

Article

When Water Turns Deadly: Investigating Source Identification and Quality of Drinking Water in Piwoyi Community of Federal Capital Territory, Abuja Nigeria

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Abstract: Essentiality of water sustain life, and a satisfactory supply must be readily available to promote health, prolong life expectancy and prevent diseases. This study assesses the sources and quality of drinking water in Piwoyi community of Federal Capital Territory, Abuja, Nigeria. Thirty-five (35) Boreholes and Two (2) Sachet water were identified sources of drinking water in Piwoyi Community. Six Samples (5 Boreholes and 1 Sachet water) were selected at random and analyzed in the laboratory. The Physicochemical parameters examined include electrical conductivity (EC), pH, temperature, turbidity, dissolve oxygen (DO), chloride, total hardness, alkalinity, nitrate, calcium, magnesium, phosphate, phosphorous, sulphate, sodium, potassium, fluoride, bicarbonate, nitrate-nitrogen, nitrite, copper, iron and zinc; and Microbiological parameters include Coliforms, E-coli and Faecal Strep. The results of analysis shows significant concentration of physicochemical and microbiological parameters in the samples of water analyzed according to Nigerian Standard for Drinking Water Quality thereby makes the water unsafe for drinking. Drinking from these sources of water will pose serious health risk to the people of Piwoyi Community. Therefore, the study helps to identify the contaminated locations as well as assist to follow emerging remedial measures toward controlling the contamination source in the community. It also recommends continuous monitoring and enforcement of environmental violations, aggressive sensitization on water sanitation and hygiene; adequate purification of water at domestic level; and government support on potable water supply and establish reasonable management strategies for sustainable water quality protection toward protecting public health.

Keywords: Emerging Remedial Measures; Health Risk Assessment; Drinking Water Resources, Piwoyi Community, Federal Capital Territory, Nigeria

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1. Introduction

Some current studies on water quality in Nigeria comprise: Assessment of Trace Elements in Surface and Ground Water Quality by Morufu Raimi and Clinton Ezekwe [1]; Water-Related Problems and Health Conditions in the Oil Producing Communities in Central Senatorial District of Bayelsa State by Raimi *et al.*, [2]; An Assessment of Trace Elements in Surface and Ground Water Quality in the Ebocha-Obrikom Oil and Gas Producing Area of Rivers State, Nigeria by Raimi Morufu Olalekan and Sabinus Chibuzor Ezugwu [3]; Health Risk Assessment on Heavy Metals Ingestion through Groundwater Drinking Pathway for Residents in an Oil and Gas Producing Area of Rivers State, Nigeria by Olalekan *et al.*, [4]; The sources of water supply, sanitation facilities and hygiene practices in oil producing communities in central senatorial district of Bayelsa state, Nigeria

by Olalekan *et al.*, [5]; Bacteriological Assessment of Selected Hand Dug Wells in Students' Residential Area: A Case Study of Osun State College of Health Technology, Ilesa, Nigeria by Henry *et al.*, [6]; The Sources of Water Supply, Sanitation Facilities and Hygiene Practices in an Island Community: Amassoma, Bayelsa State, Nigeria by Raimi *et al.*, [7]; Digging deeper" evidence on water crisis and its solution in Nigeria for Bayelsa state: a study of current scenario by Olalekan *et al.*, [8]; An Analysis of Bayelsa State Water Challenges on the Rise and Its Possible Solutions by Raimi *et al.*, [9]; 21st Century Emerging Issues in Pollution Control. 6th Global Summit and Expo on Pollution Control by Raimi [10]; Nigerians crying for availability of electricity and water: a key driver to life coping measures for deepening stay at home inclusion to slow covid-19 spread by Gift *et al.*, [11]; Access to electricity and water in Nigeria: a panacea to slow the spread of Covid-19 by Gift and Olalekan [12]; Leaving No One Behind? Drinking-Water Challenge on the Rise in Niger Delta Region of Nigeria by Olalekan *et al.*, [13]. Thus, the impact of water on all aspects of people's development is undeniable: a safe drinking water supply, sanitation for health, management of water resources, and improvement of water productivity can help change the lives of millions [4, 5, 7, 8, 9, 13, 14]. Agwu [15], Morufu and Clinton [1] and Raimi and Sabinus [3] identifies Surface water (rivers, streams, lake and dams etc.) and Ground water (boreholes, wells etc.) as sources for drinking water. However, pollutants can be introduced into the natural water directly through point sources (septic tanks, disposal sites, industrial discharge of chemicals or spillage of oil, healthcare waste etc.,) near the source of water or indirectly through non-point source into the freshwater body by lateral or side movement [16, 17, 18, 19, 20]. More findings according to NOIPOLL in 2015 reveals significant proportion of Nigerians identified sachet water, popularly known as 'Pure water' as the major source of their drinking water in homes and offices. This source of drinking water might be affordable and easily accessible to Nigerians, but its hygiene and quality has been questioned by the National Agency for Food and Drug Administration and Control (NAFDAC) especially due to fault in the process of packaging. Other related sources of drinking water cited by NOIPOLL in 2015 include; *taps water, private boreholes, and public boreholes.*

Water is also a renewable resource in many parts of the world, water resources has become so depleted or contaminated that they are unable to meet ever-increasing demands [13, 21]. According to report in 2014 by United Nations, Nigeria was ranked the fifth dirtiest country in the world. 1.8 billion people globally use source of drinking water that is fecally contaminated. Some 2.4 billion people lack access to basic sanitation services, such as toilets or latrines [5, 7, 8, 9, 11, 12, 13]. Water scarcity affects more than 40 percent of the global population and is projected to rise [5, 7, 8, 9]. More than 80 per cent of wastewater resulting from human activities is discharged into rivers or sea without any treatment, leading to pollution [22]. Water pollution is a global concern as risks of water quality degradation translate directly into environmental, health, social and economic problems [23, 24, 25, 26, 27, 28, 29]. Water pollution has also an impact on biological diversity of aquatic ecosystems, on which a wide range of sectors, from urban development to food production and industry, rely on. Improving water quality and wastewater management is a pre-requisite for access to clean water and sanitation [20, 30, 31, 32]. Homeowners are responsible for monitoring the quality of well water by testing for bacterial quality every 6 months; chemical quality every 2 years; and test more often if you notice changes in physical qualities – taste, smell, or colour. Regular testing alerts you to problems with your drinking water [33]. Access to a safe drinking water source located on premises, available when needed and free of faecal (and priority chemical) contamination, and bringing a safe water supply close to households is essential to prevent WASH-related diseases and facilitate hygiene by providing more water for a variety of purposes. It also addresses the gender inequity of the burden of water collection borne by women [2, 4, 5, 7, 9, 24, 34].

1.1. Drinking Water Quality

Drinking water must be free from pathogens and toxic chemicals. Drinking water quality management has two distinctive entry points: one related to the standards to be met on a day-to-day basis under routine operating conditions; the other related to managing incidents that threaten drinking water quality and may result in disease outbreaks [1, 2, 3, 8, 11, 12, 13, 34, 35]. Water quality criteria developed by scientists provides basic scientific information about the effect of water pollutants on a specific water use. Water quality criteria is based on variables that characterize the quality of water and/or the quality of the suspended particulate matter, the bottom sediment and the biota [20, 31]. A water quality index is collected by aggregating several water quality measurements into a single number. Indices are, therefore, simplified expressions of a complex set of variables. They have proved to be very efficient in communicating water quality information to decisions makers and to the public [1, 3, 4, 36]. The parameters for determining water quality are highlighted as follows:

1.1.1. Bacteriological Quality

Coliform index is a measure of concentration of coliform organisms or E coli in a water sample. It is defined as the reciprocal of the smallest quantity of sample (in ml) which would give a positive E coli test. This index is now obsolete and now Most Probable Number (MPN). MPN is the bacterial density which if it had been actually present in the sample under examination, would more frequently than any other, have given the observed analytical results. For example, if 10-ml standard portions are examined not more than 10% should show the presence of coliform bacteria, and if 100-ml standard portions are examined not more than 60% should show the presence of coliform bacteria. When the membrane filter (MF) technique applied, the arithmetic mean coliform density of all standard samples must not exceed 1.0 per 100-ml. Moreover, coliform colonies per standard sample must not exceed 3/50-ml, 4/100-ml, 7/200-ml or 13/500-ml [6, 37]

1.1.2. Physicochemical Quality

Physicochemical indices are based on the values of various physicochemical qualities in a water sample. These are vital for water quality monitoring [2, 3, 4, 5, 7, 8, 38]. A number of scientific procedures and tools have been developed to assess the water contaminants [8, 9, 13, 39]. These procedures include the analyses of different parameters such as pH, turbidity, temperature, dissolved oxygen, alkalinity, fluoride, nitrate, sulphate, chlorides, iodine, lead, cadmium, manganese amongst others. These parameters can affect the drinking water quality, if their values are in higher concentrations than the safe limits set by the World Health Organization (WHO) and other regulatory bodies [1, 3, 13, 38].

