International Journal of Environment and Pollution Research

Vol.9, No.1 pp.27-44, 2021

Print ISSN: 2056-7537(print),

Online ISSN: 2056-7545(online)

COMPARATIVE ANALYSIS OF WATER QUALITY FROM HARVESTED RAIN AND BOREHOLE WATER IN OWEERI-WEST, IMO STATE

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ABSTRACT: *The growing global population in a bid to solve the challenge of water shortage has resorted to groundwater and rainwater considering their benefits. The aim of this study was to assess and compare the quality of harvested rainwater and underground water (borehole) in Owerri-west in order to ascertain their portability in the light of WHO (2010) drinking water standard. Groundwater and rainwater samples were collected from Ihiagwa, Obinze and Nekede and analysed for physicochemical and microbial quality. These samples were analyzed using laboratory analytical techniques as recommended by World Health Organization and American Public Health Association. The result from the analysis showed that the Heterotrophic Bacterial Counts (cfu/ml) of water samples were BH (6.58%), Aluminum (11.84%), Zinc (19.74%), Asbestos (28.95%) and Thatched (32.89%). Out of the four bacteria (Escherichia coli, Enterococcus faecalis, Bacillus subtilis and Staphylococcus epidermis) observed in all the water samples, Escherichia coli had the highest number of occurrence of 126(82.89) cfu/ml. All the physicochemical parameters analyzed conformed to the recommended standard value apart from pH value from borehole, and the rainwater sample from thatched roofing sheet with turbidity (10.3 NTU), objectionable taste and odour, and a general appearance that was not clear. The results observed showed the sequence of quality of groundwater and rainwater as Borehole > Aluminum > Zinc > Asbestos > Thatched. Generally, groundwater was more potable than harvested rainwater within the study area. This study however suggests that drinking water sources should be properly treated especially harvested rainwater prior to consumption using appropriate method in order to reduce the occurrence of waterborne disease.*

KEYWORDS: water quality, bacteria, physicochemical, water borne diseases

INTRODUCTION

Water is one of the most abundant and essential resources of man, and occupies about 70% of earth's surface. About 97% of this volume of earth's surface water is contained in the oceans, 21% in polar ice and glaciers, 0.3-0.8% underground, 0.009% in inland freshwaters such as lakes, while 0.00009% is contained in rivers (Eja, 2002). According to Botkin and Keller (1998),

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Print ISSN: 2056-7537(print),
Online ISSN: 2056-7545(online)

more than 97% of earth's water is in the oceans and ice caps, and glaciers account for another 2%. Also, the ocean comprises 97%, while 3% of the earth's water is fresh (Kulshneshtha, 1998). Water in its pure state is acclaimed key to health and the general contention is that water is more basic than all other essential things to life (Edungbola & Asaolu, 1984). Man requires a regular and accessible supply of water which forms a major component of the protoplasm and provides an essential requirement for vital physiological and biochemical processes. Man can go without food for twenty eight days, but only three days without water, and two third of a person's water consumption per day is through food while one third is obtained through drinking (Muyi, 2007).
Basic household water requirements have been suggested at 50 litres per person per day excluding water to gardens (Boss, 2004). Batmanghelid (2009) reported that since the water we drink provides for cell function and its volume requirements, the decrease in our daily water intake affects the efficiency of cells and other body activities. In addition to human consumption and health requirements, water is also needed in agriculture, industrial, recreational and other purposes. Water is also considered a purifier in most religions (Foel & Nennewan, 1986). Though all these needs are important, water for human consumption and sanitation is considered to be of greater social and economic importance since health of the population influences all other activities. According to Odiette (1999), environmental water usage includes artificial wet lands, artificial lakes intended to create wildlife habitat, fish ladders around dams and water releases from reservoirs to help fish spawn.

Rain water is the water which is gotten from rainfall. It occurs as a result of condensation of water molecules in the upper atmosphere. When this reaches saturation points, it falls back to the earth's surface as rain water. It is collected from different catchment roofs by man (Origho, 2009). For long term use, rain water can be piped into clean, closed underground tanks for human use. However, rainwater can be contaminated by dirty roofs, dirty containers, and tanks.
Today, increase in population, urbanization and inefficient pipe-borne water supply has made rainwater harvesting a veritable source of water supply (Schiller, 1982). In many developing countries of Africa, where housing standard has improved and impermeable roofs are constructed, rainwater harvesting systems are becoming increasingly used. Rainwater has been successfully harnessed for domestic water requirement in Kenya and Tanzania (Schiller, 1982) and in Sierra Leone (Nissen-Peterson, 1982 & Jayakaran, 1988). In Zimbabwe, between 80 and 85 percent of all measurable rainfall is collected and stored for use (Morgan, 1990). In Nigeria, the concept of rainwater harvesting or its use during the rainy season is not new particularly as a supplement to water from rivers and streams (Morgan, 1990). Some people in the rural areas and urban centres of Nigeria depend on rainwater. Rainwater, according to Efe (2006), is one of the purest sources of water supply if properly collected. But the desire for technological breakthrough and improved standard of living has placed pressure on its use.

