

Evaluation of Water Quality from Plastic Tanks in Umaru Musa Yar'adua University, Katsina, Nigeria

Hassan, M., Musa, A., and Hussaini, A.

Department of Geography, Umaru Musa Yar'adua University, P. M. B 2218, Katsina, Nigeria.

Chemistry Laboratory Unit, Umaru Musa Yar'adua University, Katsina, Nigeria

Soil and Water Laboratory Unit, Department of Geography, Umaru Musa Yar'adua University, Katsina

ABSTRACT

Freshwater is a natural asset that must be protected to ensure its quality and essential ecosystem services it provides. Providing safe and adequate drinking water is an essential to human life. The aim of this study is to assess the physico-chemical quality of water stored in plastic tanks for drinking purposes in Umaru Musa Yar'adua University Katsina. Four plastic water tanks were selected (MGT, FHT, MHT and FST) for water sampling. The concentration of pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total alkalinity (TA), chloride (Cl), turbidity, total hardness (TH), sulfate (SO₄), phosphate (PO₄), and nitrate (NO₂) were analyzed and compared with permissible limits set by Nigerian Standards for Drinking Water Quality (2007) and World Health Organization (2017). From the result, the concentrations of DO, BOD and COD were found higher than their respective permissible limits, while pH, EC, TDS, TSS, TA, Cl⁻, turbidity, TH, SO₄, PO₄, NO₂ concentrations were observed within the limits. Based on Water Quality Index (WQI) assessment, result obtained revealed that, the status of stored water of all samples was excellent indicating no health risk to consumers and suggested that the water is of good quality. It is concluded that, stored water in plastic tanks is suitable for drinking and other purposes. Constant monitoring of these water stored in plastic tanks is recommended as well as research to investigate the bacteriological parameters.

Keywords: Physico-chemical, Quality assessment, Stored water, Yar'adua university Katsina.

INTRODUCTION

Water is the essence of life and soft drinking water is basic human right essential to all and also essential for the wellbeing of mankind and for sustainable development (Musa *et al.*, 2013; Hassan *et al.*, 2017). About 71% of the Earth's surface area is covered by water, the freshwater supply has increasingly become a limiting factor. The presence of reliable source of drinking water is a vital factor in the establishment of community (Yusuf, 2005; Abdullahi and Indabawa, 2012). About one billion people are without safe drinking water, and two to three billions lack access to basic sanitary services globally. The vast majority of these people are located in sub-Saharan Africa, South Asia and East Asia. In fact, it is estimated that approximately half the people in developing countries suffer from health problems caused by poor water (UNDP, 2006; Shigut, *et al.*, 2017). In developing countries reports shows that there is a strong correlation between unsafe water and hygiene, and infant and child mortality arising from diarrhoeal and other illness (Chia, *et al.*, 2013). The decade 2005-2015 has been declared the International Water Decade by the United Nations. The UN alerted policy makers about a 'global water crisis', noting in 2006 Human Development Report that 2 million children die annually from diseases related to water-borne illnesses, and millions more women and children

spend hours just collecting water, restricting their opportunities to do other things (UN 2006).

Safe drinking water supply is one of many significant environmental issues that governments, organizations and communities worldwide strive for every day. In order to supply safe water to communities, a cleaner supply of water is crucial (Abbas *et al.*, 2015). Water especially for drinking and domestic purposes are expected to be of high quality, and free from any form of contaminants (Yerima *et al.*, 2019). In the past few decades, public concerns over the quality of water used for drinking purposes have grown considerably. These concerns have arisen as a result of increased awareness about environmental pollution and episodes of waterborne disease outbreaks (Ruma *et al.*, 2014 cited in Anadu and Harding, 2000) especially in developing countries where majority of the population live in rural areas with bare infrastructural facilities, depend on surface water and groundwater for domestic water supplies, have low awareness levels and live in poor sanitation and hygiene. Common problems of drinking water include exposure to toxic inorganic substances, heavy metals, bacterial, algal and protozoan agents, increased nitrogen concentrations and other trace chemicals and micronutrients in drinking water resources which may threaten human survival and health (Ezekwe *et al.*, 2012). The availability of good water is an

*Corresponding author. E-mail: mudassir.hassan@umyu.edu.ng Tel: +2348065047825

Author(s) agree that this article remain permanently open access under the terms of the Creative Commons Attribution License 4.0 International license

indispensable feature for preventing diseases and improving quality of life (Ruma *et al.*, 2014; Hassan *et al.*, 2017).

