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Suitability of Usuma Dam Water for Domestic Use in Federal Capital Territory, Abuja, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The quality of water sources should be tested regularly for various parameters of interest to ensure it meet the standard qualities required for intended use(s). Thus, the suitability of Usuma dam water for domestic use in Nigeria's Federal Capital Territory Abuja was assessed. The objectives were to assess the properties of Usuma dam water and ascertain its suitability for domestic purpose. A total of thirty (30) water samples were fetched directly. Ten (10) samples each from upstream, downstream and middle were collected. Precautions were taken to prevent sample contamination. Data collected were analyzed as follows: The water properties was analyzed using range and mean, suitability of water properties for domestic purpose was analyzed by comparing range and mean values with Nigerian Standard for Drinking Water Quality (NSDWQ) and the World Health Organization (WHO) standard for domestic uses. Result showed that water sample were slight acidic (6.83), EC was low (122-180 µs/cm3), TDS (120-144 Mg/l), TSS (1.2-1.7 Mg/l, turbidity (0.29-5.37 Mg/l,) total hardness (7.18-40.46 Mg/l) DO (3.8-4.7 Mg/l), BOD (2.2-4.21 Mg/l), and (25.6-55.4 Mg/l). Minerals nutrients (Ca, Mg, Cl-,Na, K, NO^-_3 and PO^-_4.) in water samples were lower than regulatory standard while heavy metals (Fe, Si, Zn, Pb, Cr, Cd, Cu, Mn, F and B) were relatively higher than regulatory standard. It was concluded that water from Usuma dam are not safe for domestic purpose especially drinking.

Keywords: Water quality; domestic water; heavy metals; water pollution; water properties.

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1. INTRODUCTION

The major concern for water globally, is usually quality not quantity related as 70-80% of earth surface is water.Water is one the most abundant natural resources as well as the most desired and useful resources in which human life and activities depend on. One of the major attribute of a place that attracts human settlement is water, as it is required for all human activities and has no substitute. The availability of water sources was the second most important criteria used in selecting Abuja as the capital of Nigeria. It had a high rating of 10%, the second highest after geographic centrality, health and climate [1]. However, despite the natural abundance of water and it's significant to man, population growth and expansion of economic activities including agriculture, industry and other urban land uses have continued to cause pollution of water, especially surface water.

The ecological impact of dam on human life remains inevitable [2]. Population growth and rapid expansion of settlements as shown in figure are causing encroachment of settlements(Jigo, Pambara, Ushafa and Peyi communities) into areas of Usuma Dam. The unplanned growth in these communities has their negative and positive impacts on the dam. This is more so that close monitoring, management and control of developments as a result of population growth is largely lacking in many of these communities.

Human activities account for the major cause and sources of water pollution which in turn affect the usability of polluted sources by man. As population grows, economic activities and water use are been diversify to meet the demand of the growing population. Consequently, there is increasing waste generation which in most cases is not properly managed but dump in water bodies. Water pollution is mainly due to negligence and believe in its abundant and infinity in supply (Adekola and Eletta, 2007; [3]. According to Ahamefule (2015), "over 70 percent of the planet is water and people have long acted as if these bodies of water could serve as a limitless dumping ground for domestic and industrial wastes. This attitude has made majority of fresh water bodies polluted and undesirable for human needs".