One of the primary areas of concern regarding the use of rainwater, for either non-potable or potable applications, is quality. The quality of water collected in a rainwater harvesting system is

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Print ISSN: 2056-7537(print),

Online ISSN: 2056-7545(online)

affected by many factors which include: the nature of the catchment system and the roof materials, environmental pollution from industries, automobiles and anthropogenic activities, the presence of dirts, debris and birds or rodents dropping on roofs and rainwater catchments (Forster, 1998; Taylor *et al.*, 2000 & Ubuoh, 2012) and the type of storage materials for harvested

rainwater. Catchment material, storage material and treatment are three design considerations that can be optimized to maximize rainwater quality (Adeniyi & Olabanji, 2005). In recent times rainwater is stored both in surface and underground tanks with or without covers. Many studies have also raised the contributions of storage tank materials to the microbiological and physicochemical quality of harvested rainwater. The risk of microbiological contamination of rainwater during collection and storage in the home has long been recognized (Lye, 2002 & Thomas *et al.*, 2003). The water storage system can also impact the quality of water (Lye, 2002). Microorganisms found to be carried by birds and animal vectors include, Cryptosporidium, Giardia, Campylobacter and Salmonella spp. (Gerba & Smith, 2005). Each of these microorganisms is known to cause gastroenteritis and other illnesses (Gerba & Smith, 2005).

Ground water is the water beneath the surface where all the voids in the rocks and soil are filled. It is a source of water for wells, boreholes and springs. A borehole is an hydraulic structure which when properly designed and constructed, permits the economic withdrawal of water from an aquifer. It is a narrow well drilled with machine. Borehole water is the water obtained from borehole drilled into the aquifer or ground water zone, which is usually a fully saturated subterranean zone, some distance below the water table (NWRI, 1997).

Ground water is already used extensively in Nigeria through wells and boreholes. Unfortunately borehole water like water from other sources is never entirely pure. It varies in purity depending on the geological conditions of the soil through which the ground water flows and some anthropogenic activities. Until very recently, ground water has been thought of as being a standard of water purity in itself, and to a certain extent, that is indeed true (Miller, 1992).

Apart from the essential role played by water in supporting human life, it also has, if polluted, a great potential for transmitting a wide variety of diseases. According to Akpan, *et al* (1996), in most developing countries like Nigeria where dangerous and highly toxic industrial and domestic wastes are disposed of by dumping them on the earth; into rivers and streams with total disregard for aquatic lives and rural dwellers, water becomes an important medium for the transmission of enteric diseases in most communities. Poisonous chemicals are known to percolate the layers of the earth and terminate in ground waters thereby constituting public health hazards. In Owerri West Local Government Area of Imo State, certain anthropogenic activity like the improper waste disposal can contribute to ground water pollution. This area suffers from non-provision of

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Print ISSN: 2056-7537(print),

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potable water supply. The inhabitants are therefore depending largely on private borehole water supply which is of doubtful quality.

In Owerri Wests Local Government Area of Imo State of Nigeria, the people use borehole water and rainwater stored in tanks without considering its quality and the health implications. There is a possibility of water-borne diseases arising from physical, chemical and microbial contamination. Therefore, the focus of this study is to assess the quality of rainwater and borehole water in the LGA for domestic use bearing in mind the physical, chemical and bacteriological characteristics as well as health considerations for human survival in the study locations in particular and the State in general.

MATERIALS AND METHODS

Study Area

This study was conducted in Owerri west, a Local Government Area in Imo state. Three villages in Owerri west were selected, viz, Ihiagwa, Nekede and Obinze. Owerri west is geographically located between Latitude 5.4166° N, and Longitude 6.9853° E (Wikipedia, 2017). Owerri west enjoys a favourable climatic condition, with the average annual temperature of 26.4 °C and an annual rainfall of 1,500mm to 2,200 mm. As of 2006 census, Owerri west had a population of 99,265. The major source of water for residential and domestic use are from rainfall and borehole. The local government relies extensively on water from borehole. They also harvest water from roofing sheets during rainfall which they see as been cheap, accessible especially during raining season and it is believed to be safe for drinking.

