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Evaluation of Groundwater Quality in Some Rural Areas of the Federal Capital Territory, Abuja, Nigeria

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ABSTRACT

This research work assessed the quality of groundwater samples obtained from Durumi, Pigbakasa, Apo village, Kagini and Damangaza rural areas in Federal capital territory, Abuja, Nigeria. The physicochemical properties and the concentration of some heavy metals in the water were determined using standard methods. The results obtained showed that the pH, electrical conductivity, alkalinity, hardness, and total dissolved solids ranged between; 5.30 – 6.85, 39.8-276.8 , 5-80 mg/l, 48-624 mg/l, and 4-9100 mg/l respectively. Pb, Cr and Cd ranged between 0.01-0.31mg/l, 0.08-0.49 mg/l and 0.07-0.25 mg/l. Bacteriological analysis indicated contamination of the water. The results were compared to WHO/EPA/NSDQW standards which revealed that some of the water was mildly acidic, has low electrical conductivity and high concentration of Pb, Cr, and Cd. The groundwater from these areas is therefore contaminated with respect to some of the parameters determined.

Key words: Abuja, assessment, groundwater, physicochemical

Abbreviation:

TDS: Total dissolved solid, WHO: World health organization, USEPA: United state environmental protection agency, EPA: Environmental protection agency, NSDQW: Nigerian standard for drinking water quality

INTRODUCTION

Water is one of the important basic amenities to life and it's essential for human survival. It covers 71% of the earth's surface and it is used for many purposes such as industrial, agricultural and domestic uses. Access to and use of safe drinking water can make an immense contribution to human health, but when polluted it becomes an undesirable substance dangerous to human health. Acute shortage of good quality water has been the challenge of most rural populace.

Water is an important resources that needs to be protected from pollution and biological contamination [1]. Unfortunately in many countries around the world clean water has become a scarce commodity as only small proportion of the populace have access to treated water [2]. Water related diseases are the single largest cause of human sickness and death, thus improvement of access to clean water is a crucial element in the reduction of underage mortality in rural areas [3]. Human welfare and economic development generally depend on the use of water. In Nigeria, water resource management and utilization is crucial to the country's effort to reduce poverty, grow the economy, ensure food security and maintain the ecological systems. Nevertheless, the issue of water resources management in the country focuses on the quality water supply [4].

Many people living in rural settlements who do not have access to clean water rely on unimproved water sources such as Dam, reservoir, rivers and groundwater. The most available sources are the groundwater and the people depend mostly on it to get their daily needs of water for domestic uses. The quality of groundwater is highly related to local environmental and geological conditions, such as the quality of soil and rock types found in the area. In Nigeria, groundwater is the most common source of water in rural communities; it has proved to be the most reliable resource for meeting water demand in rural areas.

The primary source of drinking water in most developing countries is the groundwater which can be from boreholes and wells. [5] stated that 37% of rural populace in Blantyre (Malawi) depends on boreholes while 26% depend on shallow wells. Another study in Sudan by [6] estimated that 80% of the inhabitants of Sudan depend on groundwater. [7] stated that groundwater is the major source of water for drinking, agriculture and industrial desires in Sagar city, India. Groundwater in Nigeria is accessed mainly in form of shallow deep wells which is considered as the main source of water for most rural settlements. A research work by [8] estimated 44% of populace in sub Saharan Africa depends on groundwater source.

According to Hijab *et al* [9], groundwater resources are abundant and they make a major source of drinking water in Ethiopia. About 2 billion people approximately one-third of the population worldwide depend on groundwater supplies [10]. Lack of drinking water has always been a major issue in developing countries like Nigeria where many of the rural populace do not have access to adequate water and therefore depend mostly on groundwater for domestic use. Groundwater is considered the major sources of water used for agricultural and domestic purposes in most rural communities around F.C.T. Groundwater quality depends on its chemical composition which may be modified by natural and anthropogenic sources. [9] stated that rapid urbanization has affected the availability and quality of groundwater due to waste disposal practice which should be regulated to check the contamination of water from this source. As groundwater has a huge potential to ensure future demand for water in rural areas, it is important that human activities on the surface do not affect the precious source.