In northern Nigeria, many higher institutions particular in Katsina, supply of pipe borne water as a source of drinking water is highly inadequate due to lack of water treatment plant and distribution systems near the metropolitan institutions. This problem necessitated the need to provide and store water for different purposes including drinking, cooking, washing and bathing in the institutions. The transported water from long distances are vulnerable to contaminants. Identification and assessment of risks to health from stored water relies excessively on analysis of water samples. Effective preventive management of chemicals in drinking water requires simple tools for distinguishing the few chemicals of potential local concern from the unmanageably long list of chemicals of possible significance (Tziritis *et al.*, 2016). Safe potable water is essential for healthy living and for water to be regarded as safe for drinking; it must meet certain physical, chemical and microbiological criteria recommended by international organizations such as World Health Organization (Shuaibu *et al.*, 2015). Water contaminated via pathogens agents and other elements, can have harmful effects on human health due to excessive intake of contaminated water by human beings (Steenland and Boffetta 2000; Muhammad *et al.*, 2010). High or low concentration of physical and chemical parameters in drinking water can directly or indirectly be associated with public health (Muhammad *et al.*, 2011).

Water Quality Index (WQI) is a method widely used for drinking and irrigation water quality. It serves as a representation of overall quality of water for public or any intended use as well as in the pollution abatement programs and water quality management (Gopolang and Letshwenyo, 2019). To our knowledge, no existing investigation have been made to address the quality of water supply by the university management for drinking purposes and its effects on human health in Umaru Musa Yar'adua university Katsina using index techniques. Therefore, this study is aim at investigating the quality of water stored in plastics tanks based on physic-chemical parameters for drinking purposes in the university. This study will provides information about the quality of water in plastic based storage tanks so as to enable decision makers to take necessary actions.

MATERIALS AND METHODS

Study Area

The study area is Umaru Musa Yar'adua University Katsina. It is found in Batagarawa local government area, about 15 kilometers away from the capital city Katsina. It lies between 12°53'30''-12°54'15''N and between 7°35'15''-7°35'45''E. It has about 9,939 undergraduate students. It has 378 academic staffs and 488 non-academic staffs. The university covers an estimated land area of 4,894 sq. km. (Fig. 1). The climate in the area is characterized by two distinctive wet

and dry seasons, which tend to be controlled by the inter-tropical discontinuity (ITD) with dry season relatively longer than the wet season. The rainy season last for five month (May-October) and with highest rainfall in August and September. The mean annual rainfall ranges from 600mm to 750 mm. Temperature is high throughout the year but varies with season. The hottest month being March and April recorded 34°C to 38°C and a minimum temperature were recorded in the month of December and January with the values between 14°C to 20°C. Humidity is higher during wet season with the values ranging from 70% to 85% and falls down during the dry season to about 20% (Ruma *et al.*, 2014).

Water Sampling Collection

Water was stored in plastics tanks for different uses in the university. Water samples were collected from the tanks in the university in four selected locations namely Faculty of natural and applied sciences (FST), Main gate (MGT), Male undergraduate student hostel (MHT) and Female undergraduate student hostel (FHT). These locations was selected using random sampling technique. The water samples were collected with clean polyethylene plastic container from the selected sampling sites. Prior to water sampling, the bottles were washed with double deionized water containing 20% HNO₃. Each water sample was filtered and a few drops of 5% HNO₃ were added to prevent further microbial growth. All water samples were labelled and stored at 4°C. Samples were then taken to laboratory for onward analysis. The concentrations of selected physico-chemical parameters include pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total alkalinity (TA), chloride (Cl), turbidity, total hardness (TH), sulfate (SO₄), phosphate (PO₄), nitrate (NO₂) were analyzed in the soil and water laboratory of department of geography, Umaru Musa Yaradua university Katsina.

