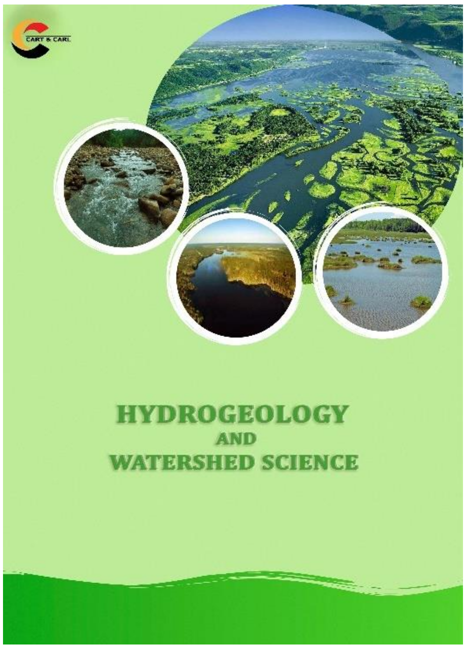
Original Article

Hydrogeology And Watershed Sciences
https://cartcarl.com/journals/hws

E-ISSN: 0331-7749



Assessment of Physicochemical and Bacteriological Parameters of Drinking Water Quality of Urban Water System in Abuja Metropolis, Nigeria

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Received: 30 October 2024
Accepted: 13 November 2024
Published: 20 November 2024

Citation

Chiatula, E.T., Udom, G.J., Emujakporue, G. (2024). Assessment of Physicochemical and Bacteriological Parameters of Drinking Water Quality of Urban Water System in Abuja Metropolis, Nigeria. *Hydrogeology and Watershed Sciences*, 1(1), 63-69. *https://doi.org/10.70726/hws.2024.116369*

Abstract

The study evaluates the physicochemical and bacteriological parameters of the drinking water quality of the urban water system in Abuja Metropolis, Nigeria. Water samples from four (4) treated water tanks (TW1-4) and twelve (12) supplied locations (L1-12) were analyzed for their physical (Colour, Temperature, Turbidity, Total Dissolved Solid), chemical (Electricity Conductivity, Total Alkalinity, Total Hardness, Chloride Ion, Salinity, Total Dissolved Solid, Dissolved Oxygen, Iron, Phosphate, Sulphate, Nitrate, Nitrite, Manganese, Residual Chlorine and MPN) and bacteriological (*Escherichia Coli* and other coliforms) parameters in the laboratory based on American Public Health Organization (APHA) standard methods. The mean pH concentration was 6.8 across all the locations, while the turbidity of the TW ranged from 2.39 NTU at SL4 to 3.44 NTU. The chlorine ion (Cl^-) of the SLs ranged from 15.62 mg/l at SLs to 20.83 mg/l at SL1, the F^{3+} of the SLs ranged from 0.1 mg/l across all locations, the PO_3 of the SLs ranged from 0.26 mg/l at SL3 to 0.28 mg/l at SL1 and SO_3 of the SLs ranged from 0.13 mg/l at SL2 to 0.22 mg/l at SL1. All the parameters reported are within the WHO/NSDWQ limit except for the NO_2^- of the SLs, which ranged from 6.47 mg/l at SL2 to 7.63 mg/l at SL1. The TW1 to TW3 showed no presence of *Escherichia Coli* and other Coliforms, while TW4 revealed a presence of *E. Coli* and other coliforms. Conclusively, supplying water from the urban water system is suitable for drinking purposes; however, there is a need for continuous monitoring of the quality for effective water management practices.

Keywords : Water Quality, Physicochemical, Bacteriological, Urban Water System, Drinking Water

Introduction

Water should be safe and readily available for domestic use, including drinking. One of the sixth Sustainable Development Goal (SDG) targets to ensure the availability and sustainable management of water and sanitation for all is universal access to safe and affordable drinking water by 2030 (Okoh et al., 2021). An important measure to determine access to safe drinking water is access to an improved water source. Approximately 68% of the world's population is projected to live in cities by 2050, representing a 13% increase in demand for water services in urban areas (Medwid & Mack, 2022). In addition to this rise in demand, water service providers face additional pressures related to institutional fragmentation, the inability to defray costs to replace deteriorating infrastructure, and increased capital costs to mitigate the impacts of climate change (Scott et al., 2018; Medwid & Mack, 2022). In the face of these challenges, urban water providers struggle to balance the rising costs of providing quality water service while keeping the service cost low for customers (Scott et al., 2018; Medwid & Mack, 2022).