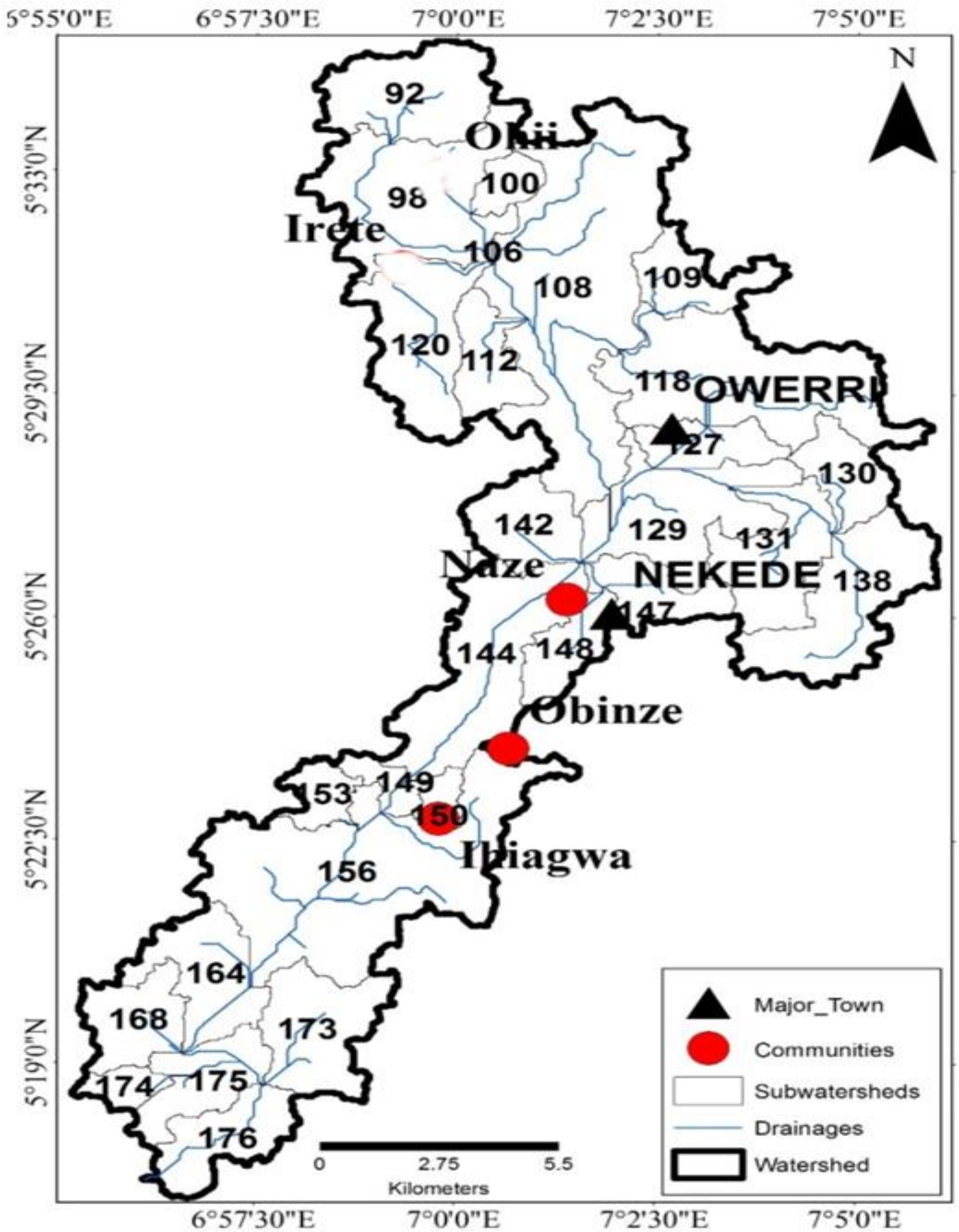

Figure 1: Map of the study area

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Print ISSN: 2056-7537(print),

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Source of Data

The first field work was to identify roof materials that are commonly used in Owerri west (Ihiagwa, Obinze and Nekede), and roofing materials that are commonly used for rainwater harvesting. Households were randomly picked in Ihiagwa, Obinze and Nekede where the four different roofing sheets were identified. The data used for this study were collected in September and October, 2018.

Sample Collection and Preservation

The water samples were collected using well-labelled plastic bottles. This is because plastic do not dissociate into water thereby reducing chemical interference in the analyses. The plastic container used for the collection of rainwater samples were set under the roofing sheets so that there will be free flow of the rainwater into the containers. The samples were collected from four different roofing sheets (Zinc, Aluminum, Asbestos and Thatched) so as to be able to observe differences in the water quality.

In view of the unpredictable condition of rain, collections of sample were flexible and were done while rain was falling. Before collection, the plastic bottles and containers were first rinsed with distilled water before water samples were collected. This was done to avoid contamination from previous water content.

Plate 1. Water samples harvested from borehole and rain water.

The samples collected were stored in the refrigerator at 4°C to preserve its chemical properties prior to analyses.

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Laboratory Analysis
The samples were taken to Springboard Laboratories, Awka for further treatment and analysis. The methodologies employed for this laboratory analysis is in accordance with APHA (2005).

Determination of Parameters

Physicochemical Analysis
The physiochemical tests included the determination of pH, temperature, turbidity, conductivity, colour, odour, appearance total dissolved solids, total suspended solids, nitrate phosphate, biological oxygen demand and dissolved oxygen. These were carried out using standard procedures (APHA, 2005).

Determination of pH

Method: pH was measured by Electrometric Method using Laboratory pH Meter Hanna model H1991300 (APHA, 2005)

Determination Turbidity
The turbidity of the samples was measured was in the laboratory using the LABTECH DIGITAL turbidity meters. The values were read out directly in Nephelometric units (NTU) after the instrument had been standardized using already- prepared standard.

Determination of Total Dissolved Solids (TDS)
The samples were evaporated and dried in weighed dishes at 105^0C to constant weight; the increase in weight over the empty dish representing the solid content. 100 ml of the samples were used and the evaporating dishes were left to cool in desiccators before the weightings were done. The result was expressed in milligram total solids per litre of samples.