Experimental Procedures

Hydrogen ion concentration (pH), and electrical conductivity (EC), were measured by using pH and EC meter (pH 3505 and EC 4510 Janway). Total dissolved solids (TDS), total suspended solids (TSS) were determined using equations. Total hardness (TH), Sulfate (SO₄), chloride (Cl) and nitrate (NO₂) and chemical oxygen demand (COD) were measured using titrimetric method, phosphate (PO₄) using UV-visible spectrophotometer. DO and BOD using HANNA HI 9143 meter. Standard method described by American Public Health Association (APHA, 2012) was used in the determination of these parameters.

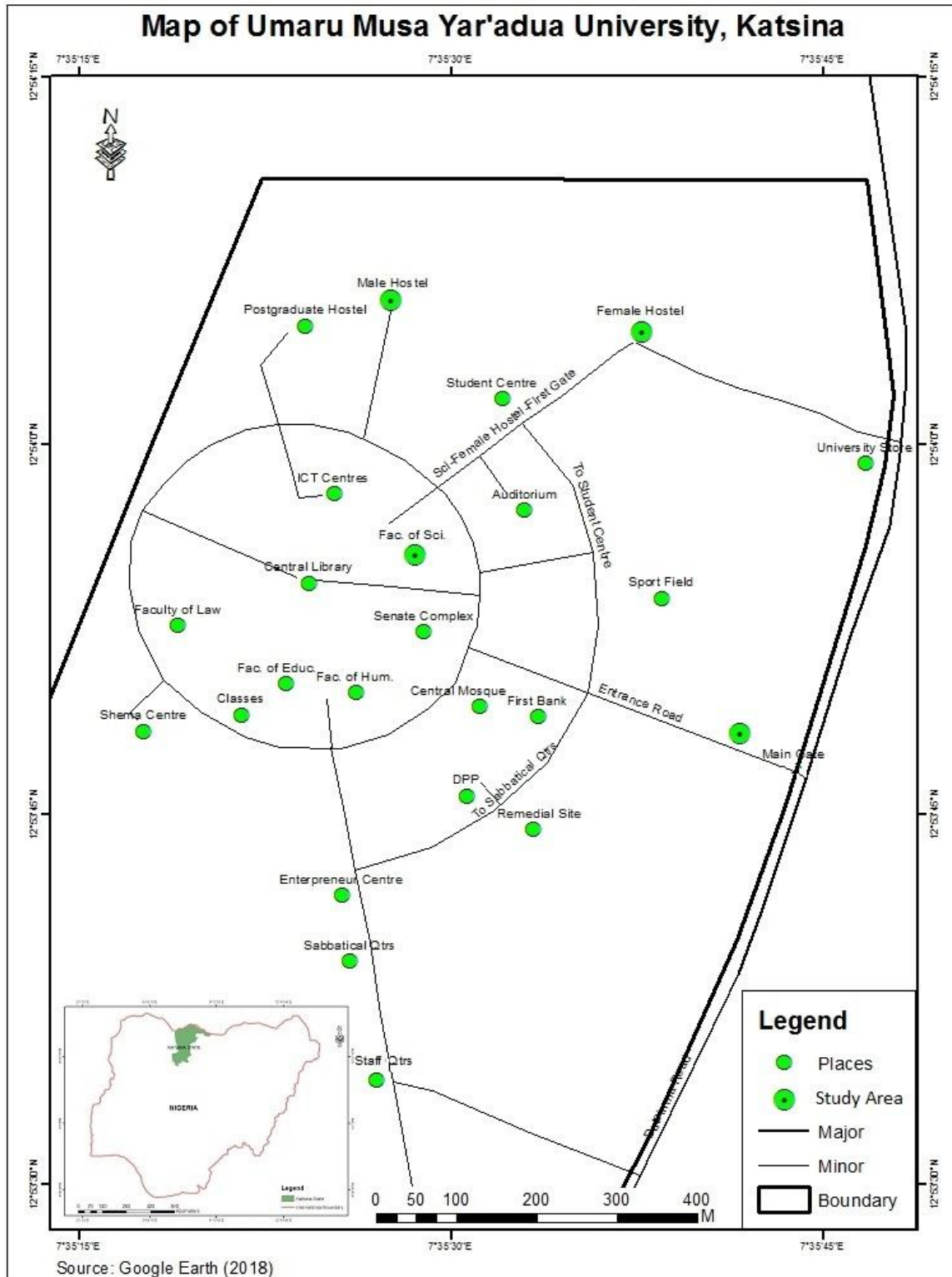


Figure 1: Map of the study area.

