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PHYSICOCHEMICAL AND BACTERIOLOGICAL QUALITY OF GROUND WATER AT ABUBAKAR TATARI ALI POLYTECHNIC BAUCHI, NIGERIA

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Abstract

Ground water is an important source of water for domestic use especially in developing countries like Nigeria. Water is said to be safe for drinking when it is free of pathogens, poisonous substances and excessive amount of mineral and organic matter. This research is aimed at assessing the ground water quality at Abubakar Tatari Ali Polytechnic, Bauchi with a view to determining it suitability for domestic utilization. Water samples were collected from the two hand dug wells and two boreholes that were available within the institution in the dry season of 2012. From each of the water sources, five replicate samples were collected for the analysis. Temperature, pH and Conductivity, were directly measured using pH, Temperature and conductivity meters respectively. Total Dissolved Solids (TDS) calculated from the conductivity values obtained. Turbidity determined with a HACH 2100 P Turbidity meter. Nitrate, nitrite, sulphate, phosphate and fluoride, chloride, contents were calorimetrically analyzed using DR890 Colorimeter. Calcium was determined by EDTA titration, while Total Alkalinity was determined by strong acid titration method. Trace elements – Total iron, Copper, Fluoride, Zinc, Lead, Chromium and Arsenic were determined using Atomic absorption Spectrophotometer (AAS) after extraction with Aqua-regia. Total and faecal coliforms were determined by Membrane Filtration method using M-Endo-Agar Les (Difco) at 37^oC and on MFC Agar at 44^oC, respectively. Results of physico-chemical analysis indicated that mean values of Turbidity (6NTU), Total Hardness (195mg/L) and Fluoride 1.59mg/L in water obtained from hand dug wells have exceeded the threshold limits recommended by regulatory authorities. The bacteriological analysis also revealed that all the two ground water sources contained high Total and Feacal Coliform counts and therefore not suitable for drinking. It is recommended among others that proper disinfection should be carried out on the water and the general sanitary condition of the area should be improved.

Keywords: Analysis, Ground water, Quality, Bauchi

Introduction

Water is a key component in determining the quality of our lives. Although water covers about 70 percent of the earth's total surface, only 0.3 % of it can be used by humans (Tiimub *et. al.*, 2012). Among the various source of water, ground water is the largest reservoir of drinkable water

Ground water is that water reservoir found in the saturated part of the ground underneath the land surface. It normally accumulate there when the water seeps into the ground and moves downward due to gravity through the pore spaces found between soil particles and cracks in rock. The water eventually reaches a depth where the soil and rock are saturated (USEPA, 2014). Ground water is an important source of water supply with a number of advantages. Ground water is commonly free from pathogenic organism due to infiltration (and therefore requires little or no treatment), turbidity and color are generally absent, and its chemical composition is almost stationary. Despite these advantages, however ground water is susceptible to pollution as a result of recent or past human activities (Aiyesanmi et. al., 2004; Umar, 2009).

It is an important source of water for agricultural and domestic use especially in developing countries like Nigeria, due to long retention time and filtration capacity of aquifers. Water that is meant for consumption must be safe. Water is said to be safe for drinking when it is free of pathogens, poisonous substances and excessive amount of mineral and organic matter.

Although water is an indispensable commodity for sustenance of life, there is however an inherent danger associated with it consumption when it is polluted. Polluted water is that which contained industrial, agricultural or domestic waste or even other naturally occurring chemical in excess amount as to render the water unacceptable for its intended usage. Any substance that causes such undesirable changes in the water quality is known as a pollutant. Assessment of the concentration of chemicals and other pollutants in ground water will help in ensuring safe water supply as a way of curtailing many direct threats to human health.

ATAP is one of the institutions of higher learning in Bauchi metropolis. The campus located along Bauchi/Jos road has been in existence for quite a long time. In recent times however there is growing interest in terms of infrastructural facilities on the campus because of its merger with another school, thus increasing the number of students on the campus. This mass increase in the students' population no doubt has increase the pressure on the available infrastructural facilities in the campus. This research is aimed at assessing the ground water quality at ATAP with a view to determining it suitability for domestic utilization.

