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Assessing the state of drinking water from storage tanks in Federal University Dutse Nigeria

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Abstract

The study assessed the quality of water obtainable in six (6) storage tanks present in the male and female hostels on the Federal University Dutse campus. Physicochemical analyses; temperature, pH, turbidity, electrical conductivity, nitrate, and phosphate were conducted using standard methods. Presumptive, confirmed, and completed tests were employed to determine total and fecal coliforms from the water samples using the most probable number (MPN) technique. Generated results from the parameters were compared with the allowable standards of the Nigerian Standard for Drinking Water Quality (NSDWQ) and the World Health Organisation (WHO). Results obtained on the physicochemical status of the water indicate that all measured parameters conformed to NSDWQ and WHO permissible standards. The results obtained in this study also show the presence of bacteria in the water present in the storage tanks which may constitute a health risk amongst students drinking it. It is therefore recommended that the water pumped and stored in these storage tanks should be adequately treated.

Keywords: Coliforms; Fecal; storage tanks; quality; water.

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1. Introduction

Water resources are gradually becoming polluted and unavailable due to human or industrial activities and hence the need to store in tanks. Most significantly, water stored in storage tanks is prone to harbor pollutants as constant washing of such tanks is hardly done. Drinking water that has been contaminated microbiologically can spread diseases like typhoid, diarrhea, dysentery, polio, and cholera with such water attributing to 485,000 diarrhea-related deaths yearly {World Health Organization (WHO, 2022)}. This author further reported that close to 2 billion people have been linked with using water contaminated with feces as a source of drinking water the world over.

Globally, the quality of drinking water has always been a major health concern whereby 2.2 billion do not have access, 4.2 billion people lack access to accomplished sanitation and 3 billion people do not have access to handwashing amenities (WHO, 2019). The author reiterated further that the inaccessibility of a large segment of the population in the rural communities to potable water, hygiene, and sanitation is a worrisome situation in most developing countries. One of the goals set by the United Nations as regards sustainable development is to safeguard people throughout the world by making sure that there is the provision of potable water and sanitation by 2030 (Centers for Disease Control and Infection, 2021).

Water quality assessment is essential because it identifies possible water pollutants and aids the adoption of measures that can be employed in preventing water-borne diseases (Spectrum Laboratories Group, 2021). This author reported further that constant water quality assessment ensures its safety to meet locally and internationally acceptable standards. Though storage of water in tanks is a norm throughout the world, however, the widespread availability of water storage tanks in Nigeria is a way of making up for the failure of a constant supply of government-owned pipe-borne water (Nnaji *et al*., 2019).

Water quality assessment can be said to be an important part of environmental monitoring since its consumption is grossly inevitable. Bacteriological quality assessment is normally employed to appraise the number of bacteria present and, if needed, to find out what sort of bacteria and their respective effects (Hanaor and Sorrell, 2014). Physical properties of water include temperature and turbidity while chemical characteristics involve parameters such as pH and dissolved oxygen, as well as the biological pointers used for water quality, which consist of phytoplankton and algae (Fondriest Environmental, 2022).

According to Aquatechtanks (2021), water storage tanks are vessels that are employed for water storage coupled with serving numerous uses which can be commercially and domestically driven. This author further reported that from ancient days to the present time, numerous modifications have been made to the ingredients employed in the production of water storage tanks but the advent of polyvinyl chloride (PVC) tanks has been the icing on the cake.

1.1. Purpose of study

Presently, there is no information specifying the safety standing of the water derived from the storage tanks in the students' hostels on the campus of Federal University Dutse, therefore, prompting the conduct of this study aimed at examining the physicochemical and bacteriological status of the water to establish its potability for human consumption.

2. Materials and Methods

2.1. Study Area

Federal University Dutse is situated in Dutse which is a city located in northern Nigeria. It has a latitudinal and longitudinal location of 11.7333N and 9.2875E respectively. It is the capital of Jigawa state. Federal University Dutse was established in November 2011.

2.2. Water Sampling

Sampling was done using a simple judgmental technique. Water was aseptically sampled from the six (6) sampling points (storage tanks) present in the study area; three (3) samples from the three (3) water storage tanks in the female hostels and three (3) samples from the three (3) water storage tanks in the male hostels in mid-June 2021. Each water sample was separately collected in a sterile two (2) Liter plastic container and before water sampling, all the containers were thoroughly washed with non-ionic detergent and subsequently rinsed with de-ionized water before being used (Amoo *et al.*, 2018; USFDA, 2018; Adeleye *et al*., 2020; Bisiriyu *et al.*, 2020; Amoo *et al.*, 2021). The sampling containers were rinsed three (3) times with distilled water at the point of collection before sampling. Each sampling container was well labeled according to the respective sampling location. Having sampled the water, it was preserved following the procedure reported by Adeleye *et al*. (2020) at 4 °C and immediately transported to the laboratory for onward physicochemical and bacteriological analyses.

2.3. Physicochemical Analyses of Water Samples

Water sampled from the storage tanks was subjected to physicochemical analyses using the procedures reported by American Water Works Association (AWWA, 2017; Okareh *et al.* 2018). pH was measured with pocket pro pH tester (HACH, United States of America), the temperature was measured using Thomas high-accuracy thermometer, total hardness was determined through digital water hardness meter PGM-1080G, electrical conductivity (EC) was estimated using HQ430D laboratory single input multi-parameter meter, sulfate was determined using turbidimetric method while nitrite was measured using EZ7750 nitrite analyzer. All the parameters were analyzed following the procedures described by APHA (2012).

2.4. Bacteriological Analyses of Water Samples

2.4.1. Presumptive Test

Total coliform and fecal coliform were derived by adopting the procedure outlined by WHO (2012). This was done by employing a three (3) tube assay of the Most