1.2. Health Effect/Impact of Drinking Unwholesome Water

Contamination of drinking-water constitutes a major burden on human health [1, 3, 4, 7, 8, 9, 13, 40]. Worldwide, millions of people, especially children, die from acute water-related diseases each year [2, 7, 8, 9, 11, 12, 13]. In addition to short-term diseases, drinking contaminated water can also cause a variety of chronic diseases such as cancer. Acute and chronic diseases caused by unsafe water influence the access to potable water (Grady *et al.*, 2014; Raimi *et al.*, 2017; Olalekan *et al.*, 2019; Raimi *et al.*, 2019; Olalekan *et al.*, 2019; Olalekan *et al.*, 2020) [2, 5, 7, 8, 9, 11, 12, 13, 41]. Chronic diarrhoea can hinder child development by impeding the uptake of essential nutrients that are critical to the development of children's minds, bodies, and immune systems [14, 42, 43, 44, 45, 46, 47, 48]. Accordingly, Raimi *et al.* [2], Morufu and Clinton [1], Raimi and Sabinus, [3] and Olalekan *et al.*, [4] reiterates that poor water quality in Nigeria has caused several diseases such as cholera, dysentery, typhoid, poliomyelitis etc. They further buttress on how cholera alone has been the cause of thousands of deaths in Nigeria, and how the paucity of water has led to situations of untold suffering, affecting the impoverished and sustainable development. Heavy metals especially arsenic and lead in drinking water can bring about public health

problems. Arsenic is one of the most dangerous trace elements and is predominantly found in rocks, soils, and natural water. It was reported that arsenic affects the organs and systems in the body, including skin, heart, respiratory organs, and kidney consequently leading to cancer of the lung, kidney, and bladder. Similarly, lead another heavy metal act as an anti-essential trace element and highly toxic cumulative element in the human body which is widely distributed in soil and groundwater [1, 3, 4]. For neurological, metabolic, and behavioural reasons, children are more vulnerable to the effects of lead compared to adults [49, 1, 3, 4]. Intake of good quality water ultimately results in improved health. When you consume good quality water you are likely to have good health because about 70% of the body content is water.

1.3. Water Supply and Sanitation Issues

Many diseases endemic throughout the country in Nigeria are generally associated with unsatisfactory drinking water supplies, poor sanitation conditions and inadequate health education programs. However, the better access to potable water can help to relieve the total burden of disease (measured in daily-adjusted life years) and will help in the improvement of public health (Federal Republic of Nigeria, 2000; Olalekan *et al.*, 2018; Raimi *et al.*, 2019; Olalekan *et al.*, 2019) [4, 5, 7, 8, 9, 50]. USAID in 2010 estimated that 54 percent of the Nigeria population lives on less than one dollar per day [11, 12, 13, 51, 52, 53]. Also, observed that total volume of water available in surface and ground water resources are sufficient to meet current drinking water demands, lack of distribution capacity, coupled with highly variable rainfall patterns has led to water scarcity in some areas, particularly the north. Accordingly, USAID 2010 also opined that water infrastructures have suffered from years of poor maintenance, and lack of adequate sanitation facilities constitutes very serious public health problem. Other factors are weak and inefficient institutions, unsustainable public sector spending, poor water quality and conflict over water use and management [4, 5, 7, 8, 9, 31].

On daily basis, over 800 children die from preventable diseases caused by poor water and lack of sanitation and hygiene [2, 5, 7, 8, 9, 11, 12, 51]. Globally, nearly 2.1 billion people lack access to safe drinking water in homes [2, 5, 7, 8, 9, 11, 12, 13]. By managing our water sustainably (water sanitation), we are able to better manage our production of food and energy and contribute to decent work and economic growth. Moreover, we can preserve our water ecosystems, their biodiversity, and take action on climate change [4, 11, 12, 20, 24, 31, 33, 52]. Access to water and sanitation is considered core socio-economic and health indicators, and key determinants of child survival, maternal, and children's health, family wellbeing, and economic productivity. Drinking water and sanitation facilities are used in raising wealth quintiles used by many integrated household surveys to analyze inequalities between rich and poor [54]. Studies also observed that as water becomes scarcer at community water points, women and children who gather the water may find themselves at the forefront of inter and intra community-based conflict as they compete against each other for access to scarce water resources. The U.S National Action Plan on Women, Peace and Security, for instance, calls for building resilience through assistance that supports women's roles in the management of natural resources, mitigation of resource related conflict, and adaptation to climate change in fragile and conflict affected states [24, 33, 52, 55, 56, 57, 58]. Thus, answers were provided for the following research questions: To identifies all sources of drinking water in Piwoyi community; To examine the physicochemical and microbiological quality of drinking water in the selected sources of drinking water in Piwoyi Community; To determine the concentrations of some heavy metals in selected sources of drinking water in Piwoyi Community.

2. Study Region

2.1. The Study Area [Abuja]

Abuja is the Federal Capital Territory of Nigeria. The city is located at the center of the country. Abuja is a well-organized and planned city, built mainly in the 1980s. Abuja geography is classified by Aso Rock, a 400-metre (1,300 ft) monolith left by water erosion. The Presidential Complex, National Assembly, Supreme Court and much of the city extend to the south of the Zuma Rock, a 792-metre (2,598 ft) monolith, lies just north of the city on the expressway to Kaduna. FCT lying between latitude $9^{\circ} 4''$ North of the equator and longitude $7^{\circ} 29''$ East of Greenwich Meridian (see figure 1 below), Abuja total land-mass approximately is 7,315 km². It is situated within the savannah region with moderate climatic conditions. Abuja Municipal Area Council covers 1,769km² (683 sq mi) Area, of which 1,728km² (667 sq mi) is land and 41km² (16 sq mi) is water [59].

2.2. Demography of Abuja

During 2006 census, Abuja population was among the ten most populous cities in Nigeria estimated around 776,298. Accordingly, the United Nations also confirmed that in 2015 that Abuja grew by 139.7% between 2000 and 2010, making it the fastest growing city in the world. In 2015, the city is experiencing an annual growth of at least 35%, retaining its position as the fastest growing city on the African continent and one of the fastest growing in the world. Also, in 2016, the metropolitan area of Abuja is estimated at six million persons.

2.3. Climate

Abuja climate classification features a tropical wet and dry climate. FCT has three weather conditions annually which are warm, humid rainy season and a blistering dry season. In between the two, there is a brief break of harmattan occasioned by the northeast trade wind, with the main feature of dust haze and dryness. Rainy season start from April and ends in October, when daytime temperature reach 28°C to 30°C and night-time lows hover around 22°C to 23°C in the dry season, daytime temperatures can soar as high as 40°C and night-time temperatures can dip to 12°C.

