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Comparative Analysis of Physicochemical and Bacteriological Qualities of Borehole and Sachet Water in Kubau Local Government Area, Kaduna State, Nigeria

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Abstract

Background*: Water to be used for human consumption must meet certain requirements according to world Health Organization, as the prevalence of water related diseases in developing countries is determined by the quality of their drinking water. The study aimed at comparing the quality of borehole and sachet water in zuntu district area, Kubau Local Government Area, Kaduna state.*

Materials and Methods*: Four (4) samples of water were collected from the district area, 2 samples each of sachet and borehole water using random sampling technique. Physicochemical and bacteriological properties were determined using standard laboratory procedures at National Research Institute for Chemical Technology, Zaria (NARICT).*

Results*: The results showed that the physicochemical parameters and bacteriological quality conform to WHO Standard. Result showed that the sachet Water samples had lower values of the parameters when compared to borehole water samples, which implies that the sachet Water is of good quality than the borehole water in the study area. However, the overall results showed that the sachet water produced in the study area were relatively safe for consumption according to the World Health Organization (WHO) standard for potable water. However, the results of microbiological parameters showed that both samples after analysis have total coliform below WHO standard.*

Conclusion: *In conclusion the study indicated that the two sources of water are safe for consumption.*

Key Word*: Borehole water; Sachet water; Microbilogical properties; physicochemical properties*

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Introduction

Water is one of the indispensable resources for the continued existence of all living things including man and adequate supply of fresh and clean drinking water is a basic need for all human beings[1]. In nature, all water contain impurities, as water flows in streams, accumulates in lakes and filters through layers of soil and rock in the ground, it dissolves or absorbs substances it come in contact with, which may be harmful or harmless[2]. One of the major and critical problems in most developing countries today harmless provision of an adequate and safe drinking water to its populace[3], Drinking water that is safe and aesthetically acceptable is a matter of high priority to regulatory agencies in Nigeria and is expected to meet the world standard. Furthermore, water for human consumption is expected to meet the World Health Organization standard and be free from physical and chemical contaminants and microorganisms in an amount that can be hazardous to health[4]. It is a known fact that no single method of purification can eliminate 100% contaminants from drinking water. However, water can be and should be made safe for consumption within acceptable limits[5].

Borehole and sachet water are generally considered "safe source" of drinking water because they are abstracted with low microbial load, and with little need for treatment before drinking[6]. However, borehole and sachet water resources in Nigeria are commonly vulnerable to pollution, which may degrade their quality[7].

Sachet water is any commercially treated water, manufactured, packaged and distributed for sale in sealed food grade containers and is intended for human consumption. The production of sachet water in Nigeria started in the late 90s and today the advancement in scientific technology has made sachet water production one of the fastest growing industries in the country. Water consumers are frequently unaware of the potential health risks associated with exposure to water borne contaminants which have often led to diseases like diarrhea. cholera, dysentery typhoid fever and parasitic diseases[8]. The continuous increase in the sale and indiscriminate consumption of packaged drinking water in Nigeria is of public health significance, as the prevalence of water related diseases in developing countries is determined by the quality of their drinking water[9].The safety of drinking water in poor and deprived communities has in the last decade been in jeopardy as a result of the introduction of refuse and sewage into sources of water supply. The introduction of sachet water was aimed at providing safe, hygienic and affordable instant drinking water to the public and to curb the magnitude of water related infections in the country[9]

Lack of information on pathogenic or parasitic organisms associated with drinking water creates some uncertainties in our understanding of the overall quality of drinking water in our markets. Some Sachet waters have been reported to contain bacteria such as *Basillus* species. *Pseudomonas* species. *Klebsiela* species, *Streptococcus* species and *oocysts* of *Cryptosporidia* species[8].

Disease-causing microorganisms transmitted via drinking sachet and borehole water are predominantly of faecal origin and are referred to as enteric pathogens. The World Health Organization[5] estimates that about 1 bilion people globally drink unsafe water and the vast majority of diarrheal disease in the world (80%) is attributable to unsafe water, sanitation and hygiene. Poor water quality, sanitation and hygiene accounts for 1.7 million deaths a year worldwide[5]. Water consumers are frequently unaware of the potential health risks associated with exposure to water borne contaminants which have often led to diseases like diarrhea, cholera, dysentery, typhoid fever and parasitic diseases. Nigeria is of public health significance, as the prevalence of water related diseases in developing countries is determined by the quality of their drinking water. The world health organization standard state that drinking water should not contain any microorganism.