Calculation of Water Quality Index (WQI)

In this study fourteen parameters were used for the calculation of WQI. WQI was calculated using the standards of drinking water quality recommended by the Nigerian Standard for Drinking Water Quality (NSDWQ, 2007) through a series of steps, it is calculated using the following equation

$$WQI = \frac{\sum(W_i Q_i)}{\sum W_i} \quad (1)$$

Sub index (Q_i) was calculated using the following equation:

$$Q_i = \frac{(V_i - V_o)}{(S_i - V_o)} \times 100 \quad (2)$$

Where,

V_i is the estimated value of ith water quality parameter at a given sample location, V_o is the ideal value for ith parameter in pure water. Note that, V_o for pH = 7, DO = 14.6, and 0 for all other parameters, and S_i is standard permissible value of ith water quality parameter.

$$W_i = \frac{K}{S_i} \quad (3)$$

Where K is a proportionality constant, which is calculated using the following equation

$$K = \frac{1}{\sum(\frac{1}{S_i})} \quad (4)$$

Table 1: Classification of water quality based on WQI method (Bouslah *et al.*, 2017).

WQI	Status	Possible Usage
1-25	Excellent	Drinking, irrigation and industrial
26-50	Good	Domestic, irrigation and industrial
51-75	Poor	Irrigation
76-100	Very poor	Restricted use for irrigation
Above 100	Unfit for drinking	Proper treatment required before use

Statistical Analysis

Mean of the measured physico-chemical parameters were presented in Table 2. Results obtained were compared with standards approved by World Health Organization WHO, (2017) and Nigerian Standard for Drinking Water Quality NSDWQ, (2007).

RESULTS AND DISCUSSION

Table 2 present the level and mean value of various physico-chemical parameters of collected water samples from plastic tanks along with standard guidelines for drinking purpose.

Table 2: Level of physico-chemical parameters. Their means and standards guidelines of WHO and NSDWQ

Parameters	MGT	FHT	MHT	FST	Mean	Standards		
						WHO 2017		NSDWQ 2007
						HDL	MPL	
pH	6.6	6.8	6.8	6.9	6.75	7.0	8.5	6.5-8.5
EC (µS/cm)	206	280	289	250	256.25	-	1500	1000
TDS (Mg/l)	8.88	10.89	9.78	9.65	9.8	500	1500	500
Turb. (NTU)	0.33	0.51	0.48	0.38	0.43	-	5.0	5.0
TSS (Mg/l)	0.98	1.56	1.38	1.10	1.25	500	500	500
DO (Mg/l)	54.41	55.52	54.97	55.85	55.18	-	5.0	5.0
BOD (Mg/l)	38.70	38.98	38.82	38.95	38.86	-	6	6
COD (Mg/l)	35.75	38.78	38.82	38.95	38.08	-	10	10
TA (Mg/l)	1.63	2.11	1.98	2.51	2.06	-	200	500
SO ₄ (Mg/l)	3.60	4.82	3.88	3.93	4.06	200	400	100
NO ₂ (Mg/l)	6.30	6.89	6.75	6.78	6.68	45	-	50
PO ₄ (Mg/l)	0.05	0.08	0.06	0.06	0.06	0.05	>50	5.0
Cl (Mg/l)	102.73	110.82	110.60	109.83	108.50	200	600	250
TH (Mg/l)	120.63	122.72	120.89	120.85	121.27	100	500	150