Materials and Methods

Study Area

This study was conducted at Abubakar Tatari Ali Polytechnic main campus (comprising schools of Engineering and Social Sciences) located at Wuntin Dada along Bauchi/Jos road in Bauchi Metropolis. The campus is situated along Bauchi- Jos road, about 4 kilometers west of Bauchi town on Lat. $10^0$18'N and Long. $09^0$48'E. To the east the campus bound the Tambari Housing Estate, Bauchi and NNPC mega station to the west and directly opposite (to the north) is Wuntin Dada settlement.

It is located on the ancient basement region the crystalline basement comprises the remnant of igneous and highly concentration of metamorphic and sedimentary rocks of cretaceous tertiary age. The micro geology is of the charnecite and bauxite of the Palaeozoic age. Relatively, there is no adverse feature of the Bauchi geology that would hinder development of the study area. For most times of year, the town is apparently hot. The highest temperature recorded at those times is between 40^oC to 45^oC. The average rainfall stands at $1.0914mm^3$ while the daily humidity increases to 94% in the middle of the rainy season but drops more drastically to less than 10% during the harmattan period (Belee, 2004).

Sampling Procedure

Water samples were collected from 2 hand dug wells and 2 boreholes that were available within the institution in the dry season (January - March) of 2012. From each of the water sources, five replicate samples were collected for the analysis. Standard precautionary measures were adopted to avoid cross contamination of samples. In order to collect water from a borehole, the tap was disinfected through flaming. This was done by lighting cotton soaked in methylated spirit. The selected boreholes were also flushed for a while to ensure that samples collected came directly from the underground water aquifer. Sterilized plastic containers were used for collecting water from hand dug wells. This was done carefully to avoid contact between the containers and walls of the wells, thus avoiding contamination of samples. Well labeled sterile bottles were used to collect the water sample, and were tightly closed immediately. The samples where transported at low temperature (4^OC) to the laboratory for physicochemical and Bacteriological analysis.

Laboratory Analysis

The choice of water quality parameters for this investigation was based on WHO (1996) and NSDWQ (2004) guidelines. The physical properties investigated were Electrical Conductivity, Temperature, Colour, Turbidity and Total dissolved solids. Chemical parameters investigated includes pH, Total Hardness, Total alkalinity**,** Calcium, Magnesium, Total iron, Copper, Fluoride, Zinc, Nitrate, Nitrite, Sulphate, Chloride, Phosphate, Ammonium, Lead, Chromium, Arsenic. The biological properties determined were total coliform and faecal coliform.

Physicochemical and Bacteriological Analysis

Temperature, pH and Conductivity, were directly measured using pH, Temperature and conductivity meters. Total Dissolved Solids (TDS) calculated from the conductivity values obtained. Turbidity determined with a HACH 2100 P Turbidity meter. Nitrate, nitrite, sulphate, phosphate and fluoride, chloride, contents were colorimetrically analysed using DR890 Colorimeter. Alkalinity was done by titrating 100 ml of the samples with 0.02 M HCl solution using methyl orange as indicator and chloride by titrating 100 ml of the samples with a standard solution of 0.0257 M $AgNO_3$ solution using 1.00 ml solution of 5.00% $K_2Cr_2O_4$ as indicator (AOAC, 1984) EDTA titration method as described by the American Public Health Association, APHA (1992) was used to determine the hardness of the water samples. Calcium and Magnesium were determined by EDTA titration, while Total alkalinity was determined by strong acid titration method. Trace elements – Total iron, Copper, Fluoride, Zinc, Lead, Chromium, Arsenic were determined using Atomic absorption Spectrophotometer (AAS, Unicom 969) after extraction with Aqua-regia.