Therefore the study aimed at comparing the quality of borehole and sachet water consumed in zuntu district area, Kubau Local Government Area, Kaduna State.

Material and Methods

Samples Collection

A total of four samples of water (2 borehole water labelled A and B and 2 sachets water labelled C and D) were collected from different point in zuntu district area, Kubau Local Government Area, Kaduna, Nigeria in January, 2022. Sample A Ung/ Sarki's boreholes, Sample B Ung/ Hamisu boreholes Sample C and D sachet table water. The water samples were collected using well-labelled plastic bottles. All the samples were transported with ice packs within few hours to the National Research Institute for Chemical Technology (NARICT) for comparative analysis of quality of water samples.

Physicochemical Analysis

The physicochemical parameters of the water samples were carried out in accordance with the method of APHA[10].

Determination of Colour Odour and Taste

Colour odour and taste were determined through sensory methods. The water samples were perceived for any change in characters according to (WHO)[5].

pH and Temperature

pH was determined using a pH meter (model HI 98130 Hanna). While the temperature of water samples was taken immediately on site using a thermometer calibrated in degree Celsius.

Electrical Conductivity

The electrical conductivity of the water samples was measured using a digital conductivity meter model NATOP PB5 (London, UK). Standardization of the meter was performed using 0.1N KCl at 25 °C.

Dissolved Oxygen

This test was performed using Winkler's method. Manganese (II) salt, iodide (I^-) and hydroxide (OH^-) ions were added in excess to the samples causing a white precipitate of $Mn(OH)_2$ to form. The precipitate formed was oxidized by the dissolved oxygen in the water sample which turn into a brown manganese precipitate and hydrochloric acid was added to acidify the solution. The brown precipitate was then converted from iodide ion (I^-) to iodine. The amount of dissolved oxygen was directly proportional to the titration of iodine with a thiosulphate solution. Three hundred millilitre (300 ml) bottles were filled with water samples respectively. Two millilitre (2 ml) of manganese sulphate and 2 ml of alkali-iodide-azide solution was added by inserting a pipette just below the surface of the liquid. The bottles were stoppered to avoid air being introduced, then the content of the bottles were properly mixed by inverting them several times. The bottles were left to stand for 3 min. The presence of oxygen was indicated by the formation of brownish-orange precipitate. Two millilitre (2 ml) of H_2SO_4 was added to the samples, then properly mixed again and inverted to dissolve the precipitate. Two hundred and one milliltre (201 ml) of the samples was measured into a clean 250 ml conical flask and titrated against sodium thiosulphate solution ($Na_2S_2O_3.5H_2O$) using the starch indicator until the solution turned colourless.

Turbidity

The turbidity of the water samples was measured using a digital turbidity meter (2100AN HARCH Model). A clean deionized water was used to standardize the turbidity meter before introducing the test samples. The turbidity reading of each water sample was then recorded.

Total Dissolved Solid

This test was performed using a conductivity meter. The automated menu of the conductivity meter was switched on to total dissolved solid. A volume of 100 cm^3 of the sample was poured into the beaker and the electrode which is part of the conductivity meter was introduced into the sample. The result of the total dissolved solid of the water sample shown on the display were noted[10].

Total Suspended Solids

The total suspended solids in the water samples were determined by simple calculation shown below:

Total suspended solids = Total solids – Total dissolved solids

Total Hardness

Water sample measuring 10 cm3 was pipetted into a conical flask. 1 cm3 of buffer solution (NH4Cl) of pH 10 and 3 drops of Erichrome black T indicator were added to the flask. The mixture was then titrated with 0.01M ethyl diamine tetra acetic acid (EDTA) until the colour changed from wine red to blue. The procedure was repeated two more times to obtain the average titer value[11].

Total Alkalinity

This test was done by measuring 100cm^3 of water into a beaker which had 3 drops of phenolphthalein indicator inside it. The solution was titrated against 0.1N HCl until the colour changed from pink to colourless[12].