The aim of this research work is to determine the quality of groundwater in some communities of Federal capital territory of Nigeria by determining some physiochemical parameters and heavy metals in the water samples obtained from these rural communities in F.C.T, Comparison of the result obtained with regional and international water standards were done. Application of local purification process (boiling) to determine their effects on the water quality in those regions was also carried out.

MATERIALS AND METHODS

Sampling

A total of twenty five groundwater samples were collected from different wells at five rural communities in the FCT which were Kagini, Damangaza, Durumi, Pigbakasa and Apo village, using 1.5 L plastic bottles. Each bottle was sterilized with diluted nitric acid before filling it with water.

The pH, conductivity, alkalinity, hardness, total dissolved solid, and the presence of some heavy metals in the samples were determined.

Determination of pH

The pH meter was calibrated and inserted in 100ml of the water samples in a measuring cylinder and the reading was taken.

Determination of Conductivity of the Samples

The conductivity probe was calibrated and inserted in 100 mL of the water samples in a volumetric flask and the reading was taken.

Determination of Alkalinity of the Water Samples

Approximately 500mL of distilled water was poured into a 1000 mL beaker. 20mL of concentrated 0.1 normality sulphuric acid was added slowly into the beaker. The burette was rinsed and filled with the Sulphuric acid solution up to zero mark using a funnel. The burette was clamped on the retort stand and the titrant was titrated against a 100 ml of the water sample in a volumetric flask containing two drops of methyl orange as an indicator. The titration was continued until a dark red colour is obtained which mark the end point. The total alkalinity was deduced using the following formular-

Volume of sulphuric acid × Normality of sulphuric acid × equivalent weight of $CaCO_3$ × 1000/volume of sample used

Normality of sulphuric acid=0.01N

Equivalent weight of $CaCO_3$=50

The volume of sample used was 100mL

It is multiplied by 1000 to convert to L from mL

Determination of Total Hardness of Samples

About 3.723g of EDTA sodium salt was weighed using an analytical balance and transferred to a 1000mL standard flask. The flask was filled with distilled water up to the 1000mL mark and stirred with magnetic stirrer until salt dissolved. The burette was rinsed and filled with EDTA solution up to zero mark. The EDTA solution was titrated against 50 ml of the sample in the volumetric flask containing 5 drops of k-10 buffer. 2 drops of net solution was added to the water samples changing it to black. The titration was carried out until the colour changed to green

The total hardness of the water samples was deduced using the following formular.

Volume of EDTA × Normality of EDTA × equivalent weight of $CaCO_3$ × 1000/Volume of sample used Normality of EDTA=0.02N

Equivalent weight of $CaCO_3$=50

The volume of sample used was 50ml

It is multiplied by 1000 to convert to L from ml

Determination of Total Dissolved Solids

The evaporating dish was weighed using an analytical balance and the weight recorded as (W_1). The filtered sample was transferred into the dish and heated in an oven to a constant mass at 103^oC. The new weight of the evaporating dish was recorded as W_2. Increase in the weight indicates the presence of dissolved solids. The total dissolved solids was deduced using the following formular

Change in weight=W_2 - W_1

TDS= change in weight ×1000 (It is multiplied by 1000 to convert it from grams to mg) / number of mL's used

It is multiplied with 1000 to convert to mg/L

Bacteriological Analysis of the Water Samples

The Presumptive Test

10 ml of lactose broth was poured into McCartney bottle and diluted with 10 ml of distilled water. A durham tube was inserted into the McCartney bottle. The bottle containing the water sample and lactose broth was stored in an incubator for 24 hours at a temperature of 36 ^0C.

The confirmatory Test

After 24 hours the McCartney bottle was removed from the incubator and observed for production of air bubbles which indicates the presence of the coliforms,

The Complete Test

The EMB was poured into the petri dish and was allowed to solidify. A sterile wire was used to streak the water sample from the confirmatory test. It was stored for 24 hours and observed for a Change in colour. Change in the colour of the EMB indicates the type of bacteria present.