Determination of Total Suspended Solids (TSS)
100 ml of samples were filtered through a glass fiber disc and transferred to previously ignited and weighed evaporating dishes. The samples were evaporated to dryness in an oven, as in the case above, and then further dried at 105^0C for two hours in the oven. They were cooled in desiccators and weighed. The difference between the weights obtained and those gotten from TS above for each sample gave the value of the total suspended solids content for the samples. The results expressed as milligram suspended solid per liter of sample.

Determination of Odour
Odour was determined through sensory methods. The water samples were perceived for any unpleasant odour and the results were recorded either as ‘pleasant’ or ‘unpleasant’ odour.

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Determination of Phosphate

The ascorbic acid method according to APHA (2005) was adopted for the determination of phosphate level of the borehole water. Ascorbic acid based reagent powdered pillow was added into 25 ml of the water sample in a cuvette. The sample was allowed stand for 2 minutes for reaction to occur. The absorbance and concentration in mg/l was read at 890 nm wavelength using HACH DR 2010 UV-visible spectrophotometer.

Determination of Biological Oxygen Demand (BOD)

BOD was determined after 5 days incubation period at 20 ± 1^0C with same HANNAH HI 9828 VI.4 PH/ORP/EC/DO Meter.

Calculation

BOD_5 (mg/l) = $D_1 - D_2$ P

Where:

D_1 is dissolved oxygen of the dilution sample 15 minutes after preparation

D_2 is dissolved oxygen of the sample after incubation periods of 5 days

P is the decimal fraction of sample used.

Determination of Sulphate

The barium chloride (turbidometric) method by APHA (2005) was adopted. The barium chloride based powered reagent pillow was added into 25 ml of water sample. The mixture was properly mixed and allowed to stand for 5 minutes for reaction to occur. The absorbance and concentration in mg/l was read at 450 mm wavelength using HACH DR 2010 UV-visible spectrophotometer.

Determination of Nitrate

The cadmium reduction as adapted from APHA (2005) was used in the determination of nitrate levels of the samples. A cadmium based reagent pillow was added into 25 ml of the water sample in a cuvette and shaken for 1 minutes and allowed to stand for another 5 minutes for complete reaction to occur. The absorbance and concentration in mg/l was read at 500 nm wavelength using HACH DR 2010 UV-visible spectrophotometer.

Bacteriological Analysis

The bacteriological test carried out involved faecal coliform count, total heterotrophic count total coliform count and isolation and characterization of bacteria from different sampling points. These were carried out as described by APHA (1998) and Cheesbrough, (2004).

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

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Eosine methylene blue (EMB) agar plate, the viable count gives the presumptive number of coliforms in the 100 ml water sample.

Total Heterotrophic Count

An aliquot (0.1 ml) of the serial dilutions of 10^{-5} and 10^{-6} of each sample was inoculated in duplicates onto well labeled nutrient agar plates. Hockey stick which has been sterilized by dipping into alcohol and flaming was allowed to cool and used to spread the sample evenly on the respective agar surface.

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

Data collected from this study was analyzed using routine statistical methods (Mean ± Standard deviation) and analysis of variance (ANOVA) procedure using Statistical Analysis System (SAS) package version 20 and the significant differences were determined at the 95% level of confidence.

Result of Biochemical Characteristics of Groundwater and Rainwater Samples

Table 1 shows the result of biochemical characteristics of groundwater and rainwater samples collected in Owerri-west. The biochemical characteristics checked to assess the microorganisms present in the samples are morphology, gram reaction, motility test, catalase test, indole test and oxidase test. Two organisms (*Bacillus subtilis* and *Staphylococcus epidermis*) were suspected in samples from Borehole (BH). The morphology characteristics showed rod and coccus. Gram reaction were positive. Test for motility showed negative. Catalase and Oxidase tests showed both positive and negative result. Indole test was negative for BH. A similar trend was observed in samples from zinc, aluminum and asbestos roofing sheet. The organism was *Escherichia coli*. Organisms from the sample of thatched roofing material are *Escherichia coli* and *Enterococcus faecalis*.

Table 1. Result of Biochemical Characteristics of Groundwater and Rainwater

Samples	Morphology	Gram Reaction	Motility Test	Catalase test	Indole test	Oxidase Test	Probable Organism
BH	Rod, coccus	+ve	-ve	+ve, -ve	-ve	+ve, -ve	*Bacillus subtilis, Staphylococcus epidermis*
Zinc	Rod	-ve	+ve	+ve	+ve	-ve	*Escherichia coli*
Aluminum	Rod	-ve	+ve	+ve	+ve	-ve	*Escherichia coli*
Asbestos	Rod	-ve	+ve	+ve	+ve	-ve	*Escherichia coli*
Thatched	Rod, Coccus	-ve, +ve	+ve, -ve	+ve	+ve, -ve	-ve	*Escherichia coli, Enterococcus faecalis*

Key: BH = Borehole
+Ve = Positive
-Ve = Negative

Result of Bacterial Count of Groundwater and Rainwater Samples

Table 2 shows the result of bacteria count when water samples were cultured on Nutrient Agar. 10 bacterial count was observed in sample from borehole (BH). 30 bacterial count was observed in sample from zinc roofing sheet, 18 bacterial count was observed in aluminum roofing sheet, 44 bacterial count was observed in sample from Asbestos roofing sheet, while 50 bacterial count was observed in the water sample from thatched roofing sheet. The sequence of bacterial count observed when water samples were cultured on Nutrient Agar are as follows: Thatched > Asbestos > Zinc > Aluminum > BH.

