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Water Quality Assessment of Lower Usuma Dam Water from Treatment plant to points of Consumption in Federal Capital Territory, Nigeria

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ABSTRACT: This study investigated and compared the bacteriological, physicochemical and heavy metals concentrations of drinking water quality of Lower Usuma Dam from treatment plant to the points of consumption in three Area Councils (Bwari, Abuja Municipal and Gwagwalada) of the Federal Capital Territory, Abuja, Nigeria. Most probable number technique was employed for coliform detection. Molecular characterization of isolated bacteria was carried out. Seven out of the 26 water samples analyzed in this study were contaminated in the range of 7 MPN/100ml to >23 MPN/100ml. Physicochemical parameters such as colour, pH, temperature, turbidity, total dissolved solids (TDS), total hardness, electrical conductivity, total alkalinity and seven heavy metals were also determined using Atomic absorption spectrophotometry. Results showed that Bwari had the highest value for colour, 16.67 Pt.Co while AMAC had the least with 1.00 Pt. Co, Gwagwalada had the highest pH value (7.33±0.12) and Bwari the lowest pH of 6.77±0.06. Bwari also had highest temperature of 30.23±2.80ºC while AMAC recorded the least (27.29±0.26ºC). Turbidity ranged from 1.86 to 2.83 NTU. The highest level of the other parameters [(TDS 54.27 mg/L, conductivity 90.10 µs/cm, total hardness 34.00 mg/L, total alkalinity 28.00 mg/L, Cl^- 20.82 mg/L)] was observed in water samples from Gwagwalada Area Council. Gwagwalada recorded the highest values for iron and zinc at 0.09mg/l and 0.003mg/l respectively. Copper concentration was highest in AMAC (0.043mg/l) and lowest in Bwari area council (0.007mg/l). There was no significant difference ($p>0.05$) in the concentration of Cr detected in all the water samples. There is need for provision of adequate sanitation facilities and improvement on monitoring of distribution system in order to maintain drinking water quality and prevent water borne disease outbreaks.

KEYWORDS: Heavy metals, Physicochemical, Points of consumption, Water Quality assessment.

1. INTRODUCTION

The availability of safe drinking water represents a global challenge, and authorities sustain substantial efforts in two priority areas: water quantity and water quality assurance (1). Also, an essential basic requirement for health protection is to provide the public with adequate supply of drinking water that is safe (2). Abuja is the capital city of Nigeria, with an area of 7,315km^2. It is geographically located in the centre of the country, lying between latitude 8.25 and 9.20 north of the equator and longitude 6.45 and 7.39 east of Greenwich Meridian. Abuja has moderate climatic conditions.

The Federal Capital Territory Water Board, Abuja, has been saddled with the responsibility of producing drinking water of adequate quality and quantity for the residents of the Federal Capital Territory, Abuja. In a bid to meet the potable water needs of the growing populace of the Federal Capital Territory, Abuja, the water treatment facilities were constructed. Lower Usuma Dam Water Treatment plant (LUDWTP) is located in Ushafa along Dutse-Bwari road, Abuja, Nigeria's capital city. It is owned by the Federal Capital Territory Water Board (FCTWB). The FCT, Abuja has a population of about 3,564,100 people (2006 est.). This study is aimed at determining the physicochemical parameters and heavy metals concentration of drinking water from Lower Usuma Dam water treatment plant to distribution in Bwari, Abuja Municipal and Gwagwalada area councils of the Federal Capital Territory, Nigeria.

2. MATERIALS AND METHODS

2.1 Media Preparation and Sterilization

All laboratory apparatus used in this work were thoroughly cleaned and washed as required. The media was prepared and sterilized following manufacturer's instructions and standard preparatory methods (3).

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2.2 Sample Collection

Water samples were aseptically collected from Lower Usuma Dam Water treatment plant (before and after undergoing treatment), and from consumer points in various locations in three Area Councils of the Federal Capital Territory, Nigeria namely Bwari, Abuja Municipal and Gwagwalada.