Water quality concerns are frequently the most important component of drinking water, as evaluated by physical, chemical, and bacteriological factors and consumer satisfaction (WHO, 2004; Addisie, 2022). Water quality monitoring is a high priority for determining current conditions and long-term trends in effective management (Arain et al., 2014). The supply of unsafe water significantly impacts the anticipation of water-transmitted diseases. The abundance of organic compounds, radionuclides, toxic chemicals, nitrites and nitrates in the water may cause deleterious effects on human health, especially cancer (Dan'azumi & Bichi, 2010; Arain et al., 2014). Therefore, it is necessary to monitor water quality for drinking regularly. In this regard, studies have considered the drinking water quality among many urban centres in Nigeria (Miner et al., 2018; Umar et al., 2020; Edeki et al., 2023); however, studies related to supply urban water system in Federal Territory Capital (FCT) are limited. Therefore, this study aims to evaluate the physicochemical and bacteriological parameters of the drinking water quality of the urban water system in Abuja Metropolis, Nigeria.

Materials and Method

Study Area

Abuja, located centrally in Nigeria, is the nation's capital city (Figure 1). Kaduna borders Abuja to the north, Niger state to the west, Nasarawa state to the east and southeast, and Kogi state to the southwest. Abuja was officially named the capital of Nigeria on December 12, 1991 (Wambebe & Duan, 2020). Abuja is the administrative and political centre of Nigeria, situated at GPS coordinates 9°5′ N 7°32′ E. The overall land area is 7315 km2 (2824 sq. mi), according to Wambebe & Duan (2020). Abuja's population currently surpasses 2.5 million people, according to Wambebe & Duan (2020).

Collection of Samples

Water Sample: Water samples were collected at various designated points representing the raw water area before treatment, water samples after treatment, and consumer points. Table 1 and Figure 2 present the details of the water collection points. For the study, 12 water samples were collected from the distributed water to various wards in the metropolis and analysed for physiochemical and biological content. Water samples were collected in leak-proof plastic bottles at different sampling points. Before the water collection, the lucid bottles will be cleaned with a 70% sterilizer to prevent impurities and other forms of contamination. Afterwards, the water samples were collected from each designated point, and the bottles were filled to the prim. The bottles were filled carefully without splashing, followed by emptying to ensure no air bubbles and gases and refilling in the same manner. All the sample bottles were sealed correctly, tagged and immediately transported to the laboratory for physicochemical analysis.