Table 2. Bacterial count of groundwater and rainwater samples

Sample Water	**Bacterial Count (cfu/ml)**					**% occurrence**
	Bacillus subtilis	***Staphylococcus epidermis***	***Escherichia coli***	***Enterococcus faecalis***	**Total**	
BH	6 (3.97)	4 (2.63)	0 (0.0)	0 (0.0)	10	6.58
Zinc	0 (0.0)	0 (0.0)	30 (19.74)	0 (0.0)	30	19.74
Aluminum	0 (0.0)	0 (0.0)	18 (11.84)	0 (0.0)	18	11.84
Asbestos	0 (0.0)	0 (0.0)	44 (28.95)	0 (0.0)	44	28.95
Thatched	0 (0.0)	0 (0.0)	34 (22.37)	16 (10.53)	50	32.89
Total	6 (3.97)	4 (2.63)	126 (82.89)	16 (10.53)	152	100

Key: BH = Borehole

Result of Total Coliform Count

Table 3 shows the result for total coliform count for groundwater and rainwater samples. BH and Zinc water samples had 0 cfu/100ml. Sample from aluminum roofing sheet had coliform count of 2 cfu/100ml. Water sample from asbestos roofing sheet had coliform count of 4 cfu/100ml, while samples from thatched roofing sheet had a coliform count of 20 cfu/100ml.

Table 3. Total coliform count of groundwater and rainwater samples

Sample Water	Coliform Count (cfu/100ml)					% occurrence
	Bacillus subtilis	***Staphylococcus epidermis***	***Escherichia coli***	***Enterococcus faecalis***	**Total**	
BH	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0	0.0
Zinc	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0	0.0
Aluminum	0 (0.0)	0 (0.0)	2 (7.69)	0 (0.0)	2	7.69
Asbestos	1 (3.85)	0 (0.0)	3 (11.54)	0 (0.0)	4	15.38
Thatched	5 (19.23)	0 (0.0)	13 (50.0)	2 (7.69)	20	76.92
Total	6 (23.08)	0 (0.0)	18 (69.23)	2 (7.69)	26	100

Key: BH = Borehole

Physicochemical parameters of groundwater and rainwater samples

Table 4 shows the result on physicochemical parameters of groundwater and rainwater. The general appearance of the water tested were clear except water collected from thatched roof that was not clear. The taste and odour of the water were unobjectionable, while the thatched roof water was objectionable. The pH of water from zinc, aluminum, asbestos and thatched roof were within WHO standard. The temperatures of the water samples were at normal range. The Biochemical oxygen demand (BOD), Total dissolved solid (TDS), Total suspended solid (TSS), Chloride and sulphate were below WHO standard. Nitrate was absent in borehole water and was present in small amount in asbestos (0.50 mg/l), aluminum (0.55 mg/l), zinc (0.80 mg/l) and thatched (1.50 mg/l).

Table 4. Physicochemical parameters of groundwater and rainwater samples

Parameters	BH	**Zinc**	**Aluminum**	**Asbestos**	**Thatched**	**WHO standard**
General Appearance	Clear	Clear	Clear	Clear	Not Clear	Clear
Taste	Unobjectionable.	Unobjectionable	Unobjectionable	Unobjectionable	Objectionable	Unobjectionable
Odour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable	Objectionable	Unobjectionable
pH	6.3	6.5	6.8	6.5	6.75	6.5 – 8.5
Temperature (°C)	26.75	26.8	27	27.1	27.1	20 - 32
Turbidity (NTU)	3.55	5.5	5.1	8.55	10.3	5
BOD (mg/l)	1.3	1.49	1.09	1.24	1.18	4
TDS (mg/l)	25.2	40	40	49	61	250
TSS (mg/l)	24.9	32.4	28.4	54.45	81.1	500
Cl^- (mg/l)	7.6	7.8	8.95	8.65	7.23	200
PO_4^{3-} (mg/l)	8.65	5.0	12.1	15.4	9.6	-
SO_4^{2-} (mg/l)	25.25	50.15	40.15	44.9	50	200
NO^{3-} (mg/l)	0	0.8	0.55	0.5	1.5	50

Key: NTU = Nephelometric Unit
BOD = Biochemical Oxygen Demand
TDS = Total Dissolved Solids
TSS = Total Suspended Solids
Cl^- = Chloride
PO_4^{3-} = Phosphate
SO_4^{2-} = Sulphate
NO^{3-} = Nitrate

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Print ISSN: 2056-7537(print),

Online ISSN: 2056-7545(online)