2.4. Vegetation

FCT falls in the Guinean Forest-Savannah Mosaic zone of the West African sub-region. Patches of rain forest, however occur in Gwagwa plains, especially in the rugged terrain to the south eastern parts of the territory, where a landscape of gullies and rough terrain is found. These areas of the Federal Capital Territory (FCT) form one of the few surviving occurrences of the mature forest vegetation in Nigeria.

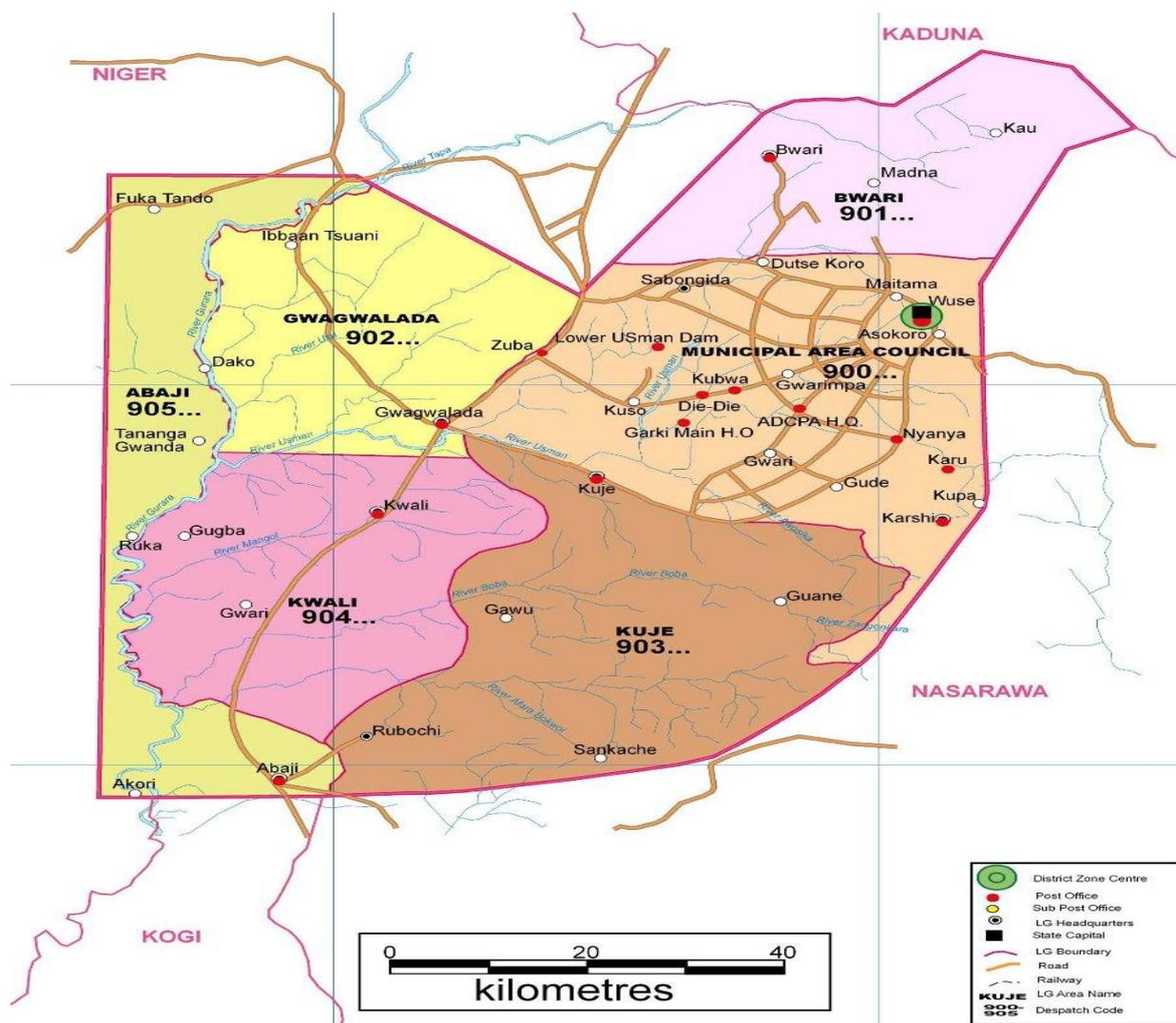


Figure 1. Map Showing the Study Area [Abuja FCT]

2.5. About Piwoyi Community

Piwoyi is one of clusters of satellite settlements in Abuja Municipal Area Council. It is located along KM 7.5, Umar Musa Yaradua Way, Airport Road, Abuja FCT, Nigeria. Piwoyi lies between latitude 8°99'N of the equator, and longitude 7°40'E of the Greenwich Meridian (see figure 1 above and figure 2 below). The community has some multipurpose structures which include Nigeria Defense College, Nike Art Gallery, Shoprite, National Assembly Annex, Schools, Hotels, Health Centre, other Government Offices, Companies as well as Living Premises. The postcode is 900107 (Postcode.info, 2013-2018). The composition of the people in Piwoyi community is heterogeneous comprises Gbagyi, Yoruba, Ibo and Hausa etc. Below is the Satellite Imagery of Piwoyi Community by NASRDA in 2012.