MGT = Main Gate Tank, FHT = Female Hostel Tank, MHT = Male Hostel Tank, FST = Faculty of Science Tank

pH was observed to be within approved limits by WHO 2017 and NSDWQ, 2007. As indicated in the related studies by Shuaibu *et al.* (2015), low pH value has less effect on human health but excess pH values in water are not suitable for drinking and may cause stress to human beings. Similar observations were made with regard to electrical conductivity, turbidity total dissolved solids and total suspended solids (Table 2) with no significant variation in the concentration for both parameters being recorded. These values were all found below the limit for drinking water. The low concentrations of these parameters in water implies that the water is safe for human consumption. Low value of EC might be due to absence of agricultural runoff into the tanks (Sreenivasulu *et al.* (2014). In case of turbidity, a similar

finding was reported by Shuaibu *et al.* (2015) that the low turbidity values indicated the presence of few organic and inorganic solids which can provide absorptive site for certain biological and chemical agents. This observation of low turbidity has confirmed that consumers of the water in the area are mostly free of gastrointestinal infections. Abdullahi and Indabawa (2012), reported EC values within approved limit by WHO and implies the water in overhead tanks is safe. Result of TDS in this study agreed with the study carried out by Hassan *et al.*,(2017) which confirmed low TDS values. This might be due to the absence of both soluble and insoluble minerals in the tanks. The low TSS values obtained in this study indicates the absence of suspended

materials in the water and similar findings were observed by Reda (2016).

From the chemical parameters, dissolved oxygen DO, biological oxygen demand (BOD) and chemical oxygen demand (COD) are important parameters in water quality assessment and has the mean values of 55.18, 38.86 and 38.08 mg/l respectively. These values are all above maximum permissible limit approved by WHO, (2017) and NSDWQ, (2007). In all samples, DO, BOD and COD concentrations were observed high. The high DO might be attributed to high of dissolution from atmosphere and photosynthesis. This study disagrees with the findings of Sreenivasulu *et al.* (2014). High BOD might be due to the presence of organic matters in the water. A similar finding by Sreenivasulu *et al.* (2014) revealed high BOD concentrations in selected tanks water except in one sample. High concentration of COD could be due to the presence of oxidizable organic and inorganic pollutants in the water. Result of COD in in line with the similar findings by Edwin

et al. (2015). In this study, alkalinity has the mean value of 2.06mg/l which is below the limit by WHO, indicating very alkaline minerals substances present in the water. Hassan *et al.* (2017) reported similar values in Kunbotso area of Kano state. Sulphate SO₄, Nitrate NO₂, phosphate, chloride and total hardness in sampled water were all found below the maximum limit approved by WHO (2017) and NSDWQ (2007) with the mean values of 4.06, 6.68, 0.06, 108.48 and 121.27 mg/l respectively (Table 2.). Low concentration of SO₄ might be due to absence of any form of fertilizers and manure. Minimum value of NO could be as a result of unavailable of organic residues. This result is contrary to the findings of Shuaibu *et al.* (2015) where nitrate was observed zero in all samples. Shuaibu *et al.* (2015) confirmed that low concentration of chloride in drinking water has less impact on human health. Minimum concentration of hardness were observed in all samples. This is due to the absence of bicarbonates, carbonates, sulphates and chlorides of calcium and magnesium in the water. A similar result of related study by Abdullahi and Indabawa (2012) was reported.

Table 3: Water Quality Index (WQI) for MGT sample

Parameters	Observed value (Vi)	Standard value (Si)	1/Si	Weight (Wi)	Sub-index (Qi)	WiQi
pH	6.6	8.5	0.118	0.122	-26.667	-3.253
EC (µS/cm)	206	1000	0.001	0.001	20.6	0.021
TDS (Mg/l)	8.88	500	0.002	0.002	1.776	0.004
Turb. (NTU)	0.33	5	0.2	0.207	6.6	1.366
TSS (Mg/l)	0.98	500	0.002	0.002	0.196	0.0004
DO (Mg/l)	54.41	5	0.2	0.207	-414.688	-85.840
BOD (Mg/l)	38.70	10	0.1	0.104	387	40.248
COD (Mg/l)	35.75	10	0.1	0.104	387.5	40.3
TA (Mg/l)	1.63	500	0.002	0.002	0.326	0.0007
SO ₄ (Mg/l)	3.60	100	0.01	0.010	3.6	0.036
NO ₂ (Mg/l)	6.30	50	0.02	0.021	12.6	0.265
PO ₄ (Mg/l)	0.05	5	0.2	0.207	1	0.207
Cl (Mg/l)	102.73	250	0.004	0.004	41.092	0.164
TH (Mg/l)	120.63	150	0.007	0.007	80.42	0.563
			Σ = 0.966	Σ = 1		Σ = -5.918