DISCUSSION

The WHO specifies that any disease causing organism must not be detectable in any 100ml of water sample and must not be present in 95% of sample taken throughout any 12 months period (WHO, 2010). The recommended bacterial indicator is coliform group of organisms. Coliform group of organisms are not pathogenic, they are aerobic, facultative anaerobic, gram negative, non-sporulating, rod shaped bacteria, that ferment lactose with gas formation and aldehyde/acid within 48 hours at 35^0C incubation (WHO, 2010). Coliform group of organisms were detected in rainwater samples from Aluminum (7.69%), asbestos (15.38%) and thatched (76.92%). The water sample from thatched recorded the highest number of coliform group which makes it generally unacceptable. Urinary tract infections, meningitis, diarrhea (one of the main causes of morbidity and mortality among children), acute renal failure and hemolytic anaemia have all been reported as health implications of water contamination by coliforms (NSDQW, 2007). 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 (WHO, 2010). The Heterotrophic Bacterial Counts (cfu/ml) of water samples were observed in this sequence BH (6.58%) < Aluminum (11.84%) < Zinc (19.74%) < Asbestos (28.95%) < Thatched (32.89%). Out of the four bacteria (*Escherichia coli*, *Enterococcus faecalis*, *Bacillus subtilis* and *Staphylococcus epidermis*) observed in all the water samples, *Escherichia coli* had the highest number of occurrence of 126(82.89) cfu/ml. This result is similar to the observation of Sylvester & Ebinyo (2015) who reviewed the microbial quality of potable water in Nigeria.

The occurrence of coliform in the potable water sources could be due to the presence of human and animals' excreta in such water (Egbe *et al.,* 2013 & Aboh *et al.,* 2015). The excreta could provide appropriate nutrients require for growth and proliferation. Generally, *E. coli* and *Enterobacter aerogenes* in potable water indicates presence of recent faecal matters (Onilude *et al.,* 2013 & Ndahi *et al.,* 2015). Isikwue and Chikezie (2014) stated that feacal coliform in water is influenced by presence of wastewater and septic system effluent, animal waste, sediment load, temperature and nutrients levels. International standards for water quality aimed at preventing pathogenic microbes in potable water, which is due to the fact that pathogen that contaminates water could transmit infectious diseases (Bukar *et al.,* 2015). Nwachukwu *et al.* (2010) reported that people often overlook both the immediate and future consequences of gradual exposure to contaminated domestic water sources and thereby lead to undesirable health effects. He also reported high rate of diarrhea in Owerri and the Imo River basin region. This could be as a result of lack of portable water.

The general appearance of all water samples were clear apart from the sample from thatched roof which was not clear. This might have been as a result of the material of the roofing sheet. The taste and odour of all water samples were unobjectionable and met the WHO standard. However, the taste and odour of water sample from thatched roof was objectionable, thus not acceptable. The pH value of borehole sample was observed to be 6.3 which was below the WHO limit of 6.5 – 8.5. However, water samples from zinc, aluminium, asbestos and thatched roofing materials had pH range of 6.5 – 6.75 which was within WHO standard. The pH value of rainwater samples shows that harvested rain water within Owerri-west is not acidic in comparison to research work by Igwo-Ezikpe and Awodele (2010), which showed that the pH of four industrial areas of Lagos state namely: Ilupeju, Costain, Ikeja and Ikorodu were 4.94, 4.20, 4.22 and 4.30 respectively. This was attributed to vehicular activities and old practice of bush burning by farmers and hunters. Similar pH results obtained from groundwater samples from this study have also been reported by other scholars (Onwuka *et al.,* 2004). pH values affect biological and chemical reaction in water bodies and it is a factor that determines water suitability for various purposes including toxicity to animals and plants.The temperature of all the water samples were moderate. High water temperature enhances the growth of microorganisms and may increase problems related to taste, odour and colour (WHO, 2011).

The turbidity of groundwater (3.55 NTU) was within WHO standard of 5NTU. However, the turbidity of rainwater (5.1 -10.3 NTU) were above the WHO standard. Turbidity in water is caused by suspended particles or colloidal matter that obstructs light transmission through the water (WHO, 2012). It may be caused by inorganic or organic matter or a combination of the two. High turbidity values observed could be an indication of possible sources of microbial contamination (WHO, 2012).

The Total Dissolved Solids (TDS) provide a rough indication of the overall suitability of water. The palatability of water with a total dissolved solids (TDS) level of less than about 500 mg/L is generally considered to be good. Drinking water becomes significantly and increasingly unsafe at TDS levels greater than about 250 mg/l (WHO, 2011). The total dissolved solids (TDS) of all water samples were within WHO standard though the value from thatched roofing sheet was higher than others. This might be due to droplets from birds, fallen of leaves, particulate matters and other assorted materials present on the roof.