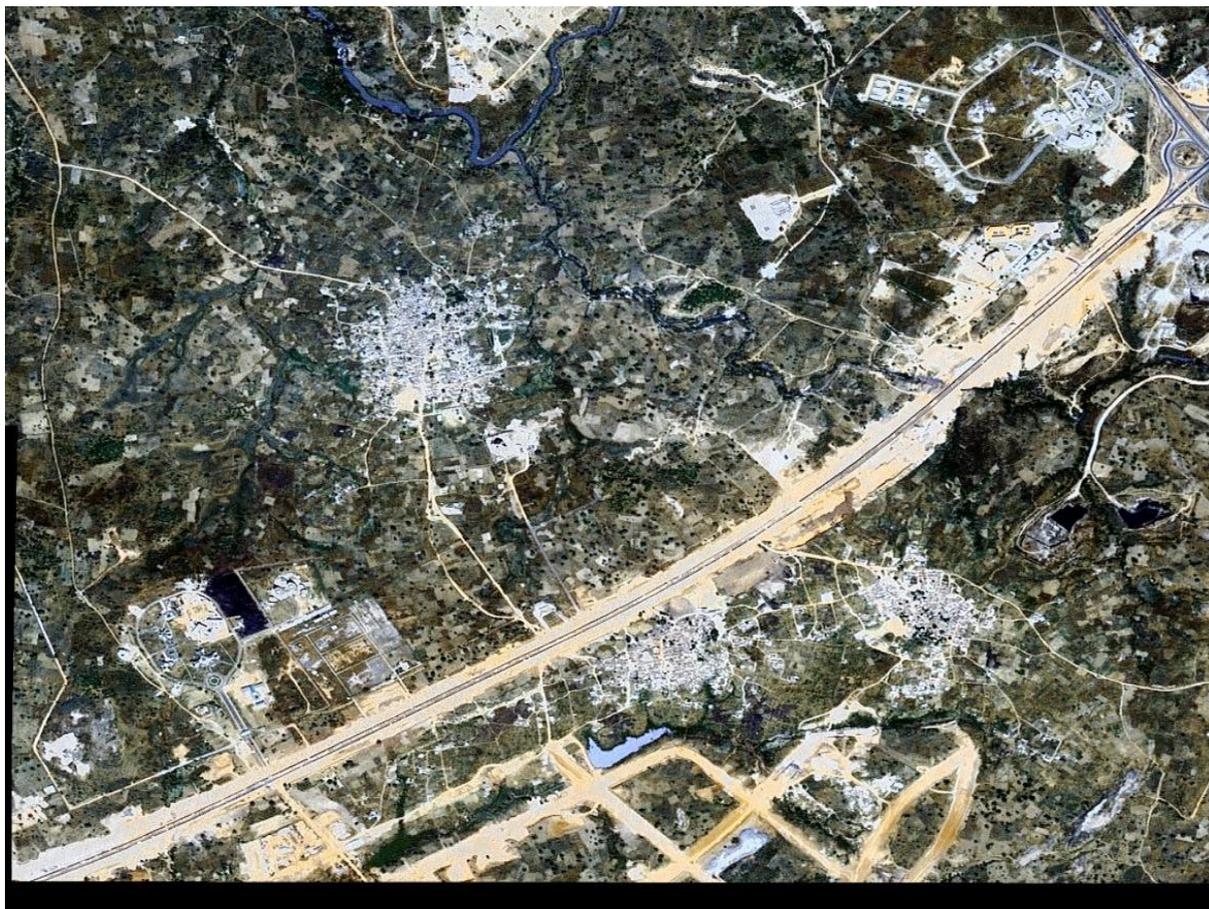


Figure 2. Map Showing the Satellite Imagery of Piwoyi Community

3. Materials and Methods

3.1. Sampling and analytical techniques

Water Samples were collected at different identified points viz-a-viz Mpape (P1), Baptist Church (P2), ECWA (P3), Chief Palace/Market (P4), Angwa Hausa (P5) and Sachet Water (P6). Most patronized borehole by water vendors and communal collecting water for drinking from different points were identified through direct observations and personal interview. Two different categories of Sachet water (Pure Water) used for drinking were also identified and most drink sachet water (Clime Sachet Water) was collected within Piwoyi Community.

3.2. Sample Collection Time

Raw Water Samples were collected at early hour of 6:00 am to 7:30 am under normal atmospheric temperature of 25°C.

3.3. Sample Bottle

75cl distilled plastic bottles were used to collect raw water sample from different points.

3.4. Sample Collection Procedure

- Pre-printed label is attached to the bottle indicating the specific areas of collections for ease of identifications.
- The bottle sample is positioned to allow raw cold water to flow into it at a moderate rate from different sources identified.
- The bottle was filled just below the neck of the bottle.

- The bottles were securely covered with tight lid to prevent leakage and kept in a cold box (4°C) during transportation to the laboratory for analysis.
- Sachet water samples selected for this study were collected at the same time and transported to laboratory under normal conditions.

3.5. Sampling, Preservation and Analysis

The water sampling and the analysis follows standard procedures described in APHA [60]; Morufu and Clinton [1]; Raimi and Sabinus [3]; Olalekan *et al.*, [4].

4. Results and Discussion

4.1. Results

The results of physicochemical and microbiological quality of drinking water including concentrations of some selected heavy metals are presented in table 1 below.

Table 1. Results of Physicochemical, Microbiological and Heavy metals parameters for drinking water (boreholes and sachet water) samples in comparison with NSDWQ (Nigerian Standard for Drinking Water Quality).

Parameters	Units	Mpape (Point 1)	Baptist Church (Point 2)	ECWA (Point 3)	Chief Pal- ace/Market (Point 4)	Angwa Hausa (Point 5)	Clime Sachet Water (Point 6)	NSDWQ	Remarks
Conductivity	uS/cm	438	953	744	1027	487	90	1000	BS-BS-BS-AS-BS-BS
Temperature	°C	29.3	29.3	29.3	29.3	29.2	27.2	27-28	AS-AS-AS-AS-AS-BS
Hydrogen Po- tential (pH)		6.6	6.0	6.9	6.1	7.0	6.9	6.5-8.5	WS
Turbidity	NTU	3.0	4.0	9.0	18	15	20	5	BS-BS-AS-AS-AS-AS
Total Dissolve Solid (TDS)	Mg/L	294	639	499	688	326	60	500	BS-AS-WS-AS-BS-BS
Dissolve Oxy- gen (DO)	Mg/L	7.36	7.80	5.93	6.51	6.35	6.40	7.50	WS-AS-BS-BS-BS-BS
Chloride (Cl ⁻)	Mg/L	23	112	71	121	26	7.0	200	BS
Total Hard- ness (TH)	Mg/L	234	468	588	411	255	81	150	AS-AS-AS-AS-AS-BS
Alkalinity	Mg/L	266	187	210	143	239	56	100	AS-AS-AS-AS-AS-BS
Nitrate (NO ₃ ⁻)	Mg/L	3	51	38	84	21	9	50	BS-AS-BS-AS-BS-BS
Calcium (Ca ²⁺)	Mg/L	72	85	87	80	68	29	75	WS-AS-AS-AS-BS-BS
Magnesium (Mg ²⁺)	Mg/L	10	62	91	51	21	2	20	BS-AS-AS-AS-AS-BS
Phosphate	Mg/L	0.43	0.19	0.28	0.43	0.15	0.13	0.3	AS-BS-WS-AS-BS-BS
Phosphorous	Mg/L	0.15	0.03	0.06	0.15	0.02	0.01	-	
Sulphate	Mg/L	0	81	0	0	02	0	100	BS
Sodium	Mg/L	07	39	18	53	17	0	200	BS
Potassium	Mg/L	11	09	14	03	02	13	10	AS-BS-AS-BS-BS-AS
Fluoride	Mg/L	0.00	0.00	0.00	0.00	0.00	0.19	1.5	BS
Bicarbonate	Mg/L	266	187	210	143	239	56	-	
Nitrates (NO ₂)	Mg/L	0.60	11.5	8.5	19	4.8	2.0	10	BS-AS-BS-AS-BS-BS
Nitrite (NO ₃)	Mg/L	0.1	3.0	3.0	6.0	0.9	0.007	0.2	BS-AS-AS-AS-AS-BS
Microbiological parameters from selected boreholes and sachet water in comparison with NSDWQ									
Coliforms	Cfu/100m l	02	70	180	04	06	30	10	BS-AS-AS-BS-BS-AS

E-coli	Cfu/100m 1	00	27	65	01	01	11	0	WS-AS-AS-AS-AS-AS
Faecal Strep	Cfu/100m 1	00	43	115	03	05	19	0	WS-AS-AS-AS-AS-AS
Heavy metals parameters from selected boreholes and sachet water in comparison with NSDWQ									
Copper (Cu ²⁺)	Mg/L	0.05	0.20	0.16	1.0	0.07	0.00	1.0	BS-BS-BS-WS-BS-BS
Iron (Fe ²⁺)	Mg/L	0.32	0.00	3.30	0.00	0.00	0.00	0.3	AS-BS-AS-BS-BS-BS
Zinc (Zn ²⁺)	Mg/L	1.13	3.27	2.10	3.37	1.10	0.00	5	BS

Source: Field Survey

Note: BS – Below Standard, AS - Above Standard, WS - Within Standard

Table 1 shows the results of the assessment of the quality of drinking water in Piwoyi community of Federal Capital Territory, Abuja. Results shows borehole and sachet water in the six (6) locations measured for physico-chemical parameters analysed. For conductivity, Mpape, Baptist church, ECWA, Angwa Hausa and Clime sachet water were all below Nigerian standard for drinking water quality (NSDWQ). While Chief palace/market were above recommended standard. Temperature from point 1 to point 5 were above recommended standard, while, clime sachet water were below standards. pH was within recommended standards in all locations. Turbidity at ECWA, Chief palace/Market, Angwa Hausa and Clime sachet water were above recommended standards. For TDS, Baptist church, Chief palace/Market were above standards. DO, only point 2 is above recommended standards. For Chloride, all samples taken are below standards. Total hardness (TH) from point 1 to 5 are above recommended standards. Same goes for Alkalinity. For Calcium, point 2, 3 & 4 were above recommended standards. Magnesium at point 2, 3, 4 & 5 are above recommended standards, Phosphate at point 1 & 4 are above standards. Sulphate in all locations are below standards. Same goes for Sodium and Fluoride. Potassium at point 1, 3 & 6 are above standards. Nitrate at point 2 & 4 are above standards, Nitrite at point 2, 3, 4 & 5 are above recommended standards. For microbiological parameters, Coliform at point 2, 3 & 6 are above recommended standard, E-coli at point 2, 3, 4, 5 & 6 are above recommended standards. Same goes for faecal strep. For Heavy Metal, Copper and Zinc in all locations fall below NSDWQ recommended standards. Iron at point 1 & 3 are above recommended standards.