2.3 Bacteriological analysis of water samples

2.3.1Total Coliform Test

According to (3), the objective of the total coliform test in routine examination of public water supplies is to determine the efficiency of treatment plant operations and the integrity of the distribution system. Tests for coliform detection were carried out using multiple tube fermentation technique, a 3- stage test which involves presumptive, confirmatory and completed tests. Test was done following standard methods (3).

2.3.2Presumptive test

Fermentation tubes were arranged in replicates in rows of 10 tubes in each row. Ten 10-ml portions were taken and inoculated in sterile lactose broth with Durham tubes to check for lactose fermentation and gas production. Test portions in the medium were mixed by gentle agitation. The inoculated test tubes were incubated at 37ºC for 24hrs. After the incubation, growth was observed as gas inside the inverted vials and/or acid reaction (shades of yellow colour).

Tubes with production of acidic reaction and/or gas bubbles were taken as positive tubes. Results were calculated and reported using 10-tube Most Probable Number (MPN) index Table (3).

For non-potable water, dilutions were made. Five tubes per dilution was used. Five 10-ml, five 1.0-ml, and five 0.1-ml sample portion volumes were tested. Values corresponding to the number of positive and negative results are reported as MPN/100ml (3).

2.3.3 Confirmatory test

Positive presumptive tubes were subjected to the confirmed test. Brilliant green bile broth was used. They were inoculated and incubated. Tubes showing gas production in any amount were taken as positive confirmed phase.

2.3.4 Completed test

Test was done by simultaneous culturing into brilliant green bile broth for total coliforms or other lactose-based broth and culturing to establish the presence of thermo-tolerant coliform bacteria at elevated temperature (44±0.5) for 24hours. Growth, gas formation and acidic reaction were considered positive completed test.

2.3.5 Confirmatory test for *Escherichia coli*

One or more Eosin Methylene blue (EMB) agar was streaked from each positive presumptive tube. Bacterial colonies having green metallic sheen on EMB are considered positive. Isolates were purified by subculturing. Discrete colonies were transferred for further biochemical tests.

2.4 Identification of Bacterial Isolates

Identification of bacterial isolates was carried out using biochemical and molecular characterization methods.Biochemical tests were done according to biochemical tests outlined in the Bergey's Manual of Determinative Bacteriology (4).

2.5 Molecular Characterization of Bacterial Isolates

2.5.1 DNA extraction

Genomic DNA extraction of isolated Bacterial isolates was carried out using the Bacterial DNA Extraction Kit (Qiagen, USA) following the protocol provided by the manufacturer (5). Overnight cultures grown in nutrient broth (NB) were centrifuged for 10 min at 5000 x g, to harvest cells. The pellet was washed 3 times in Tris-EDTA buffer (TE buffer) (10mM Tris-HCl pH 8.0, 0.1 Mm EDTA) and incubated at 37 °C for 30 min in an incubator. Proteinase K and extraction buffer was added, mixed by vortexing and incubated at 56 °C in a water-bath for 30 min. The DNA was precipitated with ethanol (96 – 100 %, v/v) and transferred into the DNeasy Mini spin column for binding of DNA to the column, washed with two different 500 µl washing buffers and eluted with 200 µl elution buffer. The resulting DNA was stored at -20 °C.

2.5.2 Amplification of the 16S rRNA Genes by PCR

The 16S rRNA gene from genomic DNA was amplified by Polymerase Chain Reaction (PCR) using bacteria universal primers (27F– AGAGTTTGATCCTGGCTCAG and 1492R–GGTTACCTTGTTACGACTT). The PCR amplification was carried out in a

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Techne TC-412 Thermal Cycler (Techne, UK) in a 50 µl reactions containing 25 µl of 2 X PCR Master Mix, 1.5 µl of template DNA (0.5 µg), 1 µl of both forward and reverse primers (2.5 µM of each) and 21.5 µl of nuclease free water in a PCR tube added in that order. PCR was carried out at an initial denaturation step at 94 °C for 2 min, followed by 30 cycles at 94 °C for 30 secs, 52 °C for 30 sec and 72 °C for 2 min, and a final extension step at 72 °C for 5 min.