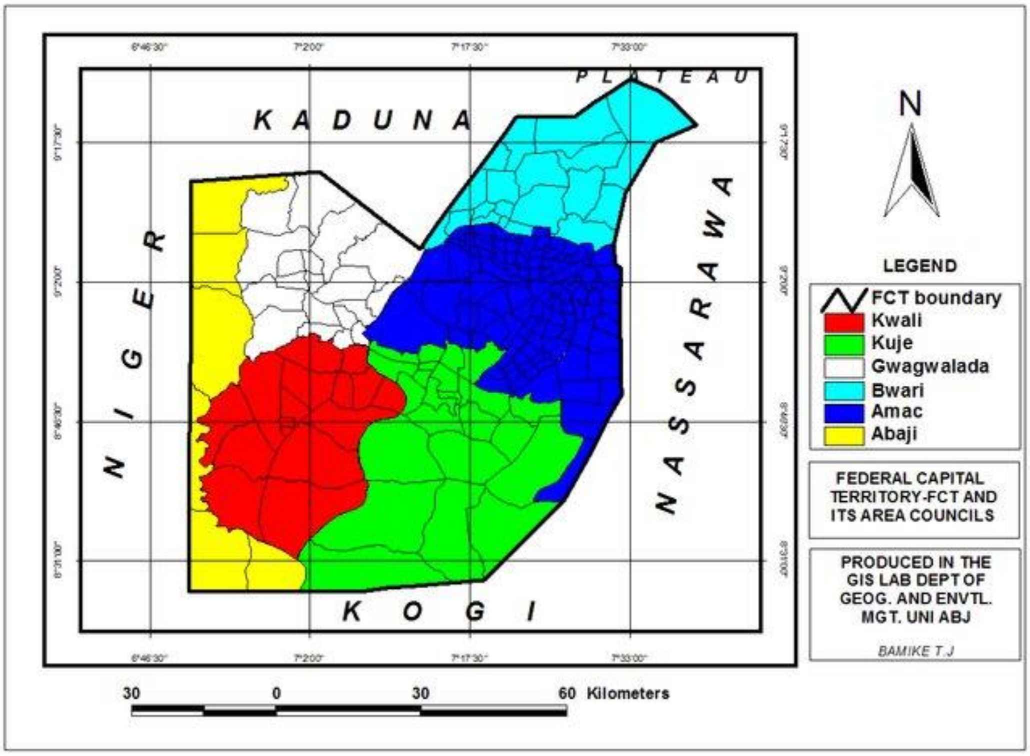
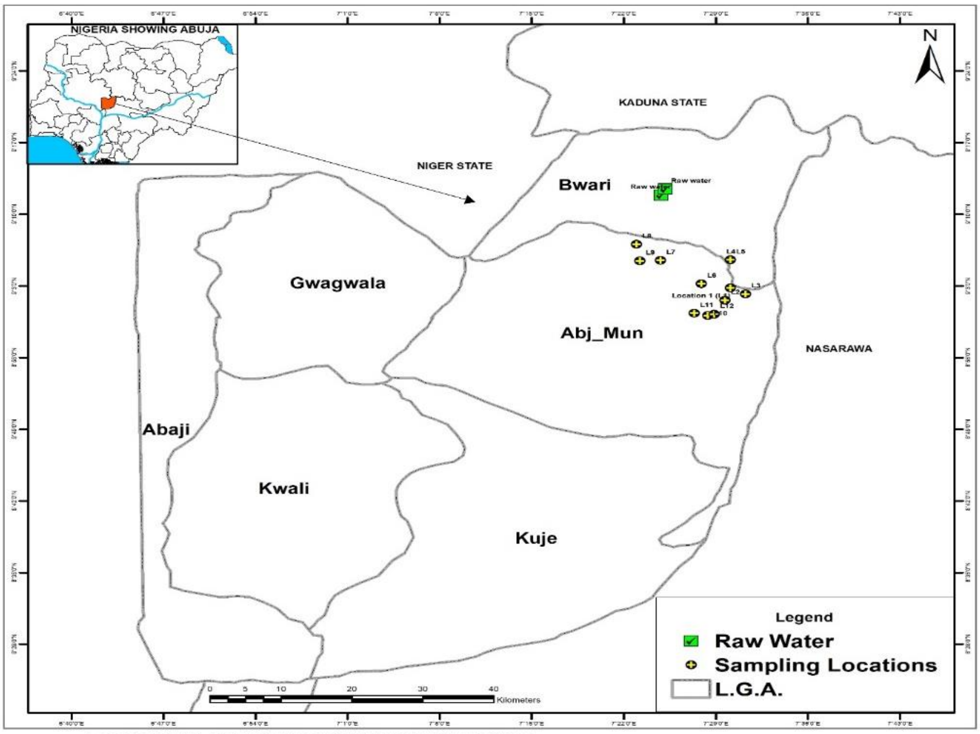


Figure 1: Overview of the Study Area

Table 1: Details of Water Samples Collection Points

Symbol	Coordinate		Locations
Location 1 (L1)	9.047458	7.502290	Area 11
L2	9.027499	7.495193	Garki 2
L3	9.036763	7.521436	Asokoro
L4	9.093440	7.502080	Model Pri. Sch Maitama
L5	9.093440	7.502080	Model Sec. Sch Maitama
L6	9.053712	7.465419	Zone 1
L7	9.091685	7.413622	Gwarimpa, 1
L8	9.117873	7.383067	Gwarimpa, 2
L9	9.091446	7.387267	Life Camp 1
L10	9.001758	7.473448	Gudu
L11	9.006280	7.456270	Kaura Market
L12	9.003525	7.481655	Apo Legislative Quarters