4.2. Discussion

4.2.1. Comparison of Physicochemical and Heavy metals results of drinking water samples analysis with Nigerian Standard for Drinking Water Quality (NSDWQ).

Water chemistry depends on various factors such as geological and hydrogeological settings, intensity and rate of rock weathering, climatic conditions, recharge water quality, types and intensity of human activities, and connections and interactions of different water bodies [2, 3, 4, 57, 8, 9, 13, 31]. These factors vary in different environments, and their interactions can create complex water chemistry [1, 3, 4, 5, 10]. To explore the general hydrochemistry of water in the study area, the statistical summary of borehole water and sachet water is presented in Table 1. Thus, water in Piwoyi community of Federal Capital Territory, Abuja is mainly used for domestic and agricultural purposes. Physiochemical indices were compared with the Nigerian Standard for Drinking Water Quality and World Health Organization guidelines for drinking water quality purpose.

Indeed, pure water is not a good conductor of electric current rather a good insulator. Increase in ions concentration enhances the electrical conductivity of water. Generally, the amount of dissolved solids in water determines the electric conductivity. According to Nigeria standard, electrical conductivity should not exceed 1000uS/cm. But the value obtained from Mpape (438), Baptist Church (953), ECWA (744), Angwa Hausa (487) and Clime Sachet Water (90) are below the permissible level except Chief Palace/Market that

is higher (1027). Hence, the spatial distribution shows a higher EC towards the Chief Palace/Market. Indicating that man-made activities and geochemical processes greatly responsible for the increase in EC. The temperature is one of the most important factors that affect the biological activity of aquatic organisms. The average temperature value of the water samples (Boreholes and sachet water) in the study area ranges between 27.2°C and 29.3°C. Temperature in this study was found to be within the permissible level of WHO 30°C and NSDWQ. Turbidity is caused by organic detritus; silica and other mineral substances such as zinc, iron, clay and microorganisms. Turbidity is the characteristics of water which causes light to scatter and absorbed rather than transmitting in straight lines. Maximum turbidity permitted as per Nigerian standard is 5mg/l. The turbidity value of water sample is higher in ECWA (9.0), Chief Palace/Market (18), Angwa Hausa (15) and Clime Sachet Water (20) but lower in Mpape (3.0) and Baptist Church (4.0) area respectively. Thus, excess Turbidity according to Morufu and Clinton [1]; Raimi and Sabinus [3]; Olalekan *et al.*, [4]; Olalekan *et al.*, [13] makes the water not appealing for recreation, spiritualism and gives poor visibility due to reduction in the amount of sunlight scattered or absorbed by particulates. Furthermore, the high turbidity is indicative of high volume of suspended particulate matters (silt, clay, waste effluents etc.). High volume of turbidity according to Morufu and Clinton [1], Raimi and Sabinus [3], Olalekan *et al.*, [4]; Olalekan *et al.*, [13] held that excessive dissolved solids can give a kind of taste to water, increases corrosion or encrustation of metallic equipment and poses problems to household plumbing and other utensils (boilers, toilet flushes, washing machines, metallic plates and faucets). The hydrogen ion concentration of pH is a parameter that shows the chemical and biological characteristics and it is used in classifying alkalinity or acidity of waters. While, the pH of water is a measure to determine acidic and alkaline character in water. Principal system that regulates pH in natural water is carbonate system which comprises CO₂, H₂CO₃ (Carbonic acid) and HCO₃⁻, CO₃⁻ value of pH of good quality water varies between 6.5 and 8.5. In addition, drinking water normal pH level varies between 6.5 and 8.5. Thus, current investigations depict average normal pH value in Mpape (6.6), ECWA (6.9), Angwa Hausa (7.0) and Clime Sachet water (6.9) except Baptist Church (6.0) and Chief Palace (6.1) fall within the acidic level, indicating that point 2 and 4 is generally slightly acidic. These pH values are slightly lower than those of other locations. These results indicate that the study area has basic character and is in Class-I (6.5-8.5) in terms of pH value. On pH scale, a value 7 is refers to as neutral water, below 7 is acidic water while any value above 7 is basic water [1, 3, 4, 10, 13]. Water has the ability to dissolve both organic and inorganic minerals and salts, such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium and sulphates. These minerals produced unwanted taste and diluted colour in appearance of water. Water with high level of Total Dissolve Solid (TDS) indicates that the water is highly mineralized. Desirable limits according to Nigeria standard is 500mg/l. However, the study shows high TDS in Baptist Church (639), Chief Palace/Market (688), and others are within the acceptable limits in Mpape (294), ECWA (499), Angwa Hausa (326) and Clime Sachet Water (60). High value of TDS in ground water are generally not harmful to man, but high concentrations of these may affect persons who are suffering from kidney and heart diseases [13]. Water containing high solid may cause laxative or constipation effect [1, 3, 4]. It major causes include saline water intrusion, ejection of untreated domestic wastewater, beach placer mining of coastal sand dunes, and lithological formation of salt in subsurface rocks [31]. These groundwater with elevated TDS can cause gastrointestinal irritation, heart disease and kidney stones in humans [1, 3, 4, 13, 61]. Adequate dissolve oxygen is necessary for good water quality. Oxygen is necessary element to all forms of life. Oxygen affects vast number of other water indicators, not only biochemical but aesthetic ones like the odour, clarity and taste. The desirable limits for Dissolve Oxygen is 6mg/l. Therefore, the results of analysis show an increase in dissolve oxygen above 6mg/l except ECWA at 5.93. Furthermore, chlorides is obtained from natural deposits of sedimentary rocks or dissolution of salts of hydrochloric acid as table salt

(NaCl), NaCO_2 , and added through sewage etc. High concentration of chlorides may be injurious to people suffering from heart and kidney diseases. 200mg/l is maximum as Nigeria standard. All the sample areas are within the permissible level by Nigeria standard. Hard water is water that has high mineral content and it is formed when water percolates through deposits of limestone and chalk which are largely made up of calcium and magnesium carbonates. Total hardness is expressed as the sum total of magnesium and calcium concentrations of 2-4mmol/L. The desirable standard for Total Hardness in water is 150mg/l. The results of analysis shows that all the samples of water collected from boreholes are hard. The Clime sachet water is within the desirable limit of 80mg/l. Thus, long-term dietary exposure to hard to very hard water may lead to increased incidences of health problems such as anencephaly, parental mortality, and cardiovascular disorders [4, 13].