RESULT AND DISCUSSION

Table 1: Statistical evaluation of some physiochemical parameters of groundwater samples obtained from Durumi, Pigbakasa, Apo village, Kagini and Damangaza in FCT with the permissible ranges

Parameters	Range	Mean value	WHO	NSDWQ	EPA
pH	6.5-6.88	6.35	6.5-8.5	6.5-8.5	6.5-8.5
Conductivity	39.8-276.8	147.45	1500	1000	1000
Alkalinity mg/L	5-80	19.6	200	200	200
Hardness mg/L	48-624	270.35	200	150	200
TDS mg/L	4-9100	1196.2	1000	1000	1000
Bacteriological analysis	All contaminated	-	0/100	0/100	0/100
Lead mg/L	0.01-0.31	0.095	0.015	0.015	0.015
Chromium mg/L	0.08-0.49	0.344	0.15	0.15	0.15
Cadmium mg/L	0.07-0.25	0.16	0.05	0.05	0.05

Table 2: Mean physiochemical parameters of groundwater obtained from five villages under FCT.

Villages	pH	EC	Total Alkalinity mg/L	Total Hardness Mg/L	TDS mg/L	Bacteriological Analysis	Lead mg/L	Chromium mg/L	Cadmium mg/L
Kagini	6.72	240.8	10.6	243	4476	All contaminated	0.04	0.09	0.09
Damangaza	6.40	76.7	12.6	486.5	903	All contaminated	0.08	0.21	0.14
Durumi	5.56	202.1	29.6	164	215	All contaminated	0.19	0.35	0.22
Pigbakasa	6.50	78.7	23.7	204.5	95	All contaminated	0.012	0.42	0.23
Apo village	6.58	138.8	8.25	259.5	292	All contaminated	0.06	0.47	0.22
WHO	6.5-8.5	1500	200	200	1000	0/100	0.015	0.15	0.05
EPA	6.5-8.5	1000	200	200	1000	0/100	0.015	0.15	0.05

NSDWQ /	6.5-8.5	1000	200	150	1000	0/100	0.015	0.15	0.05

Table 3: Classification of the water samples based on TDS classes

<500	12 samples	60%	Non saline	Excellent
500-1000	3 samples	15%	Non saline	Good
1000-1500	3 samples	15%	Slightly saline	Fair
>2000	2 samples	10%	Moderately saline	Poor

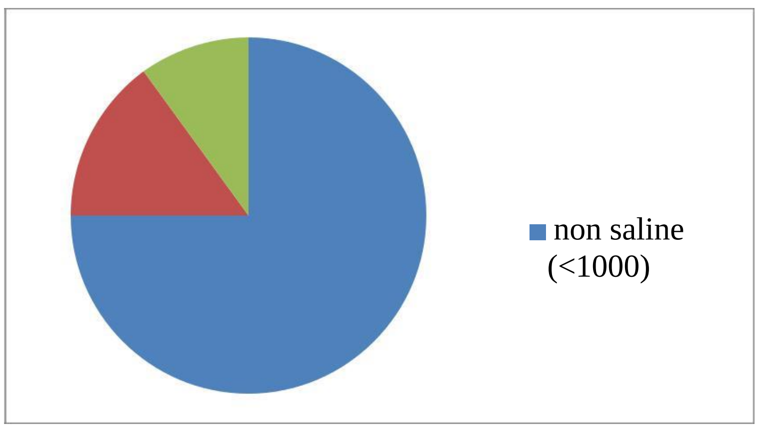

Figure 1- Classification of TDS of the water samples obtained based on salinity

Table 4: Classification of the water samples based on total hardness range

Description	Hardness (mg/L)	number of samples	%
Soft	0-75	3	15%
moderately hard	75-150	2	10%
Hard	150-300	9	45%
Very hard	over 300	6	30%