Salinity

The measurement of salinity of the water samples collected in sterile plastic bottles was done using the standard method recommended by APHA[10]. To avoid interference of sulphate and sulphide, 1 ml of hydrogen peroxide was added to 100 ml of water sample. The pH of the sample was adjusted to 7.0 with dilute H_2S0_4 or NaOH since it is only at neutral or alkaline pH that potassium chromate can indicate the end point of the silver nitrate ($AgNO_3$) titration of chloride.

Chloride

This test was performed to determine the total chlorine content of the water sample using the HACH Test Kit Model CN66/66F/66T). A colour viewing tube was filled to the 5 mL mark with the water sample. Also, another viewing tube was filled to the 5-mL mark with the water sample. Then, clippers was used to open one DPD Total chlorine reagent powder pillow, and the content was emptied inside the water sample. It was gently swirled to achieve a homogenous solution, allowed to stand for three minutes and the results were recorded.

Sulphate

The turbidimetric method was adopted in determining the level of sulphate in the water samples. One hundred millilitre (100 ml) of the sample was measured into a 250 mL Erlenmeyer flask. Five millilitre (5 ml) of conditioning reagent was added to the content of the flask, then placed on a magnetic stirrer for proper mixing. A spoonful of barium chloride crystals was added, immediately timed, and stirred at a constant speed for one minute. A portion of the solution was poured into the absorption cell of the photometer, and the turbidity was measured at 30 sec intervals for 4 min. Usually, maximum turbidity occurs within 2 min and the reading remains constant thereafter for 3 - 10 min.

Phosphate

Standards are prepared using a phosphate standard solution of 3 mg/L as phosphate ($PO4^{3-}$). This is equivalent to a concentration of 1 mg/L as phosphorus. The concentration and result from the procedure were expressed in mg/L. Six standard concentrations were prepared for every sampling date in the range of expected results. Six 25-mL volumetric flasks one for each standard was labelled 0.00, 0.04, 0.08, 0.12, 0.16, and 0.20. About 30 mL of the phosphate standard solution was poured into a 50 mL beaker. 1, 2, 3, 4, and 5 mL Class A volumetric pipette was used to transfer a corresponding volume of phosphate standard solution to each 25-mL volumetric flask.

Nitrate

An aliquot of 2 ml of 0.1M NaOH solution and 1 ml of colour developing reagent was added to a 50 ml water sample. The mixture was allowed to stand for 20 min, and the nitrate concentration was determined at wavelength 543 nm of absorbance.

Bacteriological Analysis

The bacteriological test carried out involved faecal coliform count and total coliform count. These were carried out as described by[10]

Faecal Coliform Count (Membrane Filtration)
This method is based on the use of highly porous cellulose membrane which will allow fairly large volume of water (e.g. 100 ml) to pass through rapidly under pressure but prevents passage of bacteria. The bacteria which remain on the surface of the membrane are then cultured on Eosine methylene blue (EMB) agar plate, the viable count gives the presumptive number of coliforms in the 100 ml water sample.

Total Coliform Count
Aliquots, 0.1 ml of 10^{-5} and 10^{-6} of each of the sample were inoculated in duplicates on each of the well labeled Mackonkey agar plates using the spread plate method. The plates were incubated at 37^0C for 24 hours.

Data Analysis
Results obtained from the study were analyze using SPSS 16.0 for Windows. All data were analysed using one way ANOVA was used to compare the result. $p < 0.05$ was consider significant.

III. Results

From table 1. the physical properties of borehole and sachet water were found to be clear, tasteless, odourless while pH, temperature conductivity, turbidity, total dissolve solid, total suspended solid, total alkaline and salinity were found to have lower parameters compared to the world health organization standard. The chemical properties of the inions were also of lower parameters compared to the world health organization standard.

Table 2. Shows the microbiological properties of borehole and sachet water from the study area. It reveals that sample A and B has no E. coli (0.00) and T. Coliform (0.01, 0.10) was found to be present. While sample C and D has no E. coliform (0.00) and T. coliform (0.04) was found in sample c.