Alkalinity is a measure of the capacity of water to neutralize acids or hydrogen ions. Alkalinity acts as buffer if any changes are made to the water's pH value. Alkalinity will help to keep the water's pH stabilized. The drinking water should have a neutral pH of 7. High alkalinity is good to have in our drinking water because it keeps the water safe for us to drink. The amount of alkalinity that should be in our water is 20-200mg/l for typical drinking water. Alkalinity is basically dissolved minerals in the water that help neutralize the water we drink. While, alkali strength is a measurement of the water tenure of free carbonate and caustic alkali. HCO_3^- - water varies during the study from 56 to 266 mg/l (Table 1). The maximum value is 100 mg/l. According to Nigerian standard for drinking water quality, HCO_3^- is an indicator of the presence of ions carbonates, bicarbonates, hydroxides hardness of drinking water factor. The results of analysis shows that alkalinity in Baptist Church (187), Chief Palace/Market (143), and Clime Sachet Water (56) are within the desirable limit while it is higher in Mpape (266), ECWA (210), and Angwa Hausa (239). Nitrate occurs naturally at very low concentrations in groundwater and is regarded as an important plant nutrient. Common sources of nitrate in groundwater are from inorganic fertilizers and manures, wastewater disposal on land for irrigation and oxidation of nitrogenous waste products in human or animal excreta [1, 3, 62, 63]. Main source of nitrates in water is from atmosphere, sewage, industrial effluents and agriculture. When water contains excess amount of nitrates and is ingested, bacteria convert these nitrates to nitrites. These nitrites react with secondary amine present in the food and form nitro compounds responsible for methamoglonimeaic diseases in children. Nigeria desirable standard for nitrate is 50mg/l. The study shows that nitrates is higher in Baptist Church (51), Chief Palace/Market (84), which is due to anthropogenic sources like application of agricultural fertilizers [13, 42, 43, 45, 46, 47, 48, 63]. This led to nitrate concentrations exceeding the WHO limit in 5% of the locations. Nitrate contamination is usually associated with shallow groundwater [1, 3, 4, 62, 13]. Raimi *et al.* [63] [9] [13] reported that pit latrines and public water points are observed to influence nitrate concentrations in borehole water of Baptist Church and Chief Palace/Market. This may also be another reason for an increase in nitrate concentration in borehole water in the study area. Mpape (03), ECWA (38), Angwa Hausa (21) and Clime Sachet Water (09) are within the permissible level. Thus, nitrate concentration in Mpape, ECWA, Angwa Hausa and Clime Sachet Water is lower than the guideline value, indicating suitability of the water for drinking purpose.

While, calcium (Ca^{2+}) is very essential element for human body. It serves as nutrient and body requires 0.7-2.0 mg of calcium daily. When the human body lacks Ca^{2+} , it leads to several diseases such as stroke, osteoporosis, and colorectal cancer. Its deficiency causes rickets and presence prevents absorption and transfer of toxic ions from intestine to blood. Excess amount can cause damage to kidney and impart hardness to water. The maximum desirable standard is 75mg/l. However, the results of analysis shows that calcium in sample water collected were higher in Baptist Church (85), ECWA (87), Chief Palace/Market (80), and within the desirable level in Mpape (72), Angwa Hausa (68) and Clime Sachet Water (29). Thus, drinking such water samples could yield ailments in the human body

such as hypertension, kidney stones, osteoporosis, stroke, and colorectal cancer [40, 4, 64, 13]. In addition, the high calcium concentration in Baptist Church, ECWA and Chief Palace/Market implies that the water is polluted and unfit for consumption due to calcium contribution to overall hardness in concert with magnesium and sulphates. This represents a risk of changes in bowel habits (diarrhoea) and Cholera [2, 5, 7, 13]. Presence of magnesium in excess amount acts as a laxative agent and causes hardness of water which may further cause cardiovascular mortality. Its deficiency makes a person susceptible to cardiac and may also cause sudden unexpected infant death syndrome. The maximum desirable Nigeria standard is 20mg/l. However, the result of analysis depicts high level of magnesium in Baptist Church (62), ECWA (91), Chief Palace/Market (51), Angwa Hausa (21), and within the desirable level in Mpape (10) and Clime Sachet Water (02). Thus, combinations of calcium and magnesium ions reduces the soil permeability and affect soil structure, drainage pattern as well as crop production. The phosphate exists in three forms: orthophosphate, meta-phosphate, and organically bound phosphate, each compound contains phosphorus in different chemical arrangements [3, 4, 8, 9, 13]. Phosphates are chemical compounds containing phosphorous. Manmade sources for phosphate include human sewage, agricultural run-off from crops, sewage from animal feedlots, pulp and paper industry, vegetable and fruit processing, chemical and fertilizer manufacturing and detergents [13, 20, 42, 43, 45, 46, 47, 48, 63]. Phosphates itself does not have notable adverse health effect. However, phosphate levels greater than 1.0mg/l may interfere with coagulation in water treatment processes. The results of analysis are within the desirable limits. Thus, phosphate support heavy aquatic plant growth that usually leads to algal blooms [1, 3, 4, 5, 8, 9, 13, 20]. This is a non-metallic element which is necessary for life and is found in rock as inorganic phosphates. Phosphorous plays a role in deoxyribonucleic acid (DNA), adenosine diphosphate (ADP), and adenosine triphosphate (ATP). Phosphorous is required for these necessary components of life to occur. Presence of sulphate in drinking water affects taste and in excess amount causes diseases called catharsis or purgation of alimentary canal. The maximum desirable Nigeria standard for sulphate is 100mg/l. However, Sulphates results of analysis in the water sources were identified in all the samples analysed to be within the desirable level of NSDWQ standard limits. While excess sulphate concentration might likely cause dehydration, catharsis in adults [1, 3, 4, 65]. Sodium is a silver white metallic element and found in less quantity in water. Adequate quantity of sodium in human body prevents many fatal diseases like kidney damage, hypertension, headache etc. The maximum Nigeria standard for sodium in drinking water is 200mg/l. However, the results of analysis depict that sodium are below the desirable limits of the drinking water sample. Even though sodium is essential for balanced human health, excessive sodium intake can lead to serious health risks such as vomiting, hypertension and osteoporosis and high blood pressure [1, 3, 4, 13, 40, 66]. While, excess concentrations of sodium in water are indicative of reduced ionic and microbial activities as well as increased water density. According to WHO [65], sodium salts are not acutely toxic because of the efficiency with which mature kidneys excrete sodium. However, acute effects and death have been reported following accidental overdoses of sodium chloride. Potassium is a silver white alkali which is highly reactive with water. Potassium enhances human body functions like heart protections, regulation of blood pressure, protein dissolution, muscle contraction and nerve stimulus. Its deficiency may cause depression, muscle weakness, heart rhythm disorder etc. The max desirable Nigeria standard for potassium is 12mg/l. However, the results of analysis shows that potassium is higher in ECWA (14) and Clime Sachet Water (13), which is found to be above Nigerian standard for drinking water quality (NSDWQ), and Mpape (11), Baptist Church (9), Chief Palace/Market (03), and Angwa Hausa (04) are within the permissible limit. Thus, high as well as abnormal concentrations could be due to artificial compost in farming measures such as leaching or percolating into the subsurface and weathering of K^+ bearing minerals in rocks nearby

[31]. This enriched K^+ could cause nerve and digestive disorders [13, 61]. Equally, Potassium is needed for the proper functioning of cells, notwithstanding, excess intake of it could possibly lead to high blood pressure (HBP), medically called hyperkalaemia, together with chest tightness, nausea, vomiting, diarrhoea, shortness of breath, heart failure, haemolytic anaemia and Addison disease [1, 3, 4, 67]. Fluoride occurs in nature in the form of CaF_2 , cryolite, Na_3AlF_6 and fluorapatite. Fluoride contents are also found in food like fish, tea, milk, fruits and vegetables. Its increased contents beyond certain limits cause fluorosis destruction of enamel of teeth. The Nigeria standard for fluoride is 1.5mg/l. However, the analysis of results in all samples depicts that fluoride is within the desirable limit. However, it is also essential to pay attention to the fluorine content in borehole and sachet water since the residents in the study area could likely be suffering from fluorosis in the nearest future. F^- is beneficial at low concentrations but toxic at high concentrations in drinking water [1, 3, 4, 13].