2.5.3 Assessment of Extracted DNA by Agarose Gel Electrophoresis

PCR products (amplicons) were separated by electrophoresis on a 1 % agarose with Tris-acetate-EDTA buffer (TAE) containing ethidium bromide. Where 4ul of the PCR product was mixed with 4 ul loading dye and ran at a voltage of 120V for 45min. This was later viewed under UV light to confirm the presence and quality of the bacteria DNA.

2.5.4 DNA Sequencing and Analysis

PCR products from the genomic DNA were sequenced with 518F and 800R primers using ABI PRISM Big Dye Terminator cycle sequencer. The gene sequences obtained was compared by aligning the result with the sequences in Gen Bank using the Basic Local Alignment Search Tool (BLAST) search program of the National Centre for Biotech Information (NCBI).

2.6 Physicochemical Analysis of the Water Samples

Some physicochemical parameters were determined *in-situ* after which samples were stored in clean iceboxes for onward transportation to the laboratory and analyzed same day or stored at refrigeration temperature in the original bottle until testing was done within the shortest possible time. Collection of samples and analysis proper were carried out aseptically following standard methods (3).

2.7 Heavy metals analysis

A total of seven heavy metals were determined in the water samples using Atomic Absorption Spectrophotometry as described by Gregg (6). These include iron (Fe), lead (Pb), copper (Cu), nickel (Ni), cadmium (Cd), zinc (Zn), chromium (Cr).

3. RESULTS AND DISCUSSION

The results of Most Probable Number of Lower Usuma Dam raw water and treated water are shown in Tables 1 and 2 respectively. Table 3 shows the positive presumptive tests of samples at consumption points across the area councils studied.MPN values for raw (untreated) was observed to be 180MPN/100ml whereas the MPN for treated water was <1.1 MPN/100ml as samples did not present any contamination. Bacteriological results across Bwari, AMAC and Gwagwalada ranged between 7 MPN/100ml to >23 MPN/100 ml. Biochemical tests result of samples are shown in Table 4. Molecular analysis result is shown in pictures 1 and 2.

Table 1. Most Probable Number (per 100ml) of Lower Usuma Dam Raw Water Samples

Sampling points	**Combination of positives**			**MPN Index/100ml**	**95% confidence Limits (Exact)**	
	10ml	1ml	0.1ml		Lower	Upper
Raw (Untreated)water	5	2	3	120	36	250

Table 2: Most Probable Number (per 100ml) of Lower Usuma Dam Treated Water Samples

Sampling points	No of Tubes Giving Positive Reaction out of 10(10ml each)	MPN Index/100ml	95% confidence Limits (Exact)	
			Lower	Upper
Treated water	0	<1.1	-	3.4

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Table 3: Most Probable Number (MPN INDEX/100ml) of Positive Water Samples from Consumption Pointsin the Area Councils

Sampling points	No of Tubes Giving Positive Reaction Out Of 10 (10ml each)	MPN Index Index/100ml	95% confidence Limits (Exact)	
			Lower	Upper
Bwari	8	16	4.8	24
	7	12	3.3	19
AMAC	9	23	8.1	53
Gwagwalada	10	>23	13	-
	10	>23	13	-
	9	23	8.1	53
	19	>23	13	-

Table 3: Biochemical analysis results

S/no	**Biochemical Testing**	**Reaction**	**Type of coliform bacteria isolated**
1	Indole test	Appearance of pink coloured ring	Presence of *E.coli*.
2	Methyl red test	Appearance of pink coloured ring in methyl red.	Presence of *E.coli, shigella spp. And salmonella spp.*
3	**Citrase utilization test:** (Simmon's citrate medium + Bromothymol indicator	Slant changes colour from green to blue for positive results No colour change in the medium in the medium means negative result	Positive for Salmonella, klebsiella and *Enterobacter spp.*
4	**Voges-Proskauer test**	Brownish red to pink	Presence of E. coli or absence of Enterobacter or *Pseudomonas spp*.
4	**Urease test:** **(**Urease is digested by urease enzyme resulted in release of ammonia)	Appearance of yellow colour shows negative. Appearance of pink colour positive.	Presence of *Proteus spp.*
5	**Oxidase reaction:** (Tetra methyl parapholene diamine dihydro chloride)	Appearance of purple colour within 30 minutes.	Presence of *Pseudomonas spp*.
6	Triple sugar iron (TSI)test (lactose, sucrose and glucose)	Fermentation and gas production test:	*Salmonella spp*., Proteus

