

Nickel (Ni^{2+})

The WHO standard shows that the guideline maximum concentration for nickel (Ni) is 0.020mg/L [10]. The results of the analysis from the surface water resources show that the concentrations Nickel in the water surface water samples range from 0.06 mg/L to 0.35mg/L, averaging 0.133mg/L. The concentration of nickel is above the WHO for the surface water. However, the concentration of nickel in the ground water ranges from 0.030 mg/L to 0.045 mg/L. These concentrations in the surface and groundwater are higher than WHO permissible limit and may not be safe for human consumption.

The high concentration of the ions in the water may be as a result of domestic waste disposal along the water, the use of chemicals for weeds control, the use of chemical for agricultural produce and also from the underlying rocks of the area. Water as a solvent is capable of dissolving the minerals of the underlying rocks and wastes which in turn percolates into the ground as contaminants to the ground water of the area, while others flows into the surface as run-off into streams and ponds in the area. Moreso, with the increase in improper waste disposal, use of chemicals in controlling weeds and fertilizers usage without taking into consideration the environmental effects on both ground and surface water resources of the area, may pollute the water resources of this area thereby making it unfit for human consumption.

Iron (Fe)

The WHO standard showed that the guideline maximum concentration for iron (Fe) is 0.30 mg/L and the maximum admissible concentration for iron is 0.20 mg/L [10]. The results of the analysis carried out on the samples collected from the surface water for iron shows concentration of iron varying between 0.24 mg/L and 0.74 mg/L, with an average concentration of about 0.41 mg/L. The groundwater concentration ranges from 0.12 mg/L to 0.19 mg/L, averaging 0.17 mg/L. The studied surface and ground water resources show that seven of the ten water samples analyzed for iron is within the WHO [10] permissible limit. Only the rainwater, stream water and hand pump well water have values of 0.74 mg/L 0.42 mg/L and 0.33 mg/L, respectively. The high level of iron recorded in this study might be due to the natural occurrence of iron in the geological strata of the soil, corrosion of iron and steel materials in the case of rain water hand pump well or leachates from dump sites and vehicles [2].

Manganese (Mn)

The WHO standard guideline of maximum concentration for manganese (Mn) is 0.05mg/L [10]. The results of the analysis from the surface water for manganese are below detective limit except for the rainwater that recorded a value of 0.010 mg/L, averaging 0.003mg/L, while the groundwater is also below dilution limits of 0.00 mg/L. This shows that both concentrations are below the permissible limit by WHO. The water is therefore safe for drinking or human consumption.

Copper (Cu)

The WHO standard shows that the guideline maximum concentration for copper (Cu) is 0.05 mg/L [10]. The concentrations of copper varies from 2.01mg/L to 3.61mg/L, averaging 2.99 mg/L. However, the concentration of copper in the groundwater resources ranges between 0.70mg/L and 2.41mg/L averaging 1.975mg/L. The concentration of copper in both surface and groundwater resources of the area is above the WHO [10] permissible limit for drinking water. The high concentration of copper in the water could be due to sediment dissociation, acid rain or water can also lead to corrosion of copper pipes and copper galvanized roofing sheet and so not safe for drinking.

pH

The WHO standard limits for pH is 6.5 – 8.5. The results of the analysis from the surface water for pH range between 6.95 and 7.18, averaging 7.04. The groundwater concentration ranges from 6.82 to 7.66, averaging 7.11. The results show that the pH concentration in both surface and groundwater resources are below the WHO [10] permissible limits, hence, the water is safe for drinking.

Total dissolved solid

The WHO standard limit for total dissolved solid (TDS) is 500 mg/L. The results of the analysis of the surface water for TDS shows concentration ranging between 0.00 mg/L to 20.0mg/L, averaging 15.0 mg/L the ground water concentration ranges from 20.0mg/L to 360.0mg/L, averaging 136.67 mg/L. These values are below the WHO [10] recommended limit for drinking water, hence both the surface and groundwater are safe for drinking.