Phosphate concentration levels in groundwater and rainwater samples were between 5.0 – 15.4 mg/l. Isikwue and Chikezie (2014) reported that traces of PO_4^{3-} even at 0.1 mg/L in water could have deleterious effect on water quality and such traces could increase the growing of troublesome algae in the water, and therefore, agricultural activities around these study areas could possibly lead to the values of phosphate recorded. Phosphates are not toxic to people or animals unless they are present in very high levels (Isikwue & Chikezie, 2014). Sulphate values observed fall below the WHO stipulated level of 200 mg/l. High levels of sulphate lead to dehydration and diarrhea especially in children (NSDQW, 2007). The presence of sulphate in drinking-water can cause noticeable taste and very high levels might cause a laxative effect in unaccustomed consumers (WHO, 2011).

Nitrate was detected in the groundwater sample, but they were detected in traces in rainwater samples. Natural level of nitrate in groundwater is increased by municipal and industrial wastewater including leachate from sewage sludge disposal (Lye, 2002) and sanitary landfills. High nitrate concentrations have detrimental effects on infants less than 3.6 months of age. Nitrate toxicity comes from the body's natural breakdown of nitrate to nitrite. This leads to "blue baby disease" which threatens the oxygen carrying capacity of the blood around the body (Melidis *et al.*, 2007). Nitrate is an essential ingredient of plant nutrition. It is, however regarded as an indicator of pollution in public water supply (Kathy, 2012). The findings of this research work is in agreement with the works of Onwuka *et al.* (2004), Olaoye & Olaniyan (2013), Sylvester & Ebinyo (2015), Egwuogu *et al.* (2016) and Ubuoh *et al.* (2017).

CONCLUSION

This study has provided results on the quality of harvested rainwater and groundwater in Owerri-west, Imo state, Nigeria. The results observed have shown the sequence of quality of groundwater and rainwater as Borehole > Aluminum > Zinc > Asbestos > Thatched. Generally, groundwater was more potable than harvested rainwater within the study area. Most of the physicochemical parameters of groundwater fell below the approved standards thus judged to be more acceptable than rainwater which could be risky and dangerous to health. The bacteriological analysis results of the borehole water and rainwater samples were not acceptable since they were all found to yield little to heavy growth of bacteria, thereby making them unfit for human consumption and other domestic purposes.

Recommendations

The following are recommendations for improving on the present state of groundwater and rainwater in Owerri-west:

1. All the sources of water supply in the area should be purified before drinking.
2. Human activities within the vicinities of the sources of water supply should be monitored to check factors responsible for impairment of the water.
3. Domestic groundwater sources borehole should be sited away from pit latrines, septic tanks, landfills and open dump sites, while harvesting of rainwater should be done at least after 20-30 minutes of rainfall to minimize impurities from the catchment roofs. The catchment roofs should be cleaned often.

REFERENCES

Aboh, E. A., Giwa, F. J. & Giwa, A. (2015). Microbiological assessment of well waters in Samaru, Zaria, Kaduna, State, Nigeria. *Annals of African Medicine,* 14:32-8.

Adeniyi, I. F. & Olabanji, I. O. (2005): The physico-chemical and bacteriological quality of rainwater collected over different roofing materials in Ile-Ife, South-western Nigeria. *Chemistry and Ecology*, 21(3) (2005):149-166

Akpan, C. M., Adesiyun, A. A., Adekeye, J. O., Umoh, J. U. & Nadarajah, M. (1996). *Environmental Issues and Management in Nigerian Development.* Ibadan. Evans Publisher. pp. 67-75.

APHA. (2005). Standard Methods for the Examination of Water and Waste Water, 21st ed. American Public Health Association, Washington, DC. Pp 1-252.

Batmanghelid, R. (2009). Water and its Vital Role in the Health of a Water Starved Society. *US National Research Council, Food and Nutrition Bureau*, *12* (2): 26-73.

Boss, R. (2004). Water for People, Water for Life. *United Nations World Water Development Report.* pp. 102- 117.

Botkin, D. B. & Keller, E. A. (1998). *Environmental Science: Earth as a Living Planet.* New York. (2nd edition) John Wiley & Sons Inc. pp. 472-476.

Bukar, A. M., Isa, M. A., Mustapha, A., Kyari, M. Z. & Ibrahim, F. K. (2015). Bacteriological Analysis of Sachet Water in Maiduguri Metropolis. *The Journal of Applied Sciences Research,* 2(1): 20-5.

Edungbola, L. D. & Asaolu, S. O. (1984). A Parasitological Survey: Onchocerciasis in Babana District of Kwara State, Nigeria. *American Journal of Tropical Medicine & Hygiene.* 33(999): 1147-1154.

Efe, S. I. (2006): Quality of Rainwater Harvesting for Rural Communities of Delta State, Nigeria. *The Environmentalist*, 26(3): 175-181.

Egwuogu, C. C., Okeke, H. U., Emenike, H. I., & Abayomi T. A. (2016). Rainwater Quality Assessment in Obio/Akpor LGA of River State Nigeria. *International Journal of Science and Technology Volume*, 5(7): 339-336.

Eja, M. E. (2002). *Water Pollution and Sanitation for Developing Countries.* Calabar, Seaprint (Nig) Co. pp. 9-10

Foel, E. W. & Nenneman, R. A. (1986). *How Peace came to the World.* Cambridge. MIT Press. pp. 112-121.