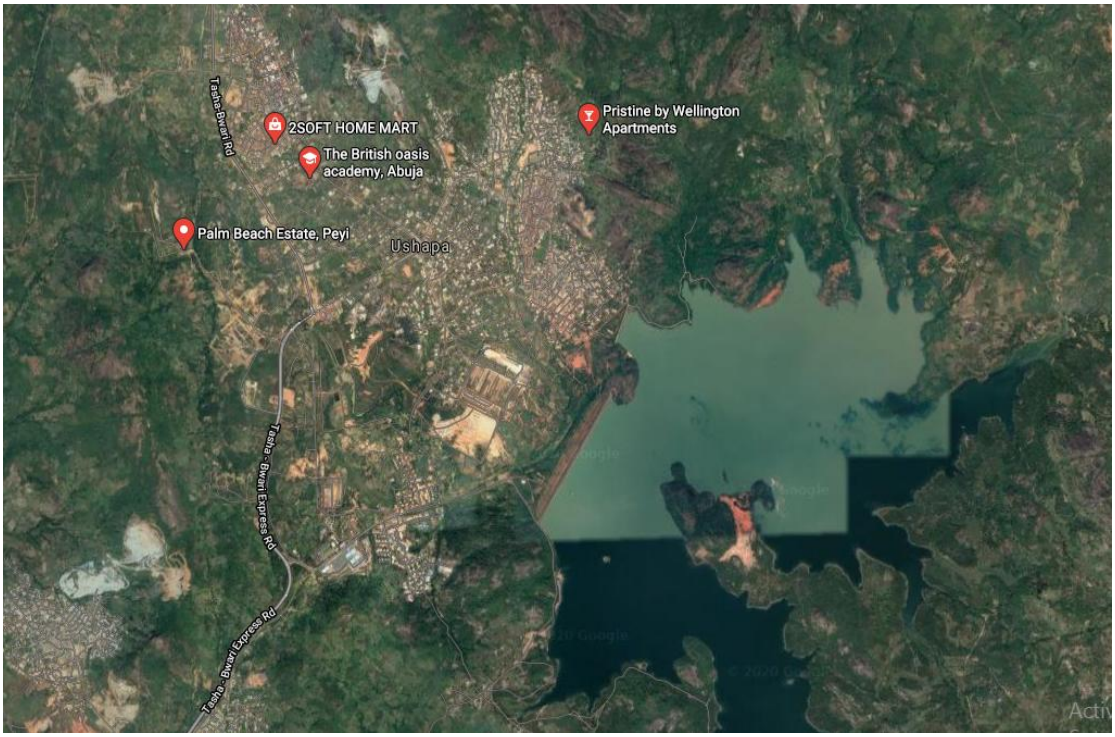

Fig. 1. Settlements close to Usuma dam (Google maps, 2020)

The implication of water pollution is that such water will no longer be safe for some uses. According to Arshad and Shakoor [4] "water quality influences its suitability for a particular use". Thus, the quality of water determines how well the water fulfills the requirement of the user". Similarly, Tanninem *et al* (2005) and Nwakonobi and Gwaza [5] explained that "specific water may be suitable for irrigation but may not be suitable for drinking and industrial uses due to presence of some other ions at toxic level". Thus, water quality is critical "in water resources planning and development for drinking, industrial and irrigation purposes" [6].

Water can be applied for variety of uses in human activities,which can be broadly classified into agriculture/irrigation, domestic, industrial, transportation and recreational, uses [7]. Each of these requires a particular characteristics or properties to give required services. Domestic uses include drinking, cooking, washing, bathing and flushing toilets while for agricultural uses includes "cropping, flock watering, fish culturing and nursery of seedlings" [8] Ahamefule, 2015).

The suitability of water for each of these uses vary and many regulatory agencies have set standard for each use. Thus. water samples can be collected and analyzed in laboratory for many physical, chemical and biological properties and compared with regulatory standards to determine its suitability for a specific use. That is why a number of scientific procedures and tools have been developed to assess water contaminants [9] as cited in Atiku *et al*., [10]. "These procedures include the analyses of different parameters such as pH, turbidity, temperature, dissolved oxygen, alkalinity 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"Atiku *et al*., [10].

Yakubu [11] advised that the quality of water sources should be tested regularly for various parameters of interest to ensure it meet the standard qualities required for intended use(s). The quality of the available water must be tested to check its fitness prior to use. However, the safety of water from Usuma dam is not regularly monitored for their various uses including for domestic purposes. River water quality monitoring is also necessary in present day society, especially for rivers affected by urban effluents [12].

Atiku *et al.,* [10] assessed the drinking water quality of some selected drinking water sources in Abuja, Nigeria. "Samples of drinking waters were collected from river, sachet (packaged), borehole and well in Jabi, Abuja, Nigeria for physicochemical and bacteriological analyses. The results show that "river water had the highest content of all the physicochemical parameters examined except pH". The physicochemical properties were generally within the World Health Organization (WHO) standards and that the highest total coliform counts of 1.03(0.08) x 10^2 cfu/ml were in the river sample while the least counts of 0.03 (0.00) x 10^2 cfu/ml were in the sachet water. All the bacteriological values did not meet international standard as they were higher than WHO standard of zero per100ml" Atiku *et al.,* [10].

Amadi *et al.,* [12] applied Water Quality Index (WQI) in evaluating the quality of Otamiri and Oramiriukwa Rivers for domestic usage by collecting and subjecting 180 water samples to comprehensive physicochemical and bacteriological analysis using APHA standard. The result showed that overall WQI for the samples was 174.49; there was high concentration of conductivity, color, total solids, turbidity, total coliform, iron, manganese, COD, BOD and nitrate. The results of the analysis when compared with the Nigerian Standard for Drinking Water Quality (NSDWQ) permissible limit showed that the rivers were polluted and that the water is not safe for domestic use and would need treatment.

Anyanwu and Okoli [13] concluded that the physicochemical attributes of domestic water sources in Nsukka were good for human consumption but the presence of E. coli and other potential enteric pathogens indicated faecal matter contamination of the water implying that they are not suitable for human consumption.

Samaila *et al*., [14] assessed water quality of hand dug wells used for domestic purposes in Vandekya Benue State, Nigeria to determine the suitability of well water in the area for domestic use. The study found that most the well water have their properties within the permissible limit for drinking purpose set by World Health Organization. But some well has higher turbidity and iron concentration than the WHO limit for drinking water.