Alkalinity

The WHO standard guideline of maximum concentration for alkalinity is 100 mg/L. The results shows that the surface water has alkalinity varying between 13.33 mg/L and 100.0 mg/L. The concentration of alkalinity in groundwater ranges from 120.0 mg/L to 493.33 mg/L. The surface and ground water resources show that three out of the ten water samples analyzed for alkalinity is within the WHO limits of 100mg/L, With the exception of pond water one, hand dug well water 1-4, hand pump water and motorized borehole water have values of 133.33 mg/L, 206.67 mg/L, 250.0 mg/L, 120.0 mg/L, 130.0 mg/L, 493.33 mg/L and 193.33 mg/L, respectively. The high level of alkalinity recorded in those samples might not be far from the nature of soil that contains high level of $HC0_3^-$, $S0_3^{2-}$ and $C0_3^{2-}$.

Microbiological analysis

The result of the microbiological analysis shows that the first pond water (PW 1) has 1.10 × 10^2 CFU/100mL for TBC, 3.0 × 10^1 CFU/100mL for Total Coliform (TC) and absent of E. coli (EC). The second pond water (PW 2) has 1.29 × 10^2 CFU/100mL for TBC, 1.7 × 10^1 CFU/100mL for TC and present of EC. The stream water (SW) has 2.35 × 10^2 CFU/100mL for TBC, 2.3 × 10^1 CFU/100mL for TC and present of EC. The sample A (rainwater) has 5 ×10CFU/100mL for TBC, 1.0 × 10^1CFU/100mL for TC and absent of EC. The Hand dug well (1) has 5.0 × 10^1CFU/100mL for TBC which is below WHO limits of 100mL. The TC in the same water sample is 3.0 × 10^1CFU/100mL and there is present of EC. The sample water F (hand dug well 1) has 1.38 × 10^2CFU/100mL for TBC, 3 × 10CFU/100mL for TC and present of EC. While sample water H (Hand dug well 4) has the TBC below WHO limit, and TC of 1.0 × 10^1CFU/mL as against 0CFU/100mL of WHO and present of EC. Some of these figures are far and above WHO standard for potable water of 100CFU/100ml for TBC, 0CFU/100mL for TC and EC, respectively. The high microbial load of the water samples analyzed might be due to poor handling, expose of wells, growth of algae, fungi and the nearness of water sources to dumpsites.

Average distributions of ions

The average value of the cations are 3.50 mg/L, 2.16 mg/L, 3.16 mg/L and 1.07 mg/L for Ca^{2+}, Mg^{2+}, K^+ and Na^+, respectively. Calcium has the highest rate of distribution as shown in Figure 2. This is followed by potassium, magnesium with sodium been the least. From the distribution of cations in the water resources, it was observed that the concentrations of Ca^{2+}, Mg^{2+},. K^+ and Na^+, are gradually rising due to the human activities on the water resources. These activities include indiscriminate dumping of refuse, gaseous emission from vehicles and application of fertilizers on farmland. It is also noted that the average concentration of these cations fall below the value of WHO [10] standard for drinking water. Figure 3 shows that the average concentration of hydrogen trioxocarbonate (iv) ion ($HC0_3^-$) is very high in the study area, with an average concentration of 80.21 mg/L. This is followed by chloride, nitrate and suphate with average concentrations of about 18.38 mg/L, 2.645 mg/L and 1.85 mg/L, respectively. It is observed that, of all the anions distribution in the water resources, only the bicarbonate ion has an average concentration that is more than the WHO recommended standard of 50.00 mg/L. Figure 4 shows the average concentrations of nickel (Ni), lead (Pb) and cadmium (Cd) are 0.27 mg/L, 0.08 mg/L and 0.05 mg/L, respectively. These values are higher than the WHO recommended values of 0.02 mg/L, 0.01 mg/L and 0.03 mg/L for nickel (Ni), lead (Pb) and cadmium (Cd). Zinc (Zn) which the more abundant metal in the analyzed metals has a concentration of 0.14 mg/L as against the WHO standard of 3.00 mg/L. Copper (Cu) is the most abundant trace element in the water resources and it has a high concentration, averaging 2.483 as against the WHO standard of 0.05 mg/L (Figure 5). Iron is the second most abundant trace element in the water samples with an average concentration of 0.193 mg/L, which is higher than the WHO [10] recommended standard of 0.30 mg/L. The least abundant tracement in the water samples is manganese (Mn) with an average concentration of 0.002 mg/L as against the WHO [10] standard of 0.05 mg/L. Figure 6 revealed that the average concentration of alkalinity is high in the study area, it has an average concentration of about 175.00 mg/L as against WHO [10] of 100.00 mg/L. This is follow by the average concentration of TDS with 88.00 mg/L as against WHO [10] of 500.00 mg/L, while that of pH is 7.08 as against the WHO standard of 6.5 – 8.5. However, the average concentration of alkalinity is far higher than the WHO standard. The measured pH and TDS values fall below the WHO [10] standards.