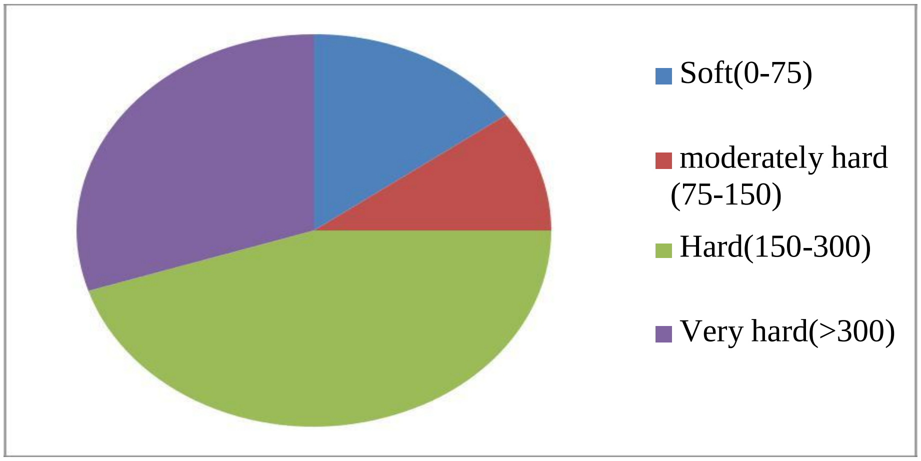

Figure 2- Classification of water samples based on total Hardness range.

Plate 1- Water samples before Incubation

Plate 2- Water samples after Incubation

Table 5: EMB analysis of the water samples obtained from the villages within FCT

Colour	Bacteria's	Water samples (%)
Orange	Enterobacter aerogenes	25%
Green metallic sheet	E.coli	40%
Pink	Other coliforms	35%

Plate 3 - Water samples before and after boiling.

Note. BB: Before Boiling; AB: After Boiling

pH

The average pH of the water samples obtained from the five villages within FCT (Kagini, Damangaza, Durumi, Pigbakasa and Apo village) ranged between 5.30 and 6.88 and were within the optimum limits of 6.5-8.5 set by WHO, EPA and NSDQW which is favorable for human consumption [11]. Some of the water samples in Durumi, Pigbakasa and Damangaza were found to be acidic and is considered unfavorable for human consumption. Acidic water may be due to the carbon dioxide in the water. According to [12] the more CO_2 present in the water, the more acidic the water. High acidity in water can be due to high level of dissolved CO_2 in the study area which is a reflection of high level of industrialization in the area [13]. According to [14], acidic water causes aesthetic problems in the water such as sour taste and also low pH may lead to increase in concentration of lead, copper and zinc which may have health effect on the people that consume it. Although pH usually has no direct impact on water consumers, it is one of the most important water quality parameter that has to be carefully monitored to avoid leaching of metals in the water, sour taste and skin irritations [15].

Conductivity

The conductivity value of all the water samples obtained from Durumi, Pigbakasa, Damangaza, Kagini and Apo village ranged from 39.8 to 276.8 and were all found to be below the optimum standard of between 1000 and 1500 set by WHO, EPA and NSDQW making the water safe for consumption. According to [16], water samples having conductivity above 1000 can pose health risk of defective endocrine functions and also total brain damage. Electric conductivity of water relates to the total concentration of dissolved ions in the water. In this analysis, all the water samples obtained from the villages were all below the standards which may be due to low concentration of dissolved ions in the water. According to EPA, conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate and phosphate ions and also presence of oil, phenol and sugar in water can lead to low conductivity in water. Conductivity is also affected by temperature (the higher the temperature, the higher the conductivity and the lower the temperature the lower the conductivity) [17]. In all the study areas the temperature was found to be between 24.9 and 26.0 which may also have contributed to low conductivity. The highest conductivity recorded was in Kagini ranging from 164 to 276, this could possibly be due to industrial and human waste observed in the study area. Overall all the water samples tested were found to be safe for consumption considering the conductivity level because none of the water samples exceeded 1000.

The Total Alkalinity

The total alkalinity of the water samples obtained from Kagini, Pigbakasa, Durumi, Damangaza and Apo village were all found to be below the 200 maximum limit set by EPA, NSDQW and WHO. The total alkalinity value ranged between 5 and 80 which was similar to the result obtained by [18] on the assessment of groundwater in Ghana. According to WHO, low alkalinity can be corrosive and can also irritate the eyes. Alkalinity less than 75mg/L can make the water corrosive leading to potentially harmful metals dissolving in the water [19]. 95% of the water samples obtained from the study areas had alkalinity lower than 75mg/L which may have a potential effect on the water and the people that consume it.