Location Map of Abuja Showing Sampling Locations

Figure 2: Overview of the Sampled Locations

Data Analysis

Numerous water quality parameters, including physical (Colour, Temperature, Turbidity, Total Dissolved Solid), chemical (Electricity Conductivity, Total Alkalinity, Total Hardness, Chloride Ion, Salinity, Total Dissolved Solid, Dissolved Oxygen, Iron, Phosphate, Sulphate, Nitrate, Nitrite, Manganese, Residual Chlorine and MPN) and bacteriological (Escherichia Coli and other coliforms) parameters were determined in the laboratory. Temperature and pH were measured at the site of sample collection. All physicochemical parameters were analyzed by following the standard methods of the American Public Health Organization (APHA) and the American Society for Testing and Materials (ASTM), similar to those described by Khalid et al. (2018) and Latif et al. (2024). The biological/bacteriological analysis of the study was done for parameters such as total coliform, which indicates the presence of various microscopic organisms in the water. Through "plate count Agar" incubated at 37ºC for 72 hours while monitoring and maintaining all laboratory standards, the biological content analysis was carried out to indicate the amount of biological organism in 100mg/L. To ascertain the quality of the outcome from various studies, standard procedures and laboratory quality assurance were strictly followed while samples were triplicates, and the mean was estimated for accuracy and precision.

Result and Discussion

The physicochemical and bacteriological concentration of the water supplied to the households across the selected wards was examined, and the outcome is presented in Table 2.

Physicochemical Concentration

pH: The mean pH concentration of the supply locations (SL) was 6.8 across all the places, and the concentrations are within the WHO and NSDWQ of 6.5-8.5. The reported concentrations were within those reported by Arain et al. (2014), Khalid et al. (2018) and Mengstie et al. (2023) at 6.5 to 7.45, while the concentrations were lower than those reported by Addisie (2024). Also, the pH is determined by the amount of dissolved carbon dioxide (CO2), which forms carbonic acid in water (Meride and Ayenew, 2016).
Turbidity: The TW's turbidity ranged from 2.39 NTU at SL4 to 3.44 NTU at SL1, with a mean concentration of 3.12, which is within the WHO and NSDWQ limit of 5.0 NTU. The reported mean concentrations were lower than those reported by Mengstie et al. (2023) and Addisie (2024) but higher than those reported by Meride and Ayenew (2016). According to Meride and Ayenew (2016), the turbidity of water depends on the quantity of solid matter present in the suspended state.
Colour: The colour of the TW ranged from 8.33 PtCo at SL2 to 8.67 PtCo at SL1 with a mean concentration of 8.48.
Temperature: The temperature of the SLs ranged from 24.93 °C at SL4 to 27.53 °C at SL1. The temperature in this study was found to be within the permissible limit of WHO (30 °C). Ezeribe et al. (2012) report similar results (29 °C) of well water in Nigeria.
Electrical Conductivity: The EC of the SLs ranged from 39.63 µS/cm at SL4 to 41.35 µS/cm at SL1 with a mean concentration of 40.84, and all the reported concentrations are within the WHO and NSDWQ limit of 1250 µS/cm, and 1000 µS/cm respectively. The concentration reported for the study was lower than those reported by Meride and Ayenew (2016) and Muhammad et al. (2024). These results indicate that water in the study area was not considerably ionized and had lower ionic concentration activity due to small dissolved solids.
Total Alkalinity: The total alkalinity of the SLs ranged from 22.67 mg/l at SL4 to 25.33 mg/l at SL1, with a mean concentration of 24.39. All the reported concentrations are within the WHO limit of 2000 mg/l. The concentrations are within the range reported by Arain et al. (2014) and Aderemi et al. (2011) for physicochemical parameters for drinking water.
Total Hardness: The total hardness of the SLs ranged from 24.67 mg/l at SL4 to 28.67 mg/l at SL1, with a mean concentration of 27.11. All the reported concentrations are within the WHO limit of 200 mg/l.
Chloride and Residual Chloride: The chlorine ion (Cl-) of the SLs ranged from 15.62 mg/l at SLs to 20.83 mg/l at SL1 with a mean concentration of 19.33, while all the reported concentrations are within the WHO and NSDWQ limit of 250 mg/l. The residual chlorine of the SLs ranged from 0.01 mg/l at SL4 to 0.06 mg/l at SL1-3 with a mean concentration of 0.05, while all the reported concentrations are within the WHO and NSDWQ limits of 0.2 mg/l and 0.25 mg/l. The salinity of the SLs across the treatment tank was 0.3 g/l, and all the reported concentrations were within the WHO limit of 200 mg/l. The Cl reported for this study was similar to those reported by Asaomaku (2022) while higher than those reported by Khalid et al. (2018) and Meride & Ayenew (2016) but lower than those reported by Muhammad et al. (2024). Chloride is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), NaCO2 and added through industrial waste, sewage, sea water etc. High chloride concentrations damage metallic pipes and structures and harm growing plants (Meride & Ayenew, 2016). The study's reported residual chlorine concentrations were within the WHO/NSDWQ set standard, while no concentration was recorded at the RW. This outcome confirmed the treatment process, such as chlorination (Goyal and Patel, 2015). The reported concentration was similar to those reported by Ibrahim et al. (2020) for drinking water.
Total Dissolved Solid: The TDS of the SLs ranged from 23.73 mg/l at SL4 to 26.57 mg/l at SL1 with a mean concentration of 25.42 while all the reported concentrations are within WHO and NSDWQ limit of 1500 mg/l and 500 mg/l respectively. The concentrations reported are lower than those reported by Meride and Ayenew (2016) and Muhammad et al. (2024). Water can dissolve many inorganic and organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates, etc. These minerals produced an unwanted taste and diluted colour in the appearance of water. This is an important parameter for water use (Muhammad et al., 2024).
Dissolved Oxygen: The dissolved oxygen of the SLs ranged from 0.57 mg/l at SL4 to 3.14 mg/l at SL1, with a mean concentration of 2.48. A DO of 5 mg/l is ideal for aquatic organisms; any value below this harms aquatic organisms. The higher the concentration of DO, the better the water quality (Ojekunle and Lateef 2017).
Iron: The F^{3+} of the SLs ranged from 0.1 mg/l across all locations, while all the reported concentrations are within the WHO and NSDWQ limit of 0.3 mg/l. The reported concentrations are within the range reported by Arain et al. (2014) and Addisie (2024) for drinking water. Fe is found in natural fresh and groundwater, and high concentrations give rise to consumer complaints, which could manifest in their taste and odour (Arain et al., 2014).
Phosphate: The PO3 of the SLs ranged from 0.26 mg/l at SL3 to 0.28 mg/l at SL1 with a mean concentration of 0.27, while all the reported concentrations were within the WHO limit of 6.5 mg/l. The reported concentrations