MGT = Main Gate Tank

Table 4: Water Quality Index (WQI) for FHT sample

Parameters	Observed value (Vi)	Standard value (Si)	1/Si	Weight (Wi)	Sub-index (Qi)	WiQi
pH	6.8	8.5	0.118	0.122	-13.33	-1.626
EC (µS/cm)	280	1000	0.001	0.001	28	0.028
TDS (Mg/l)	10.89	500	0.002	0.002	2.178	0.004
Turb. (NTU)	0.51	5	0.2	0.207	10.2	2.111
TSS (Mg/l)	1.56	500	0.002	0.002	0.312	0.0006
DO (Mg/l)	55.52	5	0.2	0.207	-426.25	-88.233
BOD (Mg/l)	38.98	10	0.1	0.104	389.8	40.539
COD (Mg/l)	38.78	10	0.1	0.104	387.8	40.331
TA (Mg/l)	2.11	500	0.002	0.002	0.422	0.0008
SO ₄ (Mg/l)	4.82	100	0.01	0.010	4.82	0.048
NO ₂ (Mg/l)	6.89	50	0.02	0.021	13.78	0.289
PO ₄ (Mg/l)	0.08	5	0.2	0.207	1.6	0.331
Cl (Mg/l)	110.82	250	0.004	0.004	44.328	0.177
TH (Mg/l)	122.72	150	0.007	0.007	81.813	0.573
			Σ = 0.966	Σ = 1		Σ = -5.427

FHT = Female Hostel Tank

Table 5: Water Quality Index (WQI) for MHT sample

Parameters	Observed value (Vi)	Standard value (Si)	1/Si	Weight (Wi)	Sub-index (Qi)	WiQi
pH	6.8	8.5	0.118	0.122	-13.33	-1.626
EC ($\mu\text{S/cm}$)	289	1000	0.001	0.001	28.9	0.029
TDS (Mg/l)	9.78	500	0.002	0.002	1.956	0.004
Turb. (NTU)	0.48	5	0.2	0.207	9.6	1.987
TSS (Mg/l)	1.38	500	0.002	0.002	0.276	0.0006
DO (Mg/l)	54.97	5	0.2	0.207	-420.521	-87.048
BOD (Mg/l)	38.82	10	0.1	0.104	388.2	40.373
COD (Mg/l)	38.82	10	0.1	0.104	388.2	40.373
TA (Mg/l)	1.98	500	0.002	0.002	0.396	0.0008
SO ₄ (Mg/l)	3.88	100	0.01	0.010	3.88	0.039
NO ₂ (Mg/l)	6.75	50	0.02	0.021	13.5	0.284
PO ₄ (Mg/l)	0.06	5	0.2	0.207	1.2	0.248
Cl (Mg/l)	110.60	250	0.004	0.004	44.24	0.177
TH (Mg/l)	120.89	150	0.007	0.007	80.593	0.564
			$\Sigma = 0.966$	$\Sigma = 1$		$\Sigma = -4.595$

MHT = Male Hostel Tank

Table 6: Water Quality Index (WQI) for FST sample

Parameters	Observed value (Vi)	Standard value (Si)	1/Si	Weight (Wi)	Sub-index (Qi)	WiQi
pH	6.9	8.5	0.118	0.122	-6.667	-0.813
EC ($\mu\text{S/cm}$)	250	1000	0.001	0.001	25	0.025
TDS (Mg/l)	9.65	500	0.002	0.002	1.93	0.004
Turb. (NTU)	0.38	5	0.2	0.207	7.6	1.573
TSS (Mg/l)	1.10	500	0.002	0.002	0.22	0.0004
DO (Mg/l)	55.85	5	0.2	0.207	-429.688	-88.945
BOD (Mg/l)	38.95	10	0.1	0.104	389.5	40.508
COD (Mg/l)	38.95	10	0.1	0.104	389.5	40.508
TA (Mg/l)	2.51	500	0.002	0.002	0.502	0.001
SO ₄ (Mg/l)	3.93	100	0.01	0.010	3.93	0.039
NO ₂ (Mg/l)	6.78	50	0.02	0.021	13.56	0.285
PO ₄ (Mg/l)	0.06	5	0.2	0.207	1.2	0.248
Cl (Mg/l)	109.83	250	0.004	0.004	43.932	0.176
TH (Mg/l)	120.85	150	0.007	0.007	80.567	0.564
			$\Sigma = 0.966$	$\Sigma = 1$		$\Sigma = -5.827$