Aniebone [15] investigated chemical and microbiological assessment of surface water

samples from Enugu area, Southeastern, Nigeria. A total number of thirteen water samples were investigated in this study. The results showed that hardness ranges from 4.00 to 53.00mg/l, the pH range from 4.32 to 7.11 and these values fall within the acceptable limit of water for domestic use. Major ion concentrations were low and within the WHO guidelines for drinking water indicating chemical suitability of surface water. All the water samples tested positive to total bacterial count and E. coli and this is evidence of faecal contamination. It was suggested that water sourced from the water bodies sampled should be treated/disinfected before consumption.

Anyanwu and Okoli [13] determined the bacteriological and physicochemical quality of various water samples from bore hole, dug well and spring, collected from ten different locations within Nsukka. The physicochemical parameters were analyzed using standard methods. The mean total bacteria count of the water samples ranged as follows: bore hole (0.92 × 104 to 1.41 × 104) cfu/ml, well water (1.80 × 104 to 2.40 × 104) cfu/ml and spring water (0.78 × 104 to 1.06 × 104) cfu/ml. The mean total coliform count of the samples in (MPN/100 ml) ranged as follows: bore hole (10 to 15), well water (14 to 18) and spring water (8 to 10). pH (5.6 to 6.4), dissolved oxygen (DO) (5.4 to 6.4), biochemical oxygen demand (BOD) (10.0 to 20.4), chloride (1.6 to 2.3) mg L-1, total hardness (48.6 to 68.0) mg L-1, total dissolved solids (6.3 to 9.7) mg L-1, sulphate (2.0 to 3.4) mg L-1 and nitrate (1.2 to 4.1) mg L-1. The study reveal that the water supply sources have good physicochemical attributes for human consumption but the presence of *E. coli* and other potential enteric pathogens indicated faecal matter contamination of the water implying that they are not suitable for human consumption.

Shalom *et al. [16]* assessed water quality in Canaaland Ota Southwest Nigeria. In this study, water points in Canaanland, Ota, and nearby Iju River were analyzed for biological and physicochemical properties including heavy metal content. Result showed that all the water samples were slightly acidic (5.96 – 6.54) except the bottled/ sachet Hebron water and Iju River water. The results were compared against drinking water quality standards laid by World Health Organization (WHO) and Nigerian Standard for Drinking Water (NSDW). The potable water samples were within the standards for consumable water and so are considered safe for human consumption. The surface waters, fall short standard in some parameters. Similarly, Chukwu [17] reported that the physical, chemical and organic parameters of wells water in Minna, Niger State surpass the upper limits set by WHO.

Okoro *et al. [10]* carried out a comparative analysis of three borehole water sources in Nsukka urban area, Enugu state, Nigeria."Samples were collected from three locations within the area and analysed for some physico-chemical and microbial parameters, which were compared with the Nigerian Standard for Drinking Water Quality (NSDWQ) and the World Health Organization (WHO) standard. The physicochemical parameters include; pH, Hardness, Total Solids, Alkalinlity, Turbidity, Sulphate, Phosphate, Silica, Cu, Pb, Fe, Residual Chlorine and Chloride with results ranging from 6.29-6.43, 15-483mg/l, 41.4-227.2mg/l, 0.00-0.00mg/l, 0.2-0.5NTU, 12.48-17.92mg/l, 0.6-1.3mg/l, 0.12-0.29mg/l, 0.00-0.00mg/l, 0.00-0.25ppm, 0.1630-0.2853ppm, 0.00-0.00mg/l and 64.98-78.61mg/l respectively. All the physicochemical parameters were within the standard limits recommended by WHO and NSDWQ, except for the following; pH, Hardness that were above the NSDWQ standard limit".

Ezeribe et al., [18] found that most of the parameters determined did not exceed the permissible limit of the world Health Organization (WHO, 2006) for drinking purpose. Turbidity levels, nitrates and fluoride concentrations in Dass, and Langtang North exceeded the WHO (1984) standard specified for drinking water.
Muhammad *et al. [19]* assessed and compared the ground water quality in Bahawalpur city with WHO standards. Findings reveal that groundwater quality in Bahawalpur is deteriorating. Situation was much worse in Islamic colony where 48%, 55% and 41% residents have diluted, brackish and water with slight smell respectively. Water properties EC, TDS, hardness, pH and so on were considerably high from WHO permissible limits for drinking.

Behailu *et al. [20]* determined the level of common cations, anions, heavy metals and physical parameters in drinking water supply system in Konso and its surrounding area, Southwestern of Ethiopia. Water samples were collected from 23 different locations in the area where there is hand pump or motorized supply system that are used for drinking purpose. Collected samples were analyzed for

physicochemical parameters including total alkalinity, Temperature, pH, Electrical Conductivity, Total dissolved solids, Turbidity, Alkalinity, Total hardness and Total suspended solid. Common cations (Li+, K+, Na+,Ca2+ and Mg2+), Common anions (NO3−, SO42−, PO42−, F− and Cl−) and Heavy metals (Pd, Ni, Mn, Pb, Co, Zn, Cu) were analyzed. The obtained results were compared with some national and international standards or guidelines for drinking water. Accordingly, the results obtained show that most of the physical and some common ions and heavy metals were within the accepted range of the guideline recommended by WHO.