Förster, J. (1996). Patterns of roof runoff contamination and their potential implications on practice and regulation of treatment and local infiltration. *Water Science Technology*, 33(6): 39-48.

Gerba, C. & Smith, J. (2005): Sources of pathogenic microorganisms and their fate during land application of wastes. *Journal of Environmental Quality*, 34: 42–48.

Isikwue, M. O. & Chikezie A. (2014). Quality assessment of various sachet water brands marketed in Bauchi metropolis of Nigeria. *International Journal of Advances in Engineering and Technology*, 6 (6): 2489-95.

Jakarayan, S. C. (1988). *Rural Water Supply: Sierra Leone Example – A case of Developing World Water*. Water Engineering and Development Centre Publication, Pp 10-11.

Kulshreshtha, S. N. (1998). A Global Outlook for Water Resources to the Year 2005. *Water Resources Management.* 12(3): 167-184.

Lye, D. J. (2002). Health risks associated with consumption of untreated water from household roof catchment systems. *Journal of American Water Resource Association*, 38(5) (2002), 1301–1306.

Melidis, P., Akratos, C. S., Tsihrintzis, V. A. & Trikilidou, E. (2007). Characterization of rain and roof drainage water quality in Xanthi, Greece. *Environmental Monitoring Assessment*, 124: 15-27.

Miller (Jnr), G.T. (1992). Water and its Vital Role. *Environmental Science*. 345: 285-632.

Morgan, P. (1990). *Rainwater Harvesting in Rural Water Supply and Sanitation*. London, Macmillan Publication, Pp 53-58

Muyi, T. D. (2007). Water and the Body. *Water Resources*, 12: 13-45

Ndahi, A. K., Adamu, I. C. & Mohammed, I. U. (2015). Rapid assessment of reservoir water quality for drinking purpose: A case study of Ero and Ele reservoirs in Ekiti state Nigeria. *International Journal of Multidisciplinary Research and Development*, 2(4): 370-3.

Nissen-Peterson, E. (1982). *Rain Catchment and Water Supply in Rural Africa, Freetown*. Holder Stoughton publisher, Pp 118-127

NSDQW. (2007). Nigerian Standard for Drinking Water Quality, Nigerian Industrial Standard (NIS) 554. Standard Organization of Nigeria. Pp. 30-45. Egbe EO, Mawak JD; Oyewole OA. (2013). Microbiological Quality of Water in Fulani Settlements in GidanKwano, Minna, Niger State, Nigeria. *Journal of Microbiology Research*, 3(2): 67-70.

Nwachukwu, M. A., Feng, H. & Alinmor, K. S. (2010). Assessment of heavy metal pollution in soil and their implication within and around mechanic village. *International Journal of Environmental Science Technology*, 7(2): 347-358.

NWRI (1997). Training Guide for Basic Water Treatment Operations. Kaduna. National Water Resources Institute. p. 1.

Odiette, W. O. (1999). *Environmental Physiology of Animals and Pollution Diversified Resources.* Lagos. pp. 187- 218.

Olaoye, R. A. & Olaniyan, O. S. (2013). Quality of Rainwater from Different Roof Material. *International Journal of Engineering and Technology*, 2(8): 1413-1421.

Onilude, A. A., Adesina, F. C., Oluboyede, O. A. & Adeyemi, B. I. (2013). Microbiological quality of sachet packaged water vended in three local governments of Oyo State, Nigeria. *African Journal of Food Science and Technology*, 4(9): 195-200.

Onwuka, K. O., Uma, K. O. & Ezeigbo, H. I. (2004). Possibility of Shallow Groundwater in Enugu Town, South Eastern Nigeria. *Global Journal of Environmental Sciences,* 182(3): 33-39.

Origho, T. (2009). Assessment of the quality of rainwater harvesting in Ughelli and its rural areas, Delta State, Nigeria, Unpublished M.Sc Dissertation, Delta State University, Abraka, Nigeria. Pp. 23- 45

Schiller, E. J. (1982). *Rooftop Catchment Rainwater for Drinking*. Schiller, E.J and Drosten, R.L. (eds) Water Supply and Sanitation in Developing Countries, Michigan, Arbor Publication. Pp 45-68

Sylvester, C. I. & Ebinyo, R. I. (2015). A review of the microbial quality of potable water sources in Nigeria. *Journal of Advances in Biological and Basic Research*, 1(1): 12-19

Taylor, R., Sloan, D., Cooper, T., Morton, B. & Hunter, I. (2000). A waterborne outbreak of Salmonella Saintpaul. *Community Intelligence*, 24(11): 336–340.

Thomas, F. C., Bastable, C. & Bastable, A. (2003). Faecal contamination of drinking water during collection and household storage: the need to extend protection to the point of use. *Journal of Water and Health*, 1(3): 109-115.

Ubuoh, E. A. (2012). Susceptibility of Roofing Sheets to Atmospheric - Borne Corrosive Agents in Owerri, Nigeria. *International People-ware Appliance for Gateway to Analytical Learning (Pakistan).* 1: 1-10.

World Health Organization, WHO (2010). Guidelines for Drinking-water Quality. (Fourth edition) Geneva 27, Switzerland.