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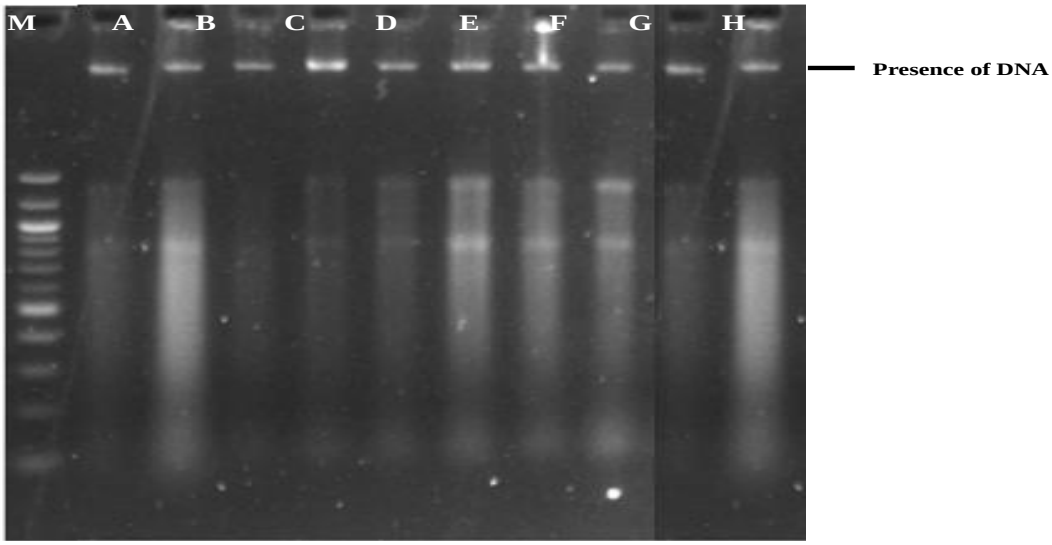

Plate 1: Water Quality assessment,

From left to right, Legend: M = 1kb – Ladder, A = isolate A (*Klebsiellapneumoniae*), B = isolate B (*Proteus mirabilis*), C = isolate C (*Salmonella enterica*serovarsTyphimurium), D = isolate D (*Escherichia coli*)), E = isolate E (*Pseudomonas aeruginosa*), F = isolates F (*Pseudomonas fluorescens*), G = isolate G (*Enterobacter cloacae*, H = isolate H (*Salmonella enterica*serovarsEko), I= isolate I (*Shigellaflexineri*), J= isolate J (*Escherichia coli*).