Despite abundance of studies on suitability of water quality for domestic purposes, none was done in the Federal Capital City of Abuja, Nigeria, which is one of the World's fastest growing cities experiencing rapid urbanization. This study, in bit to bridge this gap, assessed the suitability of water from Usuma Dam for domestic in Abuja, Nigeria. The study was guided by two objectives. First, was to assess the properties of Usuma dam water and secondly, to determine the suitability of water properties for domestic purpose.

2. MATERIALS AND METHODS

Abuja is within Köppen's climate classification,with a tropical wet and dry climate. It experiences three weather conditions annually. This includes a warm, humid rainy season and a blistering dry season. In between the two, there is a brief interlude of harmattan occasioned by the northeast trade wind, with the main feature of dust haze and dryness" [21]. The rainy season begins around March and runs through October, while the dry season usually characterized by bright sunshine begins from October and ends in March.

Abuja has witnessed a huge influx of people into the city; the growth has led to the emergence of satellite towns, such as Karu Urban Area, Suleja, Gwagwalada, Lugbe, Kuje Jigo, Pambara, Ushafa, Peyi and smaller settlements towards which the planned city is sprawling. The urban agglomeration centred upon Abuja had a population estimated at 2,440,000 in 2014. The metropolitan area of Abuja was estimated in 2016 as six million persons, the country's second most populous metro area. This rapid population growth increases human activities, waste generation and water pollution.

Data for this study were collected from primary and secondary sources. Field survey for water samples collection was undertaken in 2019. Data on regulatory standard was also collected through desk top studies of relevant literature. After which data were compared with water quality regulatory standard in desk top using statistical techniques.

A total of thirty (30) water samples were collected through direct fetching using a special water sampling grabber. Ten (10) samples each from upstream, downstream and middle of Usuma dam were collected. Clean sampling bottles and were used to collect water samples. All the samples were collected in 1.5 liter plastic bottles which were thoroughly rinsed with the waters to be sampled, well labeled then wrapped in black polythene bags, before taken to laboratory in ice packed cooler on the same day the sampling was done for analysis of various parameters.

The laboratory analysis was guided by the of the study: The water properties was analyzed using range and mean while the suitability of water properties for domestic purpose was analyzed by comparing range and mean values with NSDWQ and WHO standard for domestic uses.

3. RESULTS AND DISCUSSION

3.1 The Properties of Water Samples in the Study Area

Tables 1 present the physical and chemical properties of water samples in the study area.

Table 1 presents the physical and chemical properties of water samples in the study area as follows:

3.2 Temperature and pH

Temperature recorded ranged from 29.72-30.92°c with mean value of 30.73°c. The concentration of pH in the water sample ranged from 6.83-7.94 with mean value of 7.32. The result indicates that water sample were slight acidic (6.83) to slight alkalinity (7.94).

3.3 Electrical Conductivity (E.C)

The concentration of electrical conductivity in dry season water samples ranged from 122-180 µs/cm3 with mean value of 141.50 µs/cm3. The concentration of Total Dissolved Solids (TDS)

Table 1. The Physical and chemical properties of water samples in the study area

Parameter	Range	Mean	SD	COV
Temp.(Oc)	29.72-30.92	30.37	0.74	23
pH	6.83-7.94	7.32	0.41	9
E.C(µs/cm3)	122-180	141.50	16.81	45
TDS(Mg/l)	120-144	123	9.59	43
TSS(Mg/l)	1.2-1.7	1.37	0.17	8
Turb.(NTU	0.295.37	1.25	0.19	35
T. Hard.(Mg/l)	7.18-40.46	27.86	18.06	68
K Mg/l	2.03-3.16	2.48	0.46	22
Na Mg/l	2.02-4.46	3.13	0.60	24
Cl- Mg/l	2.48-6.3	4.33	1.12	32
Mg Mg/l	1.03-14.24	7.68	5.06	89
Ca Mg/l	4.32-34.25	20.18	15.63	96
NO^-_3 Mg/l	0.76-2.67	1.43	0.57	20
PO^-_4 Mg/l	0.03-0.33	0.15	0.09	21
DO Mg/l	3.8-4.7	4.3	0.33	11
BOD Mg/l	2.2-4.21	2.82	0.91	18
COD Mg/l	25.6.1-55.4	35.6	8.74	76
Fe Mg/l	0.53-0.96	0.77	0.13	9
Si Mg/l	0.01-0.18	0.02	0.01	23
Zn Mg/l	0.021-0.051	0.04	0.01	7
Lead Mg/l	0.002- 0.007	0.005	0.00	8
Cr Mg/l	0.016-0.086	0.03	0.02	28
Cd Mg/l	0.015-0.092	0.04	0.03	37
Cu Mg/l	0.01-0.12	0.08	0.03	34
Mn Mg/l	0.011-0.159	0.07	0.05	30
F Mg/l	0.001-0.034	0.01	0.01	26
B Mg/l	0.000-0.055	0.04	0.01	28

water samples ranged from120-144 Mg/l with mean value of 123 Mg/l. The Total Suspended Solids in water samples ranged from 1.2-1.7 Mg/l with mean value of 1.37 Mg/l. Turbidity ranged from 0.29-5.37 Mg/l with mean value of 1.25 Mg/l.