Total and faecal coliforms were determined by Membrane Filtration Method using M-Endo-Agar Les (Difco) at 37^oC and on MFC Agar at 44^oC, respectively.

Data analysis

Simple descriptive statistics (means and standard deviations) were used to interpret the raw data on the physicochemical and bacteriological parameters generated in the cause of this investigation

Result and Discussion

Physical parameters

The results of the physical parameters of the water quality obtained in the course of this investigation are as presented in Table 1.

Table 1. The mean physical characteristics of underground water in ATAP Bauchi metropolis

S/N	Parameters	Boreholes	Hand Dug wells	NSDWQ	WHO
1.	Temperature(^{0}c)	26.2	25.9	N/A	N/A
2.	Colour (Pt.Co.unit)	5.2	6.5	15	15
3.	Turbidity(NTU)	1	6	5	5
4.	Electrical Conductivity(µS/cm)	360	640	1000	1000
5.	Total Dissolved Solid (mg/L)	155	320	500	1500

Temperature

The mean temperature of water samples obtained from the hand-dug wells and boreholes were 25.9 ^{o}C and 26.2 ^{o}C respectively .Though not defined by Nigerian Standard Drinking Water Quality (NSDWQ) and World Health Organization (WHO), the temperature values are only slightly above normal room temperature as of the time of samples collection. The temperature is being influenced by solar radiation.

Colour

The colour of drinking water reflects the presence of suspended matter. Therefore the more suspended matter in water the greater is the colour. In exceptional circumstances however, color may arise naturally from the presence of colloidal Iron/Manganese in water. The mean values of 6.5pt.co.unit and 5.2pt.co.unit were recorded for hand dug well and borehole water samples respectively. All the values did not exceed those recommended by both NSDWQ and the WHO of 15pt.co.unit.

Turbidity

The turbidity measures the degree to which the water losses its transparency due to the presence of suspended particles. Turbidity in water arises from the presence of very finely divided solids (which are not filterable by routine methods). The existence of turbidity in water affects its acceptability to consumers and it will also affect markedly its utility in certain industries (EPA, 2001). From the result obtained, mean Turbidity values of water from hand dug wells and boreholes were 6NTU and 1NTU respectively. The mean turbidity value of water samples obtained from Hand dug wells was above the maximum acceptable limits of 5 NTU recommended by both NIS and WHO, The high level of turbidity in water from the hand dug well is source of concern because the particles forming the turbidity could harbour and shield pathogenic organisms and hence escape the action of the disinfectant (EPA, 2001).

Total Dissolved Solids (TDS)

This parameter arises from the dissolved substances from organic compounds as well as decomposition of inorganic substances such as nitrate and carbonate. From the result obtained, mean TDS values of 320mg/L and 155mg/L were recorded for the hand dug wells and bore water samples respectively. All the samples however did not exceed the limits of 500 and 1500 recommended by NSDWQ and WHO respectively.

Electrical Conductivity (EC)

Electrical conductivity (EC) in natural waters 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 water samples collected from the hand dug wells have relatively higher value of EC than the samples obtained from Boreholes. Mean values of 640µS/cm and 360µS/cm were recorded for water samples from hand dug wells and boreholes respectively. All the values fall within the recommended limits of 1000µS/cm set by NSDWQ and WHO.

Chemical Parameters

The chemical characteristics of the underground water obtained from ATAP are as presented in Table 2.