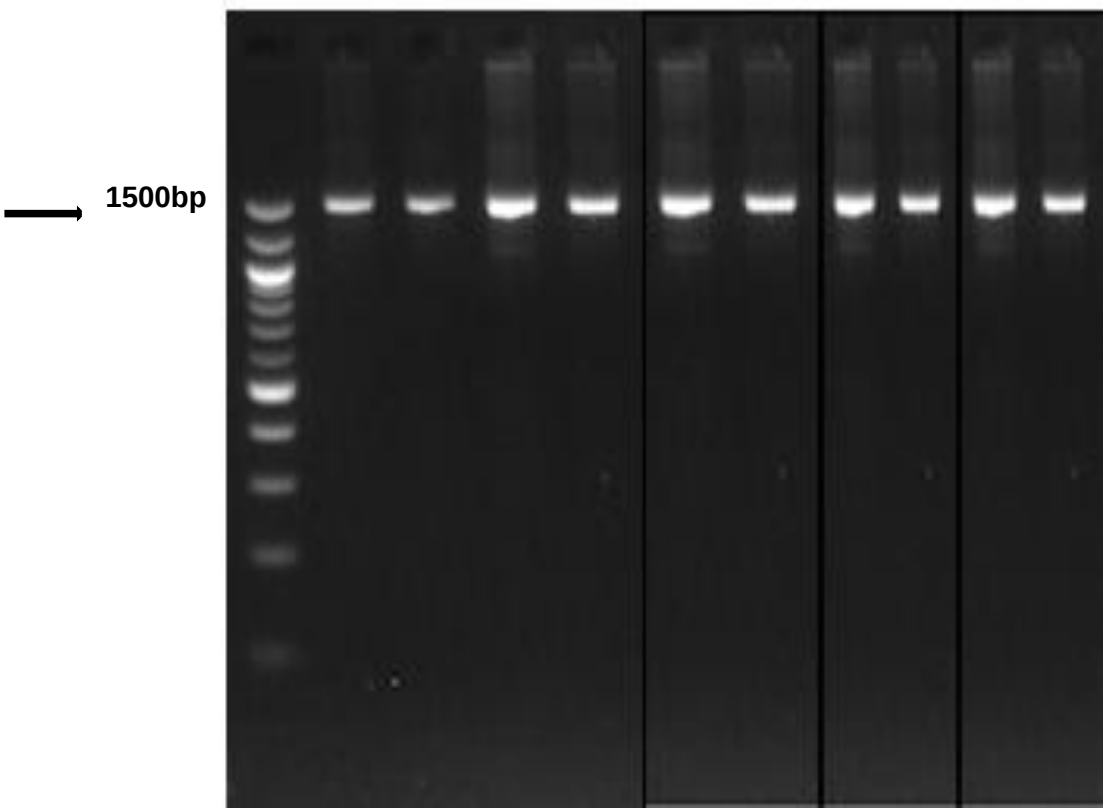

Plate 2: Agarose gel electrophoresis showing PCR result with the bond point.

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From left to right, Legend: M = 1kb – Ladder, A = isolate A (*Klebsiellapneumoniae*), B = isolate B (*Proteus mirabilis*), C = isolate C (*Salmonella enterica*serovarsTyphimurium), D = isolate D (*Escherichia coli*)), E = isolate E (*Pseudomonas aeruginosa*), F = isolates F (*Pseudomonas fluorescens*), G = isolate G (*Enterobacter cloacae*, H = isolate H (*Salmonella enterica*serovarsEko), I= isolate I (*Shigellaflexineri*), J= isolate J (*Escherichia coli*).

Physicochemical parameters in Lower Usuma Dam before and after treatment is shown in Table 4. Table 5 shows the physicochemical parameters of Treated water from Lower Usuma Dam water treatment plant to the consumption points across the distribution. The result comparing the concentrations of the heavy metals analyzed in this study is shown in figures 1.

Table 4: Physicochemical Parameters of Water Samples (untreated and treated) from Lower Usuma Dam

Parameters	Untreated water	Treated water	WHO permissible limit
Colour (Pt.Co)	50.0±1.12	0.00	15.00
pH	7.1±0.06	6.9±0.01	6.5-8.5
Temperature (°C)	28.0±2.80	27.6±1.16	30.00
Turbidity (NTU)	4.25±0.02	1.97±0.01	5.00
TDS (mg/L)	49.0±2.46	55.7±0.28	1000.00
Conductivity (µs/cm)	82.2±2.01	83.9±1.46	1250.00
Total hardness (mg/L)	32.0±2.10	28.0±1.00	500.00
Total Alkalinity (mg/L)	30.0±2.05	20.0±0.12	100.00
Chloride ion (mg/L)	21.3±1.28	25.6±1.10	250.00

Results are in mean±Std. TDS-Total dissolved solids

Table 5: Physicochemical properties of Treated Water Samples from Lower Usuma Dam to Consumer points