3.4 Total Hardness

The concentration of total hardness in water samples ranged from 7.18-40.46Mg/l with mean value of 27.86 Mg/l. The concentration of total hardness in the water samples is below the report of APHA (2005) but above the report of Akpan-Idiok *et al* (2012). APHA (2005) reported a range of 29–94 Mg/l and Akpan-Idiok reported a range of 6.41-19.20 Mg/l.

3.5 Mineral Nutrients {Potassium (K), Sodium (Na), Chloride (Cl-), Magnesium (Mg), Calcium (Ca), Nitrite (NO^-_3) and Phosphate (PO^-_4)}

The concentrations of minerals nutrients in water samples are low except for Chloride, magnesium and calcium. The concentrations are as follows: Potassium (K) ranged from 2.03-3.16Mg/l with mean value of 2.48Mg/l.Sodium (Na) ranged from 2.02-4.46Mg/l with mean value of 3.13Mg/l.Chloride (Cl-) ranged from 2.48-6.3Mg/l with mean value of 4.33Mg/l. Magnesium (Mg) ranged from 1.03-14.24Mg/l with mean value of 7.68Mg/l.Calcium (Ca) ranged from 1.03-14.24Mg/l with mean value of 7.68Mg/l.Nitrate (NO^-3) ranged from 0.76-2.67Mg/l with mean value of 1.43Mg/l.Phosphate (PO^-4) ranged from 0.03-0.33Mg/l with mean value of 0.15Mg/l. The mean concentrations of mineral nutrients{potassium(K),sodium (Na), chloride (Cl-), magnesium (Mg), calcium (Ca), nitrite (NO^-_3) and phosphate (PO^-_4)} are in the order of Ca> Mg> Cl->Na>K> NO-3> PO-4.

3.6 DO, BOD and COD

Dissolved Oxygen (DO) ranged from 3.8-4.7Mg/l with mean value of 4.3Mg/l. This is below 5.4 to 6.4Mg/l recorded by Anyanwu and Okoli [13] in bore hole, dug well and spring in Nsukka. This may be because surface water are more

exposed to pollution than underground water and Polluted have lower DO than unpolluted water.

Biological Oxygen Demand (BOD) ranged from 2.2-4.21Mg/l with mean value of 2.82Mg/l. This is above 2.1.0 to 3.0.4Mg/l recorded by Anyanwu and Okoli [13] in bore hole, dug well and spring in Nsukka. BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream. Chemical Oxygen Demand (COD) ranged from 25.6-55.4Mg/l with mean value of 35.60Mg/l.The measure of COD determines the quantities of organic matter found in water. This makes COD useful as an indicator of organic pollution in surface water "(King *et al.*, 2003 and Faith, 2006).

3.7 Heavy Metals (Iron Fe, Silicon Si, Zinc Zn, Lead Pb, Chromium Cr, Cadmium Cd, COPPER Cu, Manganese, Mn, Fluorine F, and Boron B)

The concentrations of heavy metals (iron Fe, silicon Si, zinc Zn, lead Pb, chromium Cr, Cadmium Cd, Copper Cu, Manganese, Mn, Fluorine F, and Boron B, as follows: Iron (Fe) ranged from 0.53-0.96 Mg/l with mean value of 0.77 Mg/l. Silicon (Si) ranged from 0.01-0.18 Mg/l with mean value of 0.02 Mg/l. Zinc (Zn) ranged from 0.021-0.051Mg/l with mean value of 0.04 Mg/l.Lead (Pb) ranged from 0.002- 0.007Mg/l with mean value of 0.005Mg/l.Chromium (Cr) ranged from 0.016-0.086 Mg/l with mean value of 0.03 Mg/l.Cadmium (Cd) ranged from 0.015-0.092Mg/l with mean value of 0.04 Mg/l. Copper (Cu) ranged from 0.01-0.12Mg/l with mean value of 0.08 Mg/l.Manganese (Mn) ranged from 0.011-0.159 Mg/l with mean value of 0.07 Mg/l. Fluorine (F) ranged from 0.001-0.034 Mg/l with mean value of 0.01 Mg/l. Boron (B) ranged from 0.000-0.055 Mg/l with mean value of 0.04 Mg/although, the concentration of heavy metals in the samples are high, heavy metals concentration reported by Ajala *et al*.,(2015) were higher as it reported "Cu (1.23-5.60)mg/l, Pb (2.20-4.10), Zn (2.60-5.11)mg/l and Cd (1.80-5.01)mg/l, in water". Higher concentrations of heavy metals are detrimental to plant and human health.

3.8 Biological Properties of Water Samples

Biological parameters of water quality E. coli and total coliform count were tested as they are often used as water quality markers for the health status of potable water (Table 2).