Table 1. Physicochemical properties of borehole and sachet water

Parameters	samples codes				
	A	B	C	D	WHO Limit
Colour	Clear	Clear	Clear	Clear	Clear
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
Odour	Odourless	Odourless	Odourless	Odourless	Odourless
pH	7.50	7.30	6.80	7.10	6.5 - 8.5
Temperature (°C)	26	27	25	26	25 - 30
Conductivity (µS/cm ²)	0.101	0.210	0.301	0.290	0.500
Dissolved Oxygen (mg/L)	66	83	41	43	5.0 -10.0
Turbidity (NTU)	1.00	2.00	0.67	0.82	5
Total Dissolved Solid (mg/L)	104	186	3.10	4.40	250 - 500
Total Suspended Solids (mg/L)	33.6	18.4	8.3	11.2	30
Total Hardness (mg/L)	583.3	509	21	16	500
Total Alkalinity (mg/L)	37.3	74.8	52.1	42.2	200
Salinity	0.02	0.75	0.00	0.00	200 -250
Chloride (mg/L)	0.20	0.11	0.12	0.16	250
Sulphate (mg/L)	4.2	8.38	0.56	0.93	250-500
Phosphate (mg/L)	0.04	0.05	0.02	0.40	0.5
Nitrate (mg/L)	0.24	0.11	0.13	0.06	10

Key: NTU = Nephelometric Unit

Table 2 Microbilogical properties of borehole and sachet Water in the ward.

Parameter	Sample code			
	A	B	C	D
E.coliform(cuf %)	0.00	0.00	0.00	0.00
T.coliform(cuf%)	0.01	0.01	0.04	0.00

IV. DISCUSSION

Water to be used for human consumption must meet certain requirements of. International standards for water quality[13].The physical appearance of all water samples were clear. However, Potable water must be odorless and tasteless. The taste and odour of water samples from the area was found to be tasteless and odourless, which means there is no obstructing matter in the water samples.

pH. is a water quality assessment parameter which is very important in evaluating water supply and treatment[14]. pH values is an important factor that affect chemical and biological processes. It served as a determinant for various purposes such as consumption, industrial and laboratory use. pH of the water sources could be as a result of presence of bicarbonates that eventually reach the soil[15], High values make water basic which eventually is responsible for gastrointestinal irritation. However, low values make water acidic which could impose toxicity to animals and plants. The analysis from this study show that pH of all the water samples from the boreholes and sachet located in the area range from 7.5 -7.10. These values were within the recommended limit of 6.5-8.5.by WHO.

During quality assessment of water suitable for human consumption, the temperature of the water is among the factor to be considered. It influence the rate of chemical reactions, solubility of matters, growth of microorganisms change in tastes and colours of water[16]. In this study, the temperature of both borehole and sachet water range between 25- 27 ^{o}C which is within the WHO set limit. The temperature of borehole is higher when compared to that of sachet water.

Electrical conductivity is the ability of a solution to conduct an electrical current that is directed by the migration of solutions which is dependent on the nature and number of the ionic species in the same solution[17]. It is an important tool used in assessing the purity of water. Our result shows that the electrical conductivity of all the samples were below the permissible limit of 0.500 μS/cm set by the WHO. These result indicated that they are suitable for domestic use, and other purposes[16].

Dissolved oxygen refers to the level of free, non-compound oxygen present in water. It is an important parameter used in assessing the quality of water since it influences the organisms living in a water body. Usually, the level of oxygen in water decreases when there is an increase in nutrients and organic materials from industrial wastewater, sewage discharges, and runoff from land[18]. The results obtained from this study shows that borehole and sachet water samples were above the limit set by WHO which is 5.0-10.0 mg/L. this indicated that the water samples are suitable for consumption. Dissolved oxygen is a parameter which is of high significance to all living organisms[16].

The cloudiness of water due to the presence of varieties of particles influences its turbidity. This major parameter in drinking water analysis. It is also related to the population of disease-causing microorganisms present in water which could come from soil runoff or caused by suspended particles or colloidal matter that obstructs light transmission through the water[19]. The standard recommended maximum turbidity limit set by WHO for drinking water is 5 nephelometric turbidity units (NTU). The turbidity of all the water samples from the study were below WHO standard of 5NTU.