Table 2: Physicochemical and Bacteriological Concentration/Properties of the Supplied Water to the End-users

	SUPPLY LOCATIONS A				SUPPLY LOCATIONS B				SUPPLY LOCATIONS C				SUPPLY LOCATIONS D					
	TW1	**L1**	**L2**	**L3**	**TW2**	**L4**	**L5**	**L6**	**TW3**	**L7**	**L8**	**L9**	**TW4**	**L10**	**L11**	**L12**	**WHO**	**NSQ**
pH	6.8	6.7	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.7	6.8	6.8	6.5 – 8.5	6.5 – 8.5
Tbd	1.68	1.56	1.38	1.75	0.98	1.41	1.32	1.34	1.82	3.58	3.16	3.14	1.89	2.84	1.39	2.95	5.0	5.0
Colour	2	2.1	1.9	2	0	1	0	0	7	8	8	9						
Temp	26.8	26.9	26.6	26.8	26.0	26.0	26.3	25.6	28.0	27.7	27.6	26.8	25.2	25.2	24.6	25.0	30	
EC	29.3	29.2	28.3	41.0	39.3	38.3	38.6	32.5	41.5	41.5	40.8	41.3	39.6	39.7	38.8	40.4	1250	1000
TA	26	22	24	28	26	22	22	24	26	24	26	24	20	20	26	22	2000	
TH	26	24	26	30	26	26	24	26	28	26	30	26	30	26	24	24	200	
Cl^-	21.30	19.88	14.20	19.88	19.88	19.88	18.46	19.88	21.3	19.88	21.3	19.88	12.78	17.04	14.20	15.62	250	250
Salinity	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	200	
TDS	17.60	17.36	17.59	24.70	23.1	23.0	23.1	18.73	25.2	27.6	24.4	24.6	23.9	23.7	23.3	24.2	1500	500
DO	0.70	0.43	0.79	0.79	0.63	0.72	0.70	0.60	2.59	3.01	3.18	3.13	1.48	0.66	0.55	0.51	NA	
Fe^+	0.04	0.14	0.05	0.02	0.02	1.03	1.21	0.02	0.05	0.09	0.08	0.12	0.04	-	-	-	0.3	0.3
PO_3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.2	-	-	-	6.5	
SO_3	0.07	0.26	0.18	0.08	0.02	0.04	0.06	2.11	0.09	0.04	0.03	0.31	1.02	-	-	-	400	100
Nitrate	3	2	6	0	3	5	4	3	8	8	8	6	5	-	-	-	50	50
Nitrite	5.0	1.3	0.9	5.4	0.5	2.6	1.4	3.8	5.3	5.4	5.2	8.8	3.0	-	-	-	0.5	0.2
Mn	0.003	0.009	0.008	0.003	0,001	0.003	0.005	0.001	0.004	0.006	0.006	0.006	0.026	-	-	-	0.4	0.2
R. Cl^-	0.14	0.03	0.06	0.01	0.13	0.10	0.20	0.19	0.26	0.06	0.07	0.04	0.02	0.02	0	0.01	0.2	0.2 – 0.25
MPN	<2.2				<2.2				<2.2				<16.0					
E.Coli	0				0				0				+VE					
Other Coli.	0				0				0				+VE					