Total Dissolved Solid

The analysis of the water samples obtained from Kagini, Durumi 3, Damangaza, Apo village and Pigbakasa for TDS showed a wide variation in concentration of TDS ranging from 4mg/L to 9100mg/L. Comparison with the recommended standards and guidelines for the TDS in drinking water revealed that some samples were above the maximum limits of 500mg/l set by EPA, WHO and NSDWQ. The result indicates that 60% of the groundwater samples have TDS below the permissible limit of 500mg/L which is similar to an analysis in Sudan by [20] with 87.6% of the groundwater samples lying well below 500mg/L. According to WHO, TDS level below 2000 is suitable for consumption and may not be detrimental to health. This analysis showed that 90% of the water samples were found to be below 1500 which is acceptable for household use but can possibly have poor taste [21]. TDS below 1000 are said to be non-saline but above 1000 are said to be slightly saline. Non saline water are said to be favorable while saline water are said to be unfavorable for drinking. [22] stated water with salinity level beyond 1500mg/L is considered unsuitable for drinking but could be used for irrigating crops with good salt tolerance. From this analysis 25% of the water samples were found to be saline. According to Al-turki [22], causes of high salinity in water includes over exploitation, excessive pumping, run-off water, soil weathering and agricultural drainage water. In most of the study areas, activities such as industrialization and agricultural practices are common, which may have been the causes of high salinity of water in the areas. According to [19] high salinity can damage crops, affect plant growth and degrade drinking water.

Total Hardness

Total hardness value of the samples obtained from Kagini, Durumi, Damangaza, Pigbakasa and Apo village ranged from 48mg/L to 624mg/L respectively. The total hardness was compared with the WHO, EPA and NSDWQ standards for drinking water and it was found that only 15% of the samples tested were soft while 85% of the water samples were hard. According to the classification based on WHO and EPA, 75% of the water samples are higher than the optimum limit making it unfavorable for consumption. The finding was similar to that of [20] which showed that TDS of groundwater in Sudan were above the permissible limit. WHO (2010) stated that groundwater often contained significant levels of hardness but its consumption may not pose any health effect rather it makes the water undesirable due to its strong dry taste and concentration. In another statement by [20], hard water can cause certain adverse effects on body due to the presence of other minerals which do not benefit the body such as copper and lead. The presence of minerals and metals in the water may be attributed to the presence of rocks and agricultural activities in the study areas because hardness of water is mostly caused by minerals leached from sedimentary rocks and soil, such minerals include calcium and magnesium which are the major causes of extreme hardness in water. Calcium and magnesium are used as fertilizers for crop growth which may end up in the water due to soil run-off increasing the calcium and magnesium in the water leading to increase in hardness [19].

Bacteriological Analysis of Water Samples Obtained From Five Villages Within FCT

The bacteriological analysis was carried out on all the water samples obtained from Durumi, Pigbakasa, Kagini, Damangaza and Apo village to analyze the presence of bacteria's in the water. Plate 1 shows the McCartney bottles containing the water sample obtained from the villages and lactose broth before incubation while plate 2 shows the McCartney bottles after incubation. From figure 3, no bubbles were observed while in plate 2, a lot of bubbles were observed which may be due to the presence of bacteria's in the water. Based on the analysis, all the water samples were found to be contaminated with various forms of bacteria's making the water unfavorable for consumption. According to WHO, the amount of bacteria's in the water should not exceed 0/100mL and production of air bubbles in the McCartney bottles after incubation indicates the presence of coliforms in the water.

From the table 5 above, 25% of the water samples were found to be contaminated by enterobacter aerogenes while 40% water samples were contaminated with E.coli and 35% were contaminated by different coliforms. According to [10], detection of coliform bacteria can be an indication of the presence of organisms that can cause diseases such as dysentery, hepatitis, typhoid fever and cholera. Though not all coliform bacteria can cause illness in humans, the presence of any coliform is a possible health concern. Presence of bacterias in the water is mostly attributed to poor well casing, feces of warm blooded animals or humans and inadequate treatment of groundwater. An analysis by state water resources, [10] showed that lack of water treatment, animal manure, septic system and human feces are the major sources of coliforms in drinking water and groundwater. In this analysis, all the study areas had poor sanitary system which may be the major contributor to bacterial specie in the water. In Apo village, Kagini and Damangaza, animal husbandry is highly practiced which may have contributed to the presence of bacteria's in the water. According to WHO and EPA, boiling of water helps kill the bacteria's in the water. In this analysis after the confirmatory test the water samples were boiled for an hour at 100 ^{0}C and the analysis was carried out again as shown in plate 3, no change was observed indicating the bacteria's are still present in the water but may have reduced in concentration, it may be due to high concentration of bacteria's in the water.