FST = Faculty of Science Tank

The calculated water quality index (WQI) based on physiochemical parameters for MGT is -5.918, FHT is -5.427, MHT is -4.595 and FST is -5.827 (Table 3,4,5 and 6) indicating the water quality is fit for drinking since these values were found below critical value of 100. This may not be surprising as observed during the sample exercise most of the trucks transporting and distributing the water into plastic tanks were in good hygienic condition, therefore the stored water in plastic tanks is safe for human consumptions and other purposes. No further treatment is required before use. It can be observed that biological oxygen demand and chemical oxygen demand are the only parameters that is very far exceeded the threshold limit in all samples (Table 3,4,5 and 6). The product of quality rating (Qi) and weight associated with water quality (Wi) for BOD and COD is much higher than the rest. This could be due to the

availability of organic and inorganic matters in the stored water.

CONCLUSION

On the basis of findings, it was concluded that all studied parameters were found within the recommended limit for drinking water set by the national and international standards except DO, BOD and COD which were found above the permissible limit set by NSDWQ, 2007 and WHO, 2017 guidelines for drinking water. Additionally, the quality of water is excellent as revealed by WQI assessment. The stored water in plastic tanks is fit for drinking and other uses. It is recommended that continuous monitoring of the water should be maintain as well as research to investigate the bacteriological contaminants.