The inorganic matter and small amounts of organic matter present in water in form of a solution is referred to as total dissolved solid. It is a combination of cations and anions present in water, bicarbonate, carbonate, sulphate, phosphate, magnesium, nitrate, calcium, organic ions and other ions [16]. When the total dissolved solids in water is high, it reduces the water clearness and could lead to increase in temperature of the water which finally attract the growth of microorganism [36]. Drinking water becomes unsafe and affected at a value greater than 250 mg/L[19]. The values reported in this study were far below the limit stipulated by WHO standard though the value from boreholes is higher than sachet water. This might be due to direct contact of water with soil.

Total suspended solids in water is of great importance in assessing the quality of water. The parameter may also give an indication on the level of discharge of matters. The result obtained from this study shows that both one borehole and sachet water samples were below the WHO limit (30 mg/L) but borehole A was found to be above the limit.

The presence of calcium and magnesium salts in dissolve form contributes to the total hardness of natural waters. The total hardness of water vary over a wide range due to original site of water[20]. Four categories of water were identified hardness are soft (0 – 60 mg/L), moderate (60-120 mg/L), hard (121-180 mg/L) and very hard (> 180 mg/L). Therefore, from our study, the borehole water samples were found to be very hard. However, the values for sachet water samples were below the WHO limit for total hardness which is 500 mg/L.

Total alkalinity is the measure of substances in water which gives it the ability to neutralize acidity. It acts like a buffer against low pH, keeping it fairly constant thereby protecting the water from acidic condition[21]. Alkalinity in natural water is mainly due to the presence of carbonates or bicarbonates[22]. The results obtained from this study indicated that total alkalinity of water samples from the boreholes were higher when compared to sachet water. As recommended by WHO, the acceptable limit of total alkalinity in water is 200 mg/L. This requirement was met by water samples obtained from boreholes and sachet water

Salinity is a test to determine the level of salt content which may render water unsuitable for domestic, agricultural or industrial use. The values for salinity of water samples from boreholes and sachet water were far below the limit set by WHO (200-250 mg/L).

Chloride is one of the most important anions found in water. It is useful in maintaining acid-base balances. However, when it becomes excess in drinking water, it might cause edema. The source of contamination of water by chloride is sewage and industrial effluents as well as saline intrusion. The chloride content of both borehole and sachet water less than the recommended quantity of chloride in drinking by WHO, the values obtained in this study were far below the limit recommended by WHO.

Sulphate exist in almost all natural waters. Its concentration varies depending on the nature of the site of origin. The usefulness of water for domestic purposes could be affected by high concentration of sulphate. High levels of sulphate lead to dehydration and diarrhea especially in children. From our study, the concentration of sulphate in borehole and sachet water samples were far below the limit (250-500 mg/L) recommended by WHO.

Phosphates are not toxic to people or animals unless they are present in very high levels[23].The result obtained from this study shows that concentration of phosphate in borehole and sachet water samples were below the normal value recommended limit by WHO which is 0.5 mg/L

Nitrate is the most oxidized form of nitrogen compounds. It is generally found in surface and ground water because it is the end product of aerobic breakdown of organic nitrogenous matter[24]. The nitrate is not a direct toxicant but could cause health hazard when converted to nitrite. It threatens the oxygen carrying capacity of the blood around the body when[25]. Our result shows that the nitrate content of the borehole and sachet water is below the limit (10 mg/L) recommended by WHO.

The WHO specifies that any disease causing organism must not be detectable in water for drinking (WHO, 2010). The presence of coliform in water could also be an indication of feacal contamination and has been associated with waterborne epidemic. Water source used for drinking or cleaning purposes should not contain any organism of fecal origin 25.

In this study, the total and feacal coliform counts were not detected in both water sample. However, the sample meet international standard as they were meet WHO standard of zero per 100ml. this is an indication that the water sources in this area are safer for drinking.

V. Conclusion

The comparative analysis revealed that the water samples collected differ in their parameters. The sachet water had low values of the parameters analyzed than the bohole water. Both borehole and sachet water are of good quality. Result showed that the sachet Water samples had lower values of the parameters analyzed than borehole water. However, the overall results showed that the sachet Water produced in the study area were relatively safe for drinking according to the World Health Organization (WHO) standard for potable water.

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