Table 2 shows the distribution of microbial parameters as follows: E. coli was not found in some samples. Thus, it ranged from 0-50 $x10^{-3}$ CFU/100mL with mean value of 18.30 $x10^{-3}$ CFU/100mL.T.Coliform ranged from 4 $x10^{-3}$-70 $x10^{-3}$ MPN/100ml with mean value of 29.70 $x10^{-3}$.The presences of E. coli in water sample suggest poor sanitation and open defecation within the region of sampling. "Human and animal wastes are the primary sources of bacteria E. coli in water. These sources of bacterial contamination include runoff from feedlots, pastures, and other lands where animal wastes are deposited. Additional sources include seepage or discharge from septic tanks and sewage treatment facilities (Spellman, 2003).

3.9 The Suitability of the Water for Domestic Purposes

The suitability of water samples for domestic purpose was ascertained by comparing the water properties with the Nigeria standard for drinking water quality (NSDWQ, 2007) and WHO standard for domestic purpose 2010 (Table 3).

Table 3 shows the range and mean concentrations of water properties, the NSDWQ and WHO standard for domestic purpose.

Table 4 shows the Range and Mean Concentrations of Water Properties in comparison between results and previous studies. Tables 3 and 4 shows water properties and regulatory standard as follows.

3.10 Temperature and pH

The mean record of water temperature is 30.37°c, this value is below the maximum limit of

Table 2. Distribution of microbial parameters

Parameter	Range	Mean	SD	COV
E. Coli CFU/100 mL	0-50 $x10^{-3}$	18.30 $x10^{-3}$	19.08 $x10^{-3}$	56
T.Coliform C (MPN/100 ml)	4 $x10^{-3}$-70 $x10^{-3}$	29.70 $x10^{-3}$	24.91 $x10^{-3}$	75

Table 3. The range and mean concentrations of water properties

Parameters	Range	Mean	NSDWQ, 2007	WHO, 2010
Temp.(Oc)	29.72-30.92	30.37		
pH	6.83-7.94	7.32	6.5-8.5	6.5-9.2
E.C(µs/cm3)	122-180	141.50	≥1000	≥1500 (µs/cm3)
TDS(Mg/l)	120-144	123	500	500
TSS(Mg/l)	1.2-1.7	1.37	500	-
Turb.(NTU	0.295.37	1.25	≤10	≤5
T. Hardness (Mg/l)	7.18-40.46	27.86	500	200
K(Mg/l	2.03-3.16	2.48		100
Na(Mg/l	2.02-4.46	3.13	200	60
Cl-(Mg/l	2.48-6.3	4.33	250	5
Mg(Mg/l	1.03-14.24	7.68		30
Ca(Mg/l	4.32-34.25	20.18	75	75
NO^-_3(Mg/l	0.76-2.67	1.43	50	45
PO^-_4(Mg/l	0.03-0.33	0.15	-	100
DO(Mg/l	3.8-4.7	4.3	≥6	≥6
BOD(Mg/l	2.2-4.21	2.82	-	2
COD(Mg/l	25.6.1-55.4	35.6	-	30
Fe(Mg/l	0.53-0.96	0.77		0.1
Si(Mg/l	0.01-0.18	0.02		
Zn(Mg/l	0.021-0.051	0.04		5
Lead(Mg/l	0.002- 0.007	0.005		1
Cr(Mg/l	0.016-0.086	0.03		0.05
Cd(Mg/l	0.015-0.092	0.04		0.01
Cu(Mg/l	0.10-0.12	0.08		0.05
Mn(Mg/l	0.011-0.159	0.07		0.5
F(Mg/l	0.001-0.034	0.01		0.9
B(Mg/l	0.000-0.055	0.04	-	-
E. Coli CFU/100 mL	0-50 $x10^{-3}$	18.30 $x10^{-3}$	-	0
T.Coliform C (MPN/100 ml)	4 $x10^{-3}$-70 $x10^{-3}$	29.70 $x10^{-3}$	-	-

Table 4. The range and mean concentrations of water properties in comparison between results and previous studies

Parameters	Range	Mean	NSDWQ, 2007	WHO, 2010	Rainy Season Ogbodo et al., (2014)	Dry Season Ogbodo et al., (2014)	Mean Ogbodo et al., (2014)
Temp.(Oc)	29.72-30.92	30.37			23.7	22.5	23.1
pH	6.83-7.94	7.32	6.5-8.5	6.5-9.2	7.1	7.1	7.1
E.C(µs/cm^3)	122-180	141.50	≥1000	≥1500 (µs/cm3)	67.1	79.1	73.1
TDS(Mg/l)	120-144	123	500	500	79.1	47.6	50.65
TSS(Mg/l)	1.2-1.7	1.37	500	-	-	-	-
Turb.(NTU	0.295.37	1.25	≤10	≤5	6.86	4.43	5.645
T. Hardness (Mg/l)	7.18-40.46	27.86	500	200	54	34	44
K(Mg/l	2.03-3.16	2.48		100	-	-	-
Na(Mg/l	2.02-4.46	3.13	200	60	-	-	-
Cl-(Mg/l	2.48-6.3	4.33	250	5	-	-	-
Mg(Mg/l	1.03-14.24	7.68		30	-	-	-
Ca(Mg/l	4.32-34.25	20.18	75	75	-	-	-
NO^-_3(Mg/l	0.76-2.67	1.43	50	45	8.6	2.9	5.75
PO^-_4(Mg/l	0.03-0.33	0.15	-	100	-	-	-