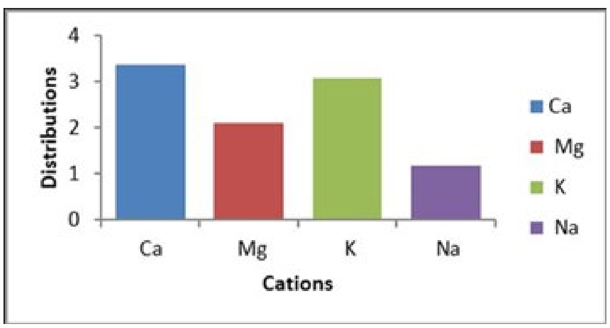

Figure 2. Average distribution of cations in the water resources of the study area

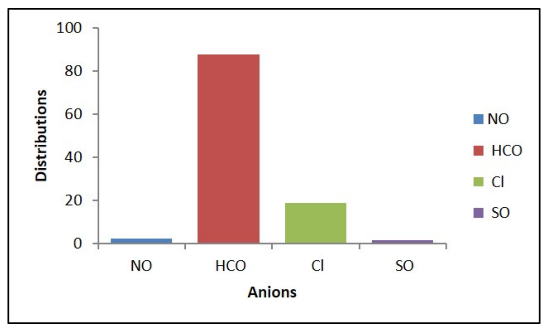

Figure 3. Average distribution of anions in the water resources of the study area

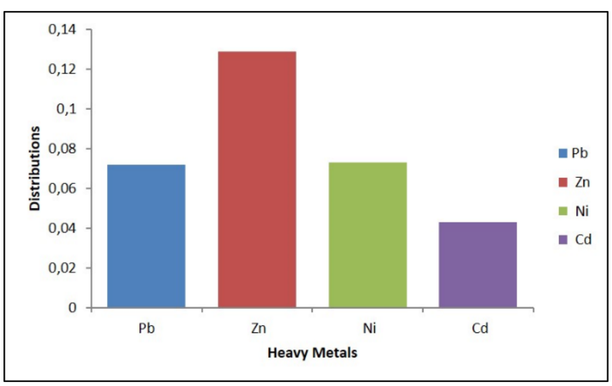

Figure 4. Average distribution of heavy metals in the water resources of the study area

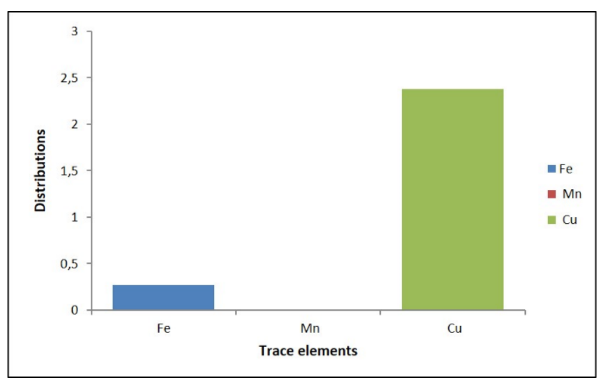

Figure 5. Average distribution of trace elements in the water resources of the study area