Nitrogen is derivatives of nitrite (NO_2), nitrate (NO_3) and ammonium nitrogen (NH_4^+). Recently, one of key sources of nitrite (NO_2) in waters are fertilizers, organic matters, and some of minerals [13, 20]. The desirable standard for Nitrite (NO_2) is 0.2mg/l. The health impact of nitrite is cyanosis and asphyxia (blue-baby syndrome) in infants under 3 months. The result of laboratory analysis for nitrites was high in Baptist Church (3.0), ECWA (3.0), Chief Palace/Market (6.0), thus indicating pollution and Mpape (0.1), Angwa Hausa (0.9) and Clime Sachet Water (0.007) are within desirable limit. Nitrate pollution of water is a widespread issue and the desirable standard for NO_3-N in drinking water is 10mg/l. The health impact of NO_3-N is Methemoglobinemia in infants. The most obvious symptom of methemoglobinemia is a bluish color of the skin, particularly around the eyes and mouth. Other symptoms include headache, dizziness, weakness or difficulty in breathing. However, the study reveals very high nitrate-nitrogen in Baptist Church (11.5) and Chief Palace/Market (19), which indicates high concentrations and other four points areas analyzed are within the permissible level. Even though nitrates have no direct toxic effects except at high doses, the fact that they can give birth to nitrites leads to toxicity. Copper toxicity is much overlooked contributor to many health problems such as anorexia, fatigue, premenstrual syndrome, depression, anxiety, liver and kidney damage, migraine and headaches, allergies, childhood hyperactivity and learning disorders. The desirable limit for copper in water is 1mg/l. The results of analysis shows that copper is within the desirable limit in all samples collected in Piwoyi community. Iron is the second most abundant metal on the earth's crust [1, 3, 4, 68]. Iron occupies the 26th elemental position in the periodic table. Iron is a most crucial element for growth and survival of almost all living organisms [4, 69]. It is one of the vital components of organisms like algae and of enzymes such as cytochromes and catalase, as well as of oxygen transporting proteins, such as hemoglobin and myoglobin [1, 3, 4, 70]. Iron is an attractive transition metal for various biological redox processes due to its inter-conversion between ferrous (Fe^{2+}) and ferric (Fe^{3+}) ions [71]. The source of iron in groundwater is anthropogenic and is related to mining activities. The production of sulphuric acid and the discharge of ferrous (Fe^{2+}) takes place due oxidation of iron pyrites (FeS_2) that are common in coal seams [69]. While, iron is found in the form of $FeCl$, $Fe(HCO_3)$, $FeSO_4$. Iron helps in metabolic process of human health. Presence in excess amount imparts objectionably colour and taste. The maximum desirable Nigeria standard for iron in water is 0.3mg/l. The result of analysis shows high concentration of iron in Mpape (0.32) and ECWA (3.30) and within the acceptable limit in other sample areas with 0.00. In the Niger Delta Region of Nigeria, many people have been exposed to elevated levels of iron through drinking water, as the collected groundwater exceeded the tolerable limit set by the NAFDAC and WHO on the quality of drinking water [1, 3, 4, 10, 13, 31]. Similarly, the abundance of species such as periphyton, benthic invertebrates and a fish diversity are greatly affected by the direct and indirect effects of iron contamination [1, 3, 4, 20, 70]. The iron precipitate will cause considerable damage by means of clogging action and hinder the respiration of fishes [31, 68]. Thus, iron being

the most abundant transition metal in the earth's crust. Biologically it is the most important nutrient for most living creatures as it is the cofactor for many vital proteins and enzymes. Iron mediated reactions support most of the aerobic organisms in their respiration process. If it is not shielded properly, it can catalyze the reactions involving the formation of radicals which can damage biomolecules, cells, tissues and the whole organism. Iron poisoning has always been a topic of interest mainly to pediatricians. Children are highly susceptible to iron toxicity as they are exposed to a maximum of iron containing products [72]. Zinc is an important mineral apparent by the human today as being excellent biologic and human health significance, mainly concerning prenatal and perinatal growth. Zinc deficiency affects around two billion public in the rising global and is related with several illnesses. In children it causes development delay, late sexual development, infection vulnerability, and diarrhea. Enzymes with a zinc particle in the sensitive focus are extensive in chemistry, such as liquor dehydrogenase in people. Zinc insufficiency is generally due to unsatisfactory dietary consumption, but can be correlated with malabsorption, Acrodermatitis enteropathica, liver damage, renal damage, sickle cell damage, diabetes, malignancy, and other chronic diseases. Assemblies at hazard for zinc deficiency contain the elderly, children in rising nations, and individuals with renal deficiency. Signs of mild zinc insufficiency are varied. Medical consequences contain depressed development, diarrhea, weakness and late sexual development, alopecia, eye and skin abrasions, decreased appetite, changed perception, decreased host protection possessions, defects in carbohydrate utilization, and reproductive spermatogenesis [5, 7, 8, 9, 13]. Thus, excess amount of zinc imparts a stringiest taste and milky appearance to water. Maximum limit according to Nigeria standard is 5mg/l. The results of analysis show that zinc is within the desirable limit.

Accordingly, the high levels of turbidity, total dissolved solids, total hardness, alkalinity, nitrate, nitrite, phosphate, calcium, magnesium, potassium and iron in most of the water sources are indicative of high level of bioaccumulation with its resultant adverse human health effect on Piwoyi community. Consequently, urgent site-specific review of the Nigerian standard for drinking water quality (NSDWQ) as earlier posited by Raimi *et al.*, [23], Omidiji and Raimi, [25]. Olalekan *et al.*, [26]; Adedoyin *et al.*, [27], Olalekan *et al.*, [28] and Raimi *et al.*, [29] is imperative. Morufu and Clinton [1], Raimi and Sabinus [3], Olalekan *et al.*, [4], Raimi, [10] and Olalekan *et al.*, [13] report that trace metals negatively impact water quality. They are carcinogenic, mutagenic as well as genotoxic to humans and organisms. They are persistent organic compounds, soluble or insoluble in forms, dictated by their valence, with acute or chronic adverse health effects. Morufu and Clinton [1], Raimi and Sabinus [3], Olalekan *et al.* [4], Raimi, [10] and Olalekan *et al.* [13] reports that elevated PAHs and THC in water, from epidemiological and experimental studies poses great human health challenges and cause deaths when ingested even at trace concentrations in all environmental matrices. This is due to their bioaccumulation, biomagnifications and bioamplification capabilities over time in the tissues of man and organisms. EFSA [73] report that hyper-reactivity of xenobiotics is exacerbated by temperature, phase association, adsorption, sequestration, speciation at thermodynamic equilibrium, complexion kinetics, lipid solubility, octanol/water partition coefficients, species characteristics, trophic interactions, adaptations in flora and fauna; being vital components of many enzymes in many redox reactions. The study reveals physio-chemical parameters and some heavy metals are in excess of NSDWQ permissible limits in all locations except chloride, sulphate, sodium, fluoride, copper and zinc. Olalekan *et al.*, [13] reports that heavy metals are biopersistent in recipient's system for a long time and cause renal dysfunction, lung cancer, bone disorders (Osteomalacia and Osteoporosis) and increases blood pressure and myocardium in a variety of animals. Morufu and Clinton [1], Raimi and Sabinus [3], Olalekan *et al.* [4], Raimi, [10] and Olalekan *et al.* [13] reports that zinc, magnesium and potassium, rank amongst one of the top 10 heavy metals with lethal pub-

lic health significance. They induce multiple organ damage even at low concentration exposure. Thus, the study populations are most likely to suffer from one or a mixture of foetus and infant mutilations or deaths, haemoglobin synthesis, kidney and gastrointestinal tract issues, joints weakness, reproduction systems complications, nervous system problems and other subclinical neuropsychological growths in infants and blood level rise. Findings in this study are therefore in agreement with Morufu and Clinton [1], Raimi and Sabinus [3], Olalekan *et al.* [4], Raimi, [10] and Olalekan *et al.* [13] in oil polluted milieu in which zinc, copper, manganese were below permissible limits, hence were unlikely to cause any adverse effects during a person's life time, except for prolonged bioaccumulation and amplification, which could disturb human health.