Parameters	Range	Mean	NSDWQ, 2007	WHO, 2010	Rainy Season Ogbodo et al., (2014)	Dry Season Ogbodo et al., (2014)	Mean Ogbodo et al., (2014)
DO(Mg/l	3.8-4.7	4.3	≥6	≥6	7.88	9.1	8.49
BOD(Mg/l	2.2-4.21	2.82	-	2	4.1	2.75	3.425
COD(Mg/l	25.6.1-55.4	35.6	-	30	-	-	-
Fe(Mg/l	0.53-0.96	0.77		0.1	-	-	-
Si(Mg/l	0.01-0.18	0.02			-	-	-
Zn(Mg/l	0.021-0.051	0.04		5	-	-	-
Lead(Mg/l	0.002- 0.007	0.005		1	-	-	-
Cr(Mg/l	0.016-0.086	0.03		0.05	-	-	-
Cd(Mg/l	0.015-0.092	0.04		0.01	-	-	-
Cu(Mg/l	0.10-0.12	0.08		0.05	-	-	-
Mn(Mg/l	0.011-0.159	0.07		0.5	-	-	-
F(Mg/l	0.001-0.034	0.01		0.9	-	-	-
B(Mg/l	0.000-0.055	0.04	-	-	-	-	-
E. Coli CFU/100 mL	0-50 $x10^{-3}$	18.30 $x10^{-3}$	-	0	-	-	-
T.Coliform C (MPN/100 ml)	4 $x10^{-3}$-70 $x10^{-3}$	29.70 $x10^{-3}$	-	-	-	-	-

<40°c set by NSDWQ and also lies within the range >20°c <40°c set by WHO. The concentration of pH ranged from 6.83-7.94. This value is within the ranges of 6.5-8.5 NSDWQ and 6.5-9.2 standard set by WHO for domestic purpose. Thus, water from Usuma Dam and River Jabiare safe for domestic purpose in terms of temperature and pH.

3.11 Electrical Conductivity (E.Cμs/cm3)

The electrical conductivity of water samples ranged from 122-180 μs/cm3 with mean value of 141.50 μs/cm is below ≥1000 μs/cm3 NSDWQ and ≥1500 μs/cm3 standard set by WHO for domestic purpose. Thus, the EC of water samples fall short of regulatory standard. Therefore, water from Usuma Dam is not safe for domestic purpose in terms of EC.

3.12 Total Dissolved Solids, Turbidity and Hardness

The concentration of Total Dissolved Solids (TDS) iswithin the regulatory standard for domestic purpose. The TDS ranged from 120-144 Mg/l. Thus, all values are below 500 Mg/l limit set by WHO. The mean concentrations of turbidity was 1.37 Mg/l, this values is within the acceptable limit of ≤5NTU set by WHO for domestic purpose and the ≤10 NTU NSDWQ. However, the range of turbidity concentration in being 0.29-5.37NTU suggests that sample(s) fall short of WHO standard for domestic purpose. The highest value 5.37NTU was recorded in the downstream. Total hardness ranged from 7.18-40.46 Mg/l, this range of values is below the maximum limits of 200Mg/l set by WHO for domestic purpose and the 500Mg/l National Standard for Drinking Water Quality. Therefore, all sampled water are safe for domestic purpose in terms of total hardness.

3.13 Mineral Nutrients (K, Na, Cl, Mg, Ca,NO_3^- and PO_4^-)

The concentrations of these minerals K, Na, Cl, Mg, Ca, NO_3^- and PO_4^- were generally below their regulatory standard. Potassium (K) ranged from 2.03-3.16 Mg/l but WHO standard for domestic purpose is I00 Mg/l. Sodium (Na) ranged from 2.02-4.46 Mg/l but WHO standard for domestic purpose is 60 Mg/l and national standard is 200Mg/l. Chloride ranged from 2.48-6.3Mg/l but NSDWQ is 250 Mg/l. Magnesium (Mg) ranged from 1.03-14.24 Mg/l but WHO standard for domestic purpose is 30 Mg/l. Calcium (Ca) ranged from 4.32-34.25 Mg/l but WHO standard for domestic purpose is 75 Mg/l. Nitrate (NO_3^-) ranged from 0.76-2.67 Mg/l but WHO standard for domestic purpose is 45 g/l. Phosphate (PO_4^-) ranged from 0.03-0.33 Mg/l but WHO standard for domestic purpose is 100 g/l.