Table 2. The mean values of chemical parameters in underground water obtained from ATAP in Bauchi metropolis

S/N	Parameters	Boreholes	Hand Dug wells	NSDWQ	WHO
1.	Total Hardness as ($CaCO_3$)mg/L	145	193	150	N/A
2.	Total alkalinity as ($CaCO_3$)mg/L	101.5	128	100	N/A
3.	Calcium,Ca^{2+}(mg/L)	45.00	67.30	75	50
4.	Total Iron,Fe^{2+}(mg/L)	0.025	0.112	0.3	0.3
5.	Copper,Cu^{2+}(mg/L)	0.005	0.084	1	1-1.5
6.	Fluoride, F^-(mg/L)	0.63	1.60	1.5	1.5
7.	Zinc,Zn^{2+} (mg/L)	0.254	0.214	5	5
8.	Nitrate,NO_3^-(mg/L)	8.306	6.00	50	N/A
9.	Nitrite,NO_3^-(mg/L)	0.005	0.075	0.2	3
10.	Manganese,Mn^{2+}(mg/L)	0.000	0.000	0.5	1-1.5
11.	Lead,Pb^{2+}(mg/L)	0.00	0.00	0.001	0.05
12.	Sulphate,SO_4^{2} (mg/L)	10.00	94.17	200	200
13.	Chloride, Cl^-(mg/L)	23.74	84.99	250	200

14.	Chromium, Cr^{+6}(mg/L)	0.000	0.000	0.05	N/A
15.	Cyanide, CN (mg/L)	0.000	0.000	0.001	0.07
16.	Arsenic(mg/L)	0.000	0.000	0.001	N/A

Total Hardness

Total hardness is defined as the sum of calcium and magnesium concentration in mg/L. It is a measure of the capacity of water to precipitate the soap. Soap is precipitated mainly by calcium and magnesium present in polyvalent cation and they are often in complex forms frequently with organic constituents (Jayalakshmi, *et. al.,* 2011). The mean values of Total Hardness recorded in samples collected from the boreholes and hand dug wells were 145mg/L and 193mg/L respectively. No specific value was mentioned by WHO as the threshold limit for Total Hardness in water. However if the limit set by NSDWQ is considered, The mean Total Hardness in water collected from the hand dug well has exceeded the limit of 150mg/L recommended by the regulatory authority. This means the water obtained from hand dug well may develop hard scales on cooking utensils and other metal objects when heated, and the life and efficiency of the heating equipment will be reduced. It may also make soap to curd in water instead of lather.

Total Alkalinity

The alkalinity in water is mainly due to the presence of bicarbonates. It is a measure of the capacity of the water to neutralize acids and it reflects its inherent resistance to changes in pH. Water samples from boreholes and hand dug wells had mean total alkalinity values of 101.50mg/L and 128mg/L respectively. The level of alkalinity in the water samples collected from all the two water sources have exceeded the limit of 100mg/L given by NSDWQ. No specific value is available for WHO water quality standard for this parameter.

Calcium

Calcium is an element that is found naturally and in abundance in the earth crust. It is an important and abundant element in the human body and an adequate intake is essential for normal growth and health. Ca is the most important element causing hardness in water. Water from the boreholes and hand dug wells had the mean Ca concentrations of 45mg/L and 67.3mg/L respectively. Compared to the threshold limits of 45mg/L and 67.3mg/L given by NSDWQ and WHO respectively, the Ca contents of all the water samples did not exceed the required standards.

Total Iron

Iron is the fourth most abundant element, by weight, in the earth's crust. Iron in groundwater is normally present in the soluble ferrous (Fe^{2+}) form. It is easily oxidized to the insoluble ferric (Fe^{3+}) state upon exposure to air. The amount of Fe in water varies depending on the geology of the area and other chemical constituents of the water. Underground water normally contained Fe^{2+} due to lack of enough oxygen in the aquifer. The water collected from borehole and hand dug well contained 0.02mg/L and 0.11mg/L of Fe respectively. All the values falls within the acceptable limits of 0.30 each recommended by NSDWQ and WHO.

Copper

Copper and its compounds are widely distributed in nature, and copper is found frequently in surface water and in some groundwater. Copper is an essential element in human metabolism, and it is well-known that deficiency results in a variety of clinical disorders, including nutritional anaemia in infants. Although the intake of large doses of copper has resulted in adverse health effects, the levels at which this occurs are much higher than the aesthetic objective (Health Canada, 1992). The mean Cu content of all the water samples collected from Boreholes and Hand dug wells were 0.005mg/L and 0.084mg/L respectively. All the values falls within the limits set by both NSDWQ and WHO.