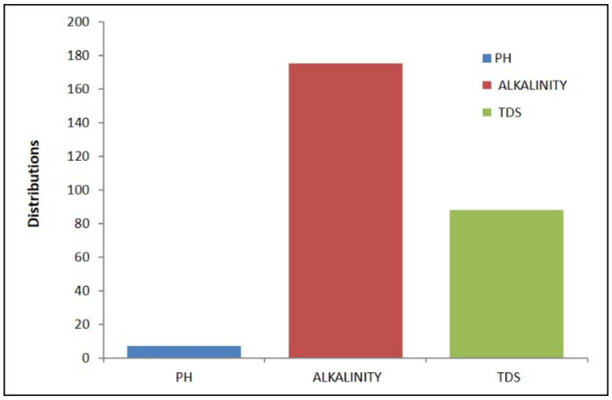

Figure 6. Average distribution of pH, alkalinity and TDS in the water resources of the study area

5. Conclusions

Water is a major necessity of life without which the existence of man on earth will be very difficult, hence the need for the provision of quality potable water. The analysis of the water resources (ground and surface waters) of Agbadu-Bunu Community and its environs was carried out with a view of accessing the water quality by determining the concentrations of cations, anions, trace elements, heavy metals, pH, alkalinity and total dissolved solid distributions as well as the microbial loads contained in the water. Result of the physio-chemical analysis revealed that all the cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) conformed to WHO standard limits for drinking water. Also, majority of the anions conformed to WHO standard limits for drinking water except for the concentration of $HC0_3^-$ in most of the individual water samples. However, the level of pH and TDS are within the WHO limits for drinking water, while the alkalinity concentration in seven sampled water falls above the WHO limits for potable water. The microbiological analysis carried out to determine the microbial loads in the water samples revealed that most of all the water samples analyzed the area is not fit for drinking. The heavy presence of microbial loads (Total Bacterial Count, Total Coliforms Count and E. Coli) in the sampled water makes it unfit for human consumption except in sample G, I and J where the microbial loads fall below the WHO limits for drinking water. It is therefore, of great concern for both the Government, the Scientist, the water companies and individuals to take into cognizance the drinking water quality of the water used around us.

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References

[1] Gucharan S, Jagdishi S. Water supply and Sanitary Engineering, 6th Edition. Standard Publishers. Distributors - Nai Saraki New Delhi, India, 128-131 (2003)
[2] Punimia BC, Ashok J, Arun J. Water supply Engineering, 2nd Edition, Laxi Publications Ltd. New Delhi, India, 256-261 (1995)
[3] Terrence M. Water supply and Sewerage. 5th Edition, illustrated. Publisher, McGraw-Hill, (1991)
[4] Olanrewaju VO, Olorundemi MO, and Alade O. Chemical characteristics of groundwater from some parts of the basement complex of Nigeria. Journal of Mining and Geology, 2007; 33(2): 135-139.
[5] Omada JI, Omali A, and Awodi JI. Physico-chemical characteristics of surface water in parts of Lokoja metropolis, Central Nigeria. Journal of Nigerian Association of Hydrogeologists, 2009; 19: 56-62.
[6] Ajibade OM, Omosanya KO, and Odunsi GO. Groundwater contamination and flow direction of urban aquifer, Ibadan, Southwestern Nigeria. Proceedings, Annual Conference of the Nigerian Association of Hydrogeologists on Water Resources Development and Climate Change (2010)

[7] Yang JE, Kim JJ, Skogley EO, and Schaf BE, A Simple Spectrophotometric Determination of Nitrate in Water, Resin, and Soil Extracts. Soil Science Society of America Journal Abstract, 1997; 62 (4): 1108-111.
[8] Brady KBC. Groundwater, Chemistry, 1998; 2: 2-3.
[9] United States Geological Survey (USGS), New Reporting Procedures Based on Long-Term Method Detection Levels and Some Considerations for Interpretations of Water-Quality U.S. Geological Survey Open-File Report, 1999; 99–193.
[10] World Health Organization (WHO), Library Cataloguing-in-Publication; Data Guidelines for drinking-water quality - 4th edition (2011).

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