3.14 DO, BOD and COD

The concentration of Dissolved Oxygen (DO) is below the regulatory standard for domestic

Plate 1. Open defecation close to Usuma dam

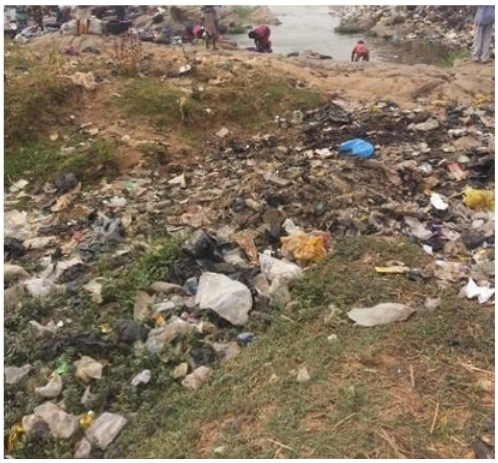

Plate 2. Waste dumping within Usaman river tributary

purpose. The DO ranged from 3.8-4.7 Mg/l,thus, all values are below ≥6Mg/l standard set by WHO. The mean concentrations of BOD were 2.82 Mg/ this value is above the 2Mg/l set by WHO for domestic purpose. Thus, water samples are not suitable for domestic uses especially for drinking purposes in terms of BOD. Some samples fall short of WHO standard for domestic purpose in terms of COD as COD ranged from 25.61-55.4 Mg/l but WHO set standard is 30 Mg/l.

3.15 Heavy Metals (Fe, Si, Zn, Pb, Cr, Cd, Cu, Mn, F and B)

The concentrations of heavy metals were generally low but some heavy metals (Fe, Cr, Cd, and Cu) fall short of regulatory standard for domestic purpose especially in dry season. The concentration of Iron (Fe) was generally higher than the WHO standard of 0.1Mg/l as it ranged from 0.53-0.96 Mg/l. The concentrations of Zinc (Zn) were generally lower than the WHO standard of 5 Mg/l as it ranged from 0.021-0.051 Mg/l.Lead concentrations were also generally lower than the WHO standard of 0.05 Mg/l as it ranged from 0.002- 0.007 Mg/l. Chromium ranged from 0.016-0.086Mg/l, the range fall short of WHO set standard for domestic uses. The mean concentration of cadmium is 0.04 Mg/l and is higher than WHO set standard for domestic purpose. Copper ranged from 0.10-0.12Mg/l, the WHO set standard for domestic purpose is 0.05 Mg/l, so samples fall short of WHO set standard for domestic purpose. Manganese (Mn) ranged from 0.011-0.159 Mg/l, the WHO set standard for domestic purpose is 0.5 Mg/l, so all samples in both seasons meet WHO set standard for domestic purpose. Fluorine (F) was generally lower than the WHO standard of 0.9 Mg/l as it ranged from 0.001-0.034 Mg/l and from 00.001-0.044 Mg/l in dry and rainy seasons respectively.

3.16 Biological Properties

The presences of E. coli in water sample suggest that the water is not safe for domestic purpose especially for drinking. WHO recommended zero tolerance of E. coli for domestic use. The presences of E. coli and elevated coliform count make the water unsuitable for domestic purpose without proper treatment. Poor sanitation and open defecation is responsible the presence of E. coli in water the study area (Plates 1& 2).

4. CONCLUSION AND RECOMMENDA-TIONS

This study indicated that water sample were slight acidic (6.83) to slight alkalinity (7.94) EC was low and ranged from 122-180 µs/cm3. Pollution indices like TDS, TSS, Turbidity, total hardness, BOD, COD and heavy metals were high. Examples, TDS from 120-144 Mg/l, TSS from 1.2-1.7 Mg/l, turbidity from 0.29-5.37 Mg/l, total hardness from 7.18-40.46 Mg/l, (DO) from 3.8-4.7 Mg/l, BOD from 2.2-4.21 Mg/l, and COD from 25.6-55.4 Mg/l. Therefore, water samples fall short of regulatory standard for drinking purpose.

The following recommendations were made based on findings of this study:

i. Communities close to the Usuma Dam should be relocated or inhabitants close to the area should be advised to properly dispose of contaminated water that create favorable breeding environment for diseases causing agents.
ii. The provision of standard drainage systems and sanitation facilities are hereby recommended in the *Jigo, Pambara, Ushafa and Peyi communities*, close locations and the entire watershed that lie close to Usuma Dam. This is highly recommended in order to control the contamination of water sources close to the dam.
iii. If the inhabitants cannot be relocated, the government should re-impose strict measures preventing locals around the area from various practices that may bring harm to the surrounding waters. Local authorities should ensure strict building standards and practices. Avoid Building on natural water ways and ensure the compliance with building code.
iv. The users of water around these areas should endeavor to treat properly by boiling, filtration, distillation before direct consumption.
v. Residents and others living within and around the area should be caution of activities capable of polluting water within the area.
vi. Government should ensure that Usuma dam are properly treated before supplying to the public.
vii. Open waste disposal should avoided by the populace. Clergy men, government and non-government organization should promote public awareness on the consequences of open and uncontrolled waste disposal.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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