Fluoride

Fluoride content in drinking water is of interest because it exhibits unique properties as its concentration in optimum dose is beneficial and concentration in excess of the optimum affect the health. High fluoride concentration in the ground water and surface water in many parts of the world is a cause of great concern. The main source of fluoride in ground water is fluoride-bearing rocks such as Fluorspar, Fluorite, Cryolite, Fluorapatite and Hydroxylapatite (Meenakshi, et. al., 2004). The concentration of fluoride in water is also dependant on other factors including the geology of the area, depth of aquifer and other physic-chemical characteristic of the water (Worl *et., al.*, 1973). The chemical analysis revealed that the mean fluoride content of water collected from boreholes and hand dug wells were 0.62mg/L and 1.59mg/L respectively. It has been established that drinking water should have a fluoride concentration from of 1-15mg/L. At this concentration, fluoride is beneficial as it prevent tooth caries especially among children. However, the consumption of water that contains ingestion fluoride in excess of 1.5 mg/l can cause dental and skeletal fluorosis. It may be concluded therefore that water samples collected from all the two sources are not good for human consumption. The water from borehole contained mean fluoride value less than 1 mg/L, while samples from Hand dug well mean fluoride in excess of 1.5mg/L

Nitrate and Nitrite

Elevated nitrate levels in drinking water are often caused by groundwater contamination from animal waste, excessive use of fertilizers, or seepage of human sewage from private septic systems. Nitrite is of particular health concern in the body because it causes the hemoglobin in the blood to change to methemoglobin. Methemoglobin reduces the amount of oxygen that can be carried in the blood. This results in cells throughout the body being deprived of sufficient oxygen to function properly. This condition is called methemoglobinemia (ATSDR, 2000). Nitrite can react with secondary amines in human stomach to form the highly carcinogenic N-nitroso compounds (Gray, 1994) The mean nitrate levels in water samples obtained from the boreholes (8.31mg/L) and 6.00mg/L were all below the recommended limits of 50mg/L set by NSDWQ and WHO. Only 0.005mg/L and 0.076mg/L mean nitrite concentrations were recorded in water samples collected from boreholes and hand dug wells respectively. Thus mean nitrite levels in water samples from the two underground water sources were also far below the threshold limits of 0.2 and 3.0 recommended by NSDWQ and WHO respectively

Manganese

Manganese occurs naturally in many surface water and groundwater sources and in soils that may erode into these waters. However, human activities are also responsible for much of the manganese contamination in water in some areas (WHO, 2011). The NSDWQ and WHO recommends a threshold limits of 0.5mg/L and 1-1.5mg/L Mn levels respectively in drinking water. No Manganese was however detected in samples obtained from all the underground water sources under consideration.

Sulphate

Sulphate minerals are widely distributed in nature, and the sulphate anion (SO_4^{2-}) is a common constituent of unpolluted water. Sulphates may be leached from most sedimentary rocks, with appreciable contributions from such sulphate deposits as gypsum. The result of this investigation revealed that mean sulphate concentrations of 10.00mg/L and 94mg/L were detected in water samples obtained from boreholes and hand dug wells respectively. All the mean values have complied with the limits of 200mg/L recommended by both NSDWQ and WHO.

Chloride

Chlorides are widely distributed in nature, usually in the form of sodium, potassium, and calcium salts (NaCl, KCl, and CaCl2), although many minerals contain small amounts of chloride as an impurity. Chlorides in water are more of a taste than a health concern, although high concentrations may be harmful to people with heart or kidney problems (Weiner, 2000). The mean chloride concentrations in both Boreholes (23.74mg/L) and hand dug wells (84.99mg/L) falls within the limits of 250mg/L and 200mg/L set by NSDWQ and WHO respectively.