Parameters	Lower Usuma Dam	Distribution Bwari	AMAC	Gwagwalada	WHO permissible limit
Colour (pt.Co)	0.00^{a}	16.67 ± 8.33^{ac}	1.00 ± 1.73^{a}	3.33 ± 1.15^{a}	15.00
pH	6.90^{a}	6.77 ± 0.06^{a}	7.00 ± 0.20^{a}	7.33 ± 0.12^{ab}	6.5-8.5
Temperature (°C)	27.60^{a}	30.23 ± 2.80^{b}	27.2 ± 0.26^{a}	29.47 ± 1.03^{a}	30.00
Turbidity (NTU)	1.97^{b}	1.98 ± 0.10^{b}	1.86 ± 0.19^{b}	2.83 ± 0.20^{ab}	5.00
TDS (mg/L)	55.70^{a}	52.57 ± 0.99^{c}	52.17 ± 2.16^{c}	54.27 ± 1.16^{c}	1000.00
Conductivity (µs/cm)	83.90^{a}	81.00 ± 10.1^{a}	84.3 ± 3.77^{a}	90.10 ± 1.21^{ab}	1250.00
Total hardness (mg/L)	28.00^{ab}	23.33 ± 3.06^{a}	20.00 ± 0.0^{a}	34.00 ± 5.29^{ab}	500.00
Total Alkalinity (mg/L)	20.00^{a}	22.00 ± 2.00^{a}	26.67 ± 4.16^{ab}	28.00 ± 0.00^{ab}	100.00
Chloride ion (mg/L)	25.56^{ab}	18.46 ± 2.46^{a}	19.41 ± 2.96^{a}	20.82 ± 2.16^{a}	250.00

Keys: TDS-Total dissolved solid.Values are in Means of duplicate result ± Standard Deviation. Superscript with same alphabets (a, b, c) within a row are not significantly different ($p>0.05$)

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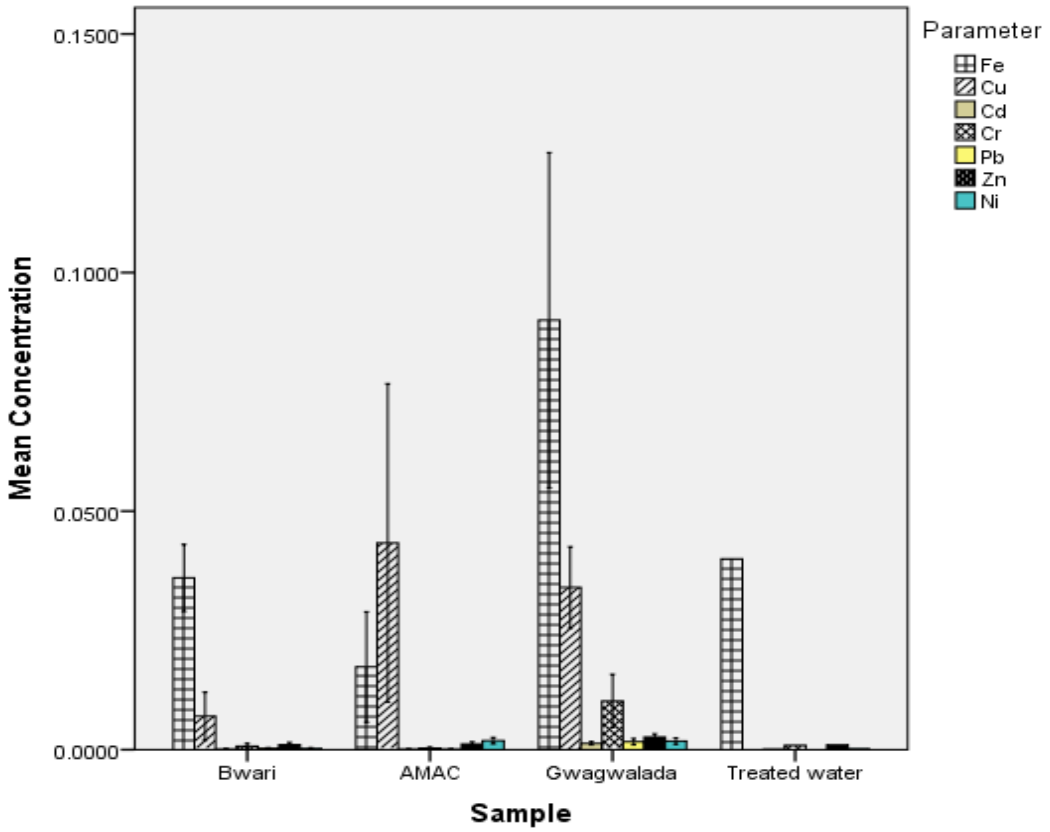

Figure 4.2: Elemental properties of treated water samples from Lower Usuma Dam to distribution sites