Heavy Metals

The lead concentration of the water samples obtained from Kagini, Damangaza, Pigbakasa, Durumi and Apo villages ranged between 0.03 and 0.31mg/L. Most of the samples were found to have exceeded the standard limits of 0.015 set by WHO, EPA and NSDWQ for drinking water except sample three from Kagini, Damangaza, Pigbakasa and sample four of Pigbakasa and Apo village. There was similar finding from the analysis carried out in southern Nigeria by [23] which showed lead concentration of between 0.24 and 0.34mg/L in wells and boreholes. Al-Turki [24] stated that lead concentration above maximum limit leads to various diseases that may have a grave impact on the health of humans and animals. According to [25], humans are at risk of exposure to lead from water source and lead poisoning also accounts for about 0.6% of the global burden of diseases. Another analysis by [26] in Zamfara state showed that Zamfara lead poisoning is the worst and most recent heavy metal incidence in Nigeria with record that claimed the lives of over 500 children within 7 months. He stated the lead poisoning was caused by illegal miners who brought rocks containing gold ores with high concentration of lead spreading the lead dust into open and ground water sources.

Discharge of chemical effluents, poor sewage system, dumping of refuse containing dead batteries and paints into the water bodies, gasoline and solid waste in the water among other factors leads to high concentration of heavy metals in the water [27-29].

The chromium concentration of the water samples obtained from the five villages within FCT were mostly above the standard limit of 0.15 set by WHO, EPA and NSDWQ except sample 1 of Kagini and Pigbakasa . The chromium concentration ranged from 0.08 to 0.49mg/L. The sources of chromium in water includes; mining, garbage disposal, soaps and detergents, industrial effluents, agricultural activities [30-33]. Long term exposure to chromium posed threat to human life and can cause kidney, liver circulatory and nerve tissue damages.

The analysis of the twenty water samples obtained from the five villages under FCT showed a wide variation of cadmium concentration higher than the standard limits of 0.05mg/l set by

WHO, NSDWQ and EPA. All the water samples exceeded the maximum limit ranging from 0.07 to 0.25 mg/L. Similar result was obtained by Asonye *et al* [34] on the study of heavy metals concentration in River Owo Agbara, Nigeria. Generally, cadmium concentration in water above 0.05 mg/L is said to be harmful to the consumers, therefore, all the villages are in danger of cadmium poisoning. According to [35] exposure to cadmium can lead to various diseases such as kidney stone and itai-itai (Osteomalacia with various grades of osteoporosis accompanied by severe renal tubular disease). Another analysis by Musa & Ahanonu [30] on assessment of shallow wells in some selected Agrarian communities in Patigi, Niger state showed a wide variation of cadmium concentration which is also similar to the result obtained in this work.. They stated that high cadmium concentration was due to the high quantity of batteries used for electrical appliances and disposed in water bodies. High concentration of cadmium could be caused by commercial use of fertilizers and disposal of sewage sludge [36]. From this analysis, all the samples of Durumi had the highest concentration of cadmium and according to WHO, level of cadmium could be higher in areas with low pH. The pH value of Durumi 3 ranged between 5.30 to 5.88mg/L which are found to be low.

CONCLUSION

Analysis of drinking water samples randomly taken from twenty sources of groundwater in some villages within the federal capital territory Nigeria revealed that there are considerable variations among the examined samples mainly with respect to their TDS, EC, hardness, cadmium, chromium, lead, pH, alkalinity and bacteria content which mostly fell above the maximum permissible levels set by WHO, NSDWQ and USEPA. Hence, the people in these rural areas are at potential risk of contracting water-borne and sanitation related diseases. Thus, the current status of the water in the various communities considered for this study is not fit as a source of drinking water for the communities.

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