REFERENCES

- Abbas, Z., Su, C., Tahira, F., Mapoma, H.W.T. and Aziz, S.Z. (2015) Quality and hydrochemistry of groundwater used for drinking in Lahore, Pakistan: analysis of source and distributed groundwater. *Environmental Earth Sciences*, 74 (5), 4281–4294.
- Abdullahi, U.A. and Indabawa, I.I (2012) Study on physicochemical and heavy metals (Pb, Fe, Mn) concentrations of tap water in Dutse, Jigawa state, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 5(2):89 – 92.
- Anadu, E.C. and Harding, A.K. (2000) Risk perception and bottled water use. *Journal of American Water Works Association*, 92 (11), 82–92.
- APHA, (2012). *Standard Methods for the Examination of Water and Wastewater*, twenty second ed. American Public Health Association, Washington, DC.
- Bouslah, S., Djemili, L. and Houichi, L. (2017) Water Quality Index Assessment of Koudiat Medouar Reservoir, Northeast Algeria Using Weighted Arithmetic Index Method. *Journal of Water and Land Development*, 35, 221-228
- Chia, A.M., Oniye, S.J. and Swanta, A.A. (2013) Domestic water quality assessment: microalgal and cyanobacterial contamination of stored water in plastic tanks in Zaria, Nigeria. *European Journal of Scientific Research*, 110 (4): 501 - 510
- Edwin, N., Ibiam, U.A., Igwenyi, I.O., Ude, V.C. and Eko, S.N. (2015) Evaluation of Physicochemical properties, mineral and heavy metal content of drinking water samples in two communities in South-East, Nigeria: A public health implication. *Journal of Environment and Earth Science*, 5(9): 89-95.
- Ezekwe, I.C., Odu, N.N., Chima, G.N. and Opigo, A. (2012) Assessing regional groundwater quality and its health implications in the Lokpaukwu, Lekwesi and Ishiagu mining areas of southeastern Nigeria using factor analysis. *Environmental Earth Science*, 67:971–986
- Gopolang, O.P. and Letshwenyo, M.W. (2019) Water Quality Index of Waste Stabilisation Ponds and Downstream of Discharge Point. *Journal of Environmental Protection*, 10, 993-1005.
- Hassan, A.S., Abubakar, I.B., Musa, A. and Limanchi, M.J. (2017) Water quality investigation by physicochemical parameters of drinking water of selected areas of Kureken Sani, Kumbotso local government area of Kano. *International Journal of Mineral Processing and Extractive Metallurgy*. 2, (5), 83-86. doi: 10.11648/j.ijmpem.20170205.14
- Muhammad, S., Shah, M.T. and Khan, S. (2010). Arsenic health risk assessment in drinking water and source apportionment using multivariate statistical techniques in Kohistan region, northern Pakistan. *Food Chemical Toxicology*, 48:2855–2864.
- Muhammad, S., Shah, M.T. and Khan, S. (2011). Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan. *Micro Chemical Journal* 98:334–43.
- Musa, J. J., Adejumo, B. A and Fumen, G. A. (2013), Comparative analysis of water samples from three different sources (A case Study of Bosso, Minna Niger State). *Journal of Environmental Science, Toxicology and Food Technology*, 4 (5): 6-10.
- NSDQW. Nigerian Standard for Drinking Water Quality. Nigerian Industrial Standard NIS 554, Standard Organization of Nigeria, 2007, pp: 30.
- Reda, A.H. (2016) Physico-Chemical Analysis of Drinking Water Quality of Arbaminch Town. *Journal of Environmental & Analytical Toxicology*, 6, 356. doi:10.4172/21610525.1000356
- Ruma, M.M., Ali Badr, A.M., Khater, S.A. and El-tantawi, A.M.M. (2014). Assessment of some physicochemical parameters levels in sachet drinking water and its effects on human health in Katsina urban Area, Nigeria. *Science World Journal*, 9(1): 19-27.
- Shigut, D.A., Liknew, G., Irge, D.D. and Ahmed, T. (2017) Assessment of physico-chemical quality of borehole and spring water sources supplied to Robe Town, Oromia region, Ethiopia. *Applied Water Science*, 7:155–164.
- Shuaibu, L., Ahmed, B.D. and Ibrahim, A.Y. (2015) Determination of physico-chemical parameters, Zinc and Iron levels in domestic waters of Katsina metropolis, Nigeria. *International Research Journal of Pure & Applied Chemistry*, 5(3): 263-272.
- Sreenivasulu, K., Hossain, K. and Daoodharam, T. (2014). Physico-chemical characteristics of freshwater of Ramanna Tank (Cheruvu), Nellore district, India. *Advances in Applied Science Research*, 5(2): 59-65.
- Steenland, K. and Boffetta, P. (2000). Lead and cancer in humans: where are we now? *American Journal of Industrial Medicine*, 38: 295–299.
- Tziritis, E., Tzamos, E., Vogiatzis, P., Matzari, C., Kantiranis, N., Filippidis, A., Theodosiou, N. and Fytianos, K. (2016) Quality assessment and hydrogeochemical status of potable water resources in a suburban area of northern Greece (Thermi Municipality, central Macedonia). *Desalin Water Treatment*, 57: 11462–11471.

- United Nations (2006). *Human Development Report 2006*. United Nations Development Programme, New York.
- United Nations Development Programme (2006) Human Development Report 2006: Beyond Scarcity: Power, poverty and the global water crisis. 2006. Available at <http://hdr.undp.org/sites/default/files/reports/267/hdr06-complete.pdf>. Accessed 16 July 2016
- W.H.O. (2017). *Guidelines for drinking-water quality*. In: Incorporating 1st Addendum, fourth ed. World Health Organization, Geneva.
- Yerima, K. M., Hamidu, H., Mohammed, A.I., Abdulmumini, Y.N., Adamu, I.H., Grema, H.M., Dauda, M., Halilu, F.B. and Kana, A.M. (2019). Heavy Metals Pollution Indices and Multivariate Statistical Evaluation of Groundwater Quality of Maru town and environs. *Journal of Material and Environmental Sciences*, 10 (1), 32-44
- Yusuf, N. (2005): Water quality analysis of pipe borne water supply to Kano metropolis. Unpublished M.Sc. Geography Dissertation. BUK.