Drinking water must be aesthetically acceptable and free from pathogenic bacteria. The standard of drinking water quality as recommended by World Health Organization (WHO) is 0cfu/100ml (2). Findings revealed that coliforms were not detected in the treated water at the treatment plant. The molecular analysis was carried out in this study to identify the isolates to know if they are traceable to the source, Lower Usuma dam raw water. Microbial source tracking to trace the origin of faecal coliform is a new approach that holds promise (7). The bacterial isolates present in Lower Usuma Dam raw water include; *Escherichia coli* 0157:H7, *Salmonella enterica*serovarsEko strain EQAS2016S1 and *Shigellaflexneri*. *Pseudomonas aeruginosa* PA01, *Enterobacter cloacae* were isolated from Bwari axis. *Proteus mirabilis* strain RCFS3 was the isolated coliform bacteria from AMAC water samples. *Klebsiella pneumonia*, *Salmonella typhymurium* strain FDAARGOS-319, *Escherichia coli* and *Pseudomonas florescens* were isolated from Gwagwalada samples. Results showed a variation in physicochemical water quality parameters before and after treatment. The study revealed that bacteriological and physicochemical water qualities of Lower Usuma Dam treated water complied with World Health Organization guidelines for drinking water quality (8). Though, electrical conductivity, total dissolved solids and chloride ion concentration were higher in treated than untreated water, they were still within permissible limits. Electrical conductivity in waters is the measure of water's ability to conduct electric current (3). It does not have direct impact on human health. It is mainly affected by dissolved salts such as potassium chloride, calcium and sodium chloride. Electrical conductivity of treated water was higher (83.90 µs/cm) than that of untreated water (82.20 µs/cm). According to WHO (8), the maximum allowable limit of conductivity is 1000µs /cm. This study is in agreement with a study (9) who reported that increase in values (82.20 µs/cm in untreated -83.90 µs/cm in treated water), may be attributed to the chemicals which were added for coagulation and disinfection for turbidity removal. Pearson correlation test ($p = 0.05$) showed a positive linear correlation (r^2 linear = 0.674) between the

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physicochemical properties of untreated and treated water samples from Usuma dam treatment plant. Across the distribution, Bwari recorded the highest mean value of 16.67 Pt.Co for colour. This is slightly above the recommended standard which is 15Pt.Co (8). Colour is a physical parameter, which could have impact on acceptability by consumers. It does not particularly have any health impact. Coloured organic substances or natural metallic ions such as manganese, iron and copper may give rise to colour in drinking water. Compared to the water samples from the treatment plant, the parameters investigated were observed to be higher in the water from the distribution channels (Bwari, AMAC, Gwagwalada) except for total dissolved solids, conductivity, and chloride ion which were higher in water from treatment plant (55.70 mg/L, 83.00 µs/cm, 25.56 mg/L). In this study, pH of water samples from the distributed channels ranged between 6.7 and 7.3. It was observed to be slightly alkaline except for water samples from Bwari channel that was slightly acidic (6.77±0.06). The pH is similar to pH of drinking water (6.8-7.8) reported by Muktar and Oyeyi (10) in their work. The drinking water pH is within WHO permissible limit (6.5-8.5) (2). Also, the temperatures of the water samples were all below the WHO permissible limit (30^{o}C), except for water samples from Bwari which was 30.23±2.80^{o}C slightly above the permissible limit. This may be due to the time and period of collection and the location of the study areas. Though high water temperature does not have direct health impact, it could affect the aesthetic quality, reduce gas solubility, increase corrosion, raise tastes, colour and odour (11). It can also enhance growth of microorganisms. Water temperature can significantly increase or decrease during distribution from the source to the customer (12). The total hardness result showed that the water is soft water (20-34mg/l). This is because water containing calcium carbonate at concentrations below 60mg/L is generally considered as soft (13). WHO permissible limit for total hardness of water is 500 mg/l (8).