4.2.2. Microbiological Comparison to Nigerian Standard for Drinking Water Quality (NSDWQ) Acceptable Risk Benchmark

The term "total coliforms" refers to a large group of Gram-negative, rod-shaped bacteria that share several characteristics. The group includes thermotolerant coliforms and bacteria of faecal origin, as well as some bacteria that may be isolated from environmental sources. Thus, the presence of total coliforms may or may not indicate faecal contamination. In extreme cases, a high count for the total coliform group may be associated with a low, or even zero, count for thermotolerant coliforms. Such a result would not necessarily indicate the presence of faecal contamination. It might be caused by entry of soil or organic matter into the water or by conditions suitable for the growth of other types of coliform. Hence, the bacteriological analysis of water determines the potability of water. According to Nigeria standard for drinking water quality (NSDWQ) throughout the year 95% of samples should not contain any coliform organisms or should not be detectable in 100 ml of any two consecutive samples and no sample contains *E. coli* in 100ml. The desirable limit of coliform according to Nigeria standard in water is 10cfu/ML. The result of analysis depicts that water samples in Baptist Church (70), ECWA (180), and Clime Sachet Water (30) depicts high coliform count. Thus, indicating faecal contamination of water with high amount of bacterial population than Nigeria acceptable limit. The reason for high number of bacterial colonies might be due to inadequate maintenance of water reservoirs and the mixing of sewage into the reservoirs or directly into the rivers. In Baptist Church (70), ECWA (180), and Clime Sachet Water (30), the high total coliform count may be indicative of the presence of high organic compounds in the water, resulting from animal and human wastes. These sources of bacterial contamination include surface runoff, pasture, and other land areas where animal wastes are deposited. Additional sources include seepage or discharge from septic tanks, sewage treatment facilities and natural soil /plant bacteria [2, 6, 13, 74]. This is similar to Rajurkar *et al.* [75] and Radha Krishnan *et al.* [76] who found that the high number of total coliforms were observed by different authors in different water bodies in India during pre-monsoon and post monsoon seasons. Others are within the permissible 2-6. While, Nigeria desirable standard for *E-coli* is 0cfu/mL. Presence of *E-coli* can result in urinary tract infections, bacteraemia, meningitis, diarrhoea (one of the main causes of morbidity and mortality among children), acute renal failure and haemolytic anaemia. The result of analysis for *E-coli* was high in Baptist Church (27), ECWA (65), Chief Palace/Market (1), Angwa Hausa (1) and Clime Sachet Water (11). No presence of *E-coli* in Mpape. Hence, these areas contain excessive *E. coli* per liter, which is much higher than the guideline value for drinking purpose (3 *E. coli* per liter). This indicates a serious contamination from excrement of livestock and local residents in this area, and poses the biggest threat to the suitability of water for drinking purpose. The presence of faecal streptococci is evidence of faecal contamination. Faecal streptococci tend to persist longer in the environment than thermotolerant or total coliforms and are highly resistant to drying. This is an indication of recent faecal contamination. The acceptable level for Faecal Strep is 0cfu/mL. There are clear evidence of faecal strep from the result of sample analyzed in Baptist Church (43), ECWA (115), Chief Palace/Market (3), Angwa Hausa (5)

and Point Clime Sachet (19). Meanwhile, Mpape has no record of Faecal Strep. Thus, major factors affecting microbiological quality of ground waters are discharges from sewage works and runoff from informal settlements. Indicator organisms are commonly used to assess the microbiological quality of surface waters and faecal coliforms (FC), which are the most commonly used bacterial indicator of faecal pollution [13, 77]. They are found in water that is contaminated with faecal wastes of human and animal origin. Total coliforms (TC) comprise bacterial species of faecal origin as well as other bacterial groups (e.g., bacteria commonly occurring in soil). The coliforms are indicative of the general hygienic quality of the water and potential risk of infectious diseases from water. High FC and TC counts in water are usually manifested in the form of diarrhoea and sometimes by fever and other secondary complications. Bathing and swimming in streams and river are also common among children and adults in Piwoyi community. The probability of ingesting infective dose of disease-causing microorganism is very high considering the fact that water borne pathogens generally have low infective dose.

5. Conclusion

In conclusion, heavy metals are a very important class of carcinogens. Owing to the nature of modern life, we are all constantly exposed to carcinogenic metals through the environment. This makes defining mechanism a very significant task. However, metals are probably the least studied of any major class of human carcinogens and, on this basis alone, deserve additional effort. Additionally, human metal exposures are invariably of a complex nature, including erratic rates of exposure and/or differing periods of exposure. The nature of metal exposure often changes with time and the advent of new technologies and different industrial applications. Thus, the results of findings on assessing the sources and quality of drinking water in Piwoyi community of Federal Capital Territory, Abuja, Nigeria reveals that the sources of water so identified have high microbial parameters as such can pose significant health threat to the people of Piwoyi Community and other visitors who drink from the source of their water. In addition, high level of some physico-chemical parameters so examine can pose significant health risk as well. Therefore, the water is considered to be unsafe for drinking. Thus, this study summarized the objectives of study as:

1. **Physicochemical qualities:** The results of analysis shows that the Electrical conductivity in the water samples are within the desirable standard (1000) except Chief Palace/Market with high conductivity (1027). Temperature of water samples were within the permissible limits (30°C). pH level in water samples are within the desirable standard except Baptist Church and Chief palace/Market with lower pH (Acidity). Turbidity of the water samples are within desirable limit in Mpape and Baptist Church, but higher in other areas. Total Dissolve Solid is higher in Baptist Church and Chief Palace/Market and within the acceptable limit in other identified water sources. Dissolve oxygen is within the acceptable limit in ECWA but higher in other identified sources. Chloride is within the permissible level. Total hardness is higher virtually in all the boreholes sampled but within the permissible level in sachet water. Alkalinity of water sampled is within the permissible level in Baptist Church, Chief Palace/Market and Sachet Water but higher in other identified sources. Nitrate is higher in Baptist Church and Chief Palace/Market but within the permissible level in other sources. Study also reveals high level of calcium in Baptist Church, ECWA, Chief palace/Market and Angwa Hausa; and within the permissible level in other sources. Magnesium is higher in Baptist Church, ECWA, Chief Palace/Market and Angwa Hausa; while others are within the permissible level of water quality. Phosphate, phosphorous, copper, zinc, iron, fluoride, sodium, potassium, are within the desirable standard of Water Quality Nigeria.
2. **Microbiological quality:** the study reveals evidence of faecal contamination, E-coli and Faecal Strep as such render the water unsafe for drinking.

6. Recommendation

The finite resource of water is fundamental to the well-being of human life, as water and sanitation are deemed to be a human right, development partners [58] and government funds should rightly continue to support improvements in WASH access for the billions of people who remain underserved [4, 5, 7, 8, 9, 11, 12, 13]. While, engaging in the process of strengthening societies and ecosystems to ensure the stability, equitability and productivity [20, 31]. Water quantity, quality and availability are changing according to the drivers such as population densification, changes in land-use systems [18, 24, 33], climatic conditions variations [20, 52, 56], worldwide poverty [13, 51] and selections of energy sources [78, 79]. Thus, this current study's predictions therefore suggest several potentially effective strategies for risk mitigation as follows:

1. There is urgent need for environmental education and aggressive sensitization of Piwoyi residents on the consumption of polluted water, Water Sanitation and Hygiene, as all SDGs are interlinked in the context of water being essential component of life. From alleviating poverty to form partnerships. SDGs are well versed in sustainable water use, and industries have the opportunity to make their production more sustainable by aligning with them. Thus, there is need for the provision of alternative drinking water and protein source.
2. There is need for government to enhance public private infrastructure partnership on provision of potable water in the community and the promulgation and enforcement of host community protection policies and laws.
3. Residents of Piwoyi community should be advised to go for medical check-up so that appropriate treatment can be given to prevent future health challenges.
4. There is need for proper sewage management and designs of sewage disposal around the community in line with relevant regulations and policies.
5. There is also need to avoid indiscriminate discharge of waste water on public places.
6. Routine purification of drinking water through necessary domestic purification process should be adopted.
7. Federal Ministry of Water Resources should ensure routine water quality analysis in all communities to enhance public health and prevention of diseases or health problems that may hinder life expectancy. This will enhance the prevention of water borne diseases and water pollution.
8. Further studies on the level of open defecation in the area will go a long towards water sanitation and hygiene (WASH).

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