Heavy Metals

Heavy metals are defined as chemical elements with specific gravity that is at least 5 times the specific gravity of water. A heavy metal is also defined as any metallic chemical element that has a relative high density and is toxic or poisonous at low concentration. These heavy metals are natural components of the earth crust that cannot be easily degraded or destroyed. To a small extent they enter our bodies via food, drinking water and air.

As trace elements, some of these metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body while others (such as Cadmium and Chromium) are not known to have any biological functions. However, at higher concentration all heavy metals are potentially toxic. Heavy metals poisoning could result for instance, from drinking contaminated water or other forms of intake via the food chain. Heavy metals toxicity can result in damaged or reduced metal and central nervous function, lower energy levels and liver kidneys liver and other vital organs. Long term exposure may result in slow but progressive physical, muscular and neurological degenerative processes that mimic Alzheimer’s disease, Parkinson’s disease, muscular dystrophy and multiple sclerosis. Allergies are not uncommon and repeated long term contact with some metals or their compounds may even cause cancer.

The heavy metals considered for this investigation were Zinc, Lead, Arsenic, Cyanide and Chromium. With the exception of Zinc, none of the heavy metals investigated in the course of this work was detected in the water samples analyzed. The mean Zinc concentrations in boreholes and hand dug wells were 0.245mg/L and 0.214mg/L respectively. All the mean values much lower than the critical limits of 5mg/L set by both NSDWQ and WHO. All the other Metals under investigation were not detected in either of the ground water sources.

Bacteriological Analysis

The bacteriological characteristics of the underground water obtained from ATAP are as presented in Table 3.

Table 3. The mean bacteriological parameters of water quality obtained from Hand dug wells and boreholes obtained from underground water sources in ATAP Bauchi

S/N	Parameters	Borehole	Hand dug well	NSDWQ	WHO
1	Faecal coliform (cfu/100ml)	199	210	0	0
2	Total Coliform (cfu/100ml)	618	531	10	0

It is well established that a large number of infectious diseases are transmitted primarily through water supplies contaminated with human and animal excreta particularly faeces. Coliform bacteria are described and grouped based on their common origin or characteristics, as either Total or Faecal Coliforms. The Total group includes Faecal Coliform bacteria such as *Escherichia coli (E .coli),* as well as other types of Coliform bacteria that are naturally found in the soil. Faecal Coliform bacteria exist in the intestines of warm blooded animals and humans, and are found in bodily waste, animal droppings, and naturally in soil (WHO, 2003) Coliform bacteria are used as water quality indicators because their presence in drinking water may indicate a possible presence of harmful, disease-causing organisms. Their detection in drinking water is also relatively simple and economical (Health Canada, 2011).

The bacteriological analysis revealed that all the underground water sources contained Coliform bacteria. The mean Feacal Colifrom in water samples obtained from hand dug wells (199 cfu/100ml) was relatively lower than that of boreholes with mean value of 210cfu/100ml. The mean Total Coliform in the boreholes water (618cfu/100ml) was however higher than that of the hand dug wells (531cfu/100ml).

According to WHO, no feacal coliform should be detected in any 100ml of drinking water. The NSDWQ however recommends that although feacal coliform should not be detected in any 100ml, the authority recommend 10cfu/100ml as the maximum permissible total coliform in any drinking water. From the result, it may be concluded that drinking water samples collected from all the underground water sources are not safe for human consumption.

Conclusion and Recommendation

The analysis of water obtained from ATAP revealed that samples obtained from the two ground water sources contained one form of contaminant or the other. In particular, the water samples contained bacterial contaminants in excess of the recommended limits set by NSDWQ and WHO. It recommended therefore that proper disinfection should be carried out on the water supply in order to eliminate these contaminants. Detail survey and evaluation on the area surrounding the ground water sources should be carried out to determine the possible sources of all the pollutants. The general sanitary condition of the area should be improved to eliminate the possible sources of contamination.

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