All parameters expressed in mg/l except Temperature (°C), EC (µS/cm), salinity (g/l), Turbidity (NTU), TW: Treated Water, L1-12: Locations are within the range Magaji (2020) reported for Sachet water produced and sold in the Gwagwalada Area of Abuja and those reported by Afolabi et al. (2023) for groundwater. Phosphate is non-toxic to humans and animals unless the concentration is very extreme.

Sulphate: The SO_3 of the SLs ranged from 0.13 mg/l at SL2 to 0.22 mg/l at SL1, with a mean concentration of 0.17. All the reported concentrations are within the WHO and NSDWQ limits of 400 mg/l and 100 mg/l, respectively. All the reported concentrations are similar to those reported by Afolabi et al. (2022) for groundwater and Magaji (2020) for Sachet water produced.

Nitrate and Nitrite: The NO^-_3 of the SL ranged from 7.11 mg/l at SL3 to 7.67 mg/l at SL1 with a mean concentration of 7.37 while all the reported concentrations are within WHO and NSDWQ limit of 50 mg/l. All the reported concentrations were within the range that Meride and Ayenew (2016) reported but lower than those reported by Ibrahim et al. (2020). According to Meride and Ayenew (2016), nitrate is one of the most important water quality parameters of concern due to diseases such as blue baby syndrome in infants. The sources of nitrate are the nitrogen cycle, industrial waste, nitrogenous fertilizers, etc.

The NO^-_2 of the SLs ranged from 6.47 mg/l at SL2 to 7.63 mg/l at SL1, with a mean concentration of 6.97. All the reported concentrations exceeded the WHO and NSDWQ limits of 0.5 mg/l and 0.2 mg/l, respectively. A similar outcome was reported in the study conducted by Ibrahim et al. (2020), with the reported concentration being higher. According to Ibrahim et al. (2020), treatments like disinfection and ion exchange must be done before they can be used for portable drinking water.

Manganese: The Mn of the SLs ranged from 0.01 mg/l for all locations, while all the reported concentrations are within WHO and NSDWQ limits of 0.4 mg/l and 0.2 mg/l, respectively. All the reported concentrations were within the range reported by Meride and Ayenew (2016), Ibrahim et al. (2020) and Afolabi et al. (2022) for drinking water and groundwater, respectively. Drinking water with a high level of manganese above the stipulated standard can be harmful to health; it can also cause stains in the laundry and make the water taste or smell bad.

Bacteriological Concentration

Assessing the bacteriological quality of drinking water is the major parameter that should be considered in any water quality monitoring. The prevalence of pathogens in drinking water indicates potential sources of human and animal waste. Water can be contaminated with microorganisms at the source or during transportation or distribution. The Treated water TW1 to TW3 showed no presence of Escherichia coli and other Coliforms, while TW4 revealed a presence of E. coli and other coliforms. The outcome indicated that the water supply from TW4 is unsuitable for human activities.

Conclusion

Providing safe and readily available water for domestic uses, including drinking, remains a national and global target worldwide, and research in this regard remains significant towards sustainable management of the available water. Through the assessment of the physicochemical and bacteriological attributes of the water from the points of collection to treatment and supply and it was revealed that all the parameters considered are within the WHO and NSDWQ allowable limits (except TW4 with E. Coli presence) and the water could be regarded as portable for human activities. The study concluded that the water supply from the urban water system is suitable for drinking purposes; however, there is a need for continuous monitoring of the water quality across the urban water system to improve the wellbeing and sustainable development of the people in the urban centre.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Credit Authorship Contribution Statement

Chiatula, E: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Visualization, Project administration, Writing - original draft. **Udom, G.J** and **Emujakporue, G.**: Supervision, Methodology, Validation, Formal analysis, Data curation, Visualization, Review & Editing.

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