Heavy metals were also determined in this study. Seven elements analyzed include iron, chromium, cadmium, lead, zinc, nickel and copper. Heavy metals exist as natural constituents of the earth crust. They cannot be degraded or destroyed, thus they are persistent environmental contaminants (14). Human exposure to harmful heavy metals can occur in many ways, ranging from the consumption of contaminated food, exposure to air-borne particles, and contact or consumption of contaminated water and accumulate over a period of time (15). Results showed that these parameters analyzed were below WHO permissible limit for drinking water quality (8), both at the treatment plant and the areas sampled for this study. In this study, the concentration of iron was found to be 0.017-0.09mg/L and this falls within the permissible limit of 0.3mg/l according to WHO (8). This could be as a result of aged and rusting metal pipes used in the distribution. This result agrees with a related study which concluded that the compliance with WHO recommendation showed that the heavy metals may not pose any ill-health related problem (16). The concentration of iron observed in the Lower Usuma dam treated water was not significantly different ($p>0.05$) from the concentration of iron in water samples across the consumption points in distribution (Bwari, AMAC, and Gwagwalada) studied.

Cadmium was observed to be statistically significant ($p<0.05$) among the elements analyzed in this study. There is low variation in the concentration of the elements in the various areas. It shows that there was no infiltration of industrial wastes that could introduce contaminants. Copper was not detected in treated water samples at Lower Usuma Dam. The concentration of copper was observed in water samples ranged between 0.043 mg/L and 0.007 mg/L. This was also below the allowable limits (8). Cadmium and lead were only detected in water samples from Gwagwalada (0.001 mg/L and 0.001mg/L) respectively and they are below WHO limits of 0.05mg/L of cadmium and 0.01mg/L for lead. The presence of slight concentration of lead in Gwagwalada other than other locations may be due to piping used in the distribution system, also the surrounding soil may have a high amount of lead which may have leached into the water during repairs (17). Cadmium occurs naturally in rocks and soils and enters water when there is contact with soft groundwater or surface water (18). Contamination of cadmium in drinking water may occur as a result corrosion of galvanized steel pipe used in piping water distribution in the area (2). These galvanized steel pipes according to WHO report, are plated with zinc, which usually has 1% of cadmium (2).

The concentration of chromium was similar in the Lower Usuma dam treated water samples and samples from Bwari area (0.001 mg/L) which was less than the concentration of chromium observed in water samples from Gwagwalada (0.010 mg/L). However, these are below WHO guidelines for drinking water quality. Chromium was not detected in water samples from AMAC distribution channel. There was no significant difference ($p>0.05$) in the concentration of chromium detected in all the water samples across the distribution. Exposure to chromium is associated with many chronic diseases such as dermatitis, kidney damage, respiratory illness and other diseases (8). Zinc concentration was similar in all the water samples (0.001 mg/L) except for water sample from Gwagwalada distribution channel (0.003 mg/L). the concentration of Zinc in water samples from Gwagwalada varied significantly ($p>0.05$) from the other water samples. Nickel was not detected in the Usuma Dam treated water and samples from Bwari

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distribution channel. Similar concentration of Nickel was observed in water sample from AMAC and Gwagwalada distribution channel. From the analysis carried out, results of the heavy metals investigated in this study are below limits set by WHO guidelines. They also agree with similar work done overview of heavy metal concentrations in public pipe borne water and its safety implications for the Communities in Abuja Metropolis North-Central Nigeria (16).

4. CONCLUSION

From this study, it is evident that Lower Usuma Dam treated water was free from total and faecal coliform contamination. Treatment was efficient at the Lower Usuma Dam water treatment plant. However, *Escherichiacoli*, *Pseudomonas*spp, *Klebsiella pneumonia*, *Salmonella typhymurium*, *Proteus mirabilis* and *Enterobacter cloacae* were isolated at some of the consumption points across the distribution. These isolates identified in this study are not traceable to the raw water source at Lower Usuma Dam as they are different strains based on their molecular characterization. The isolation of these coliforms shows evidence of recontamination of the drinking water. Physicochemical parameters and heavy metals analyzed in the study were also within set limits of international and national drinking water standards. Therefore, regular water quality assessment, improved sanitation, consumer education on hygieneand maintenance of distribution facilities by relevant authorities are essential to ensure prevention of recontamination and outbreak of water-borne diseases within the Federal Capital Territory Nigeria.

Compliance with ethical standards

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Disclosure of conflict of interest

There was no conflict of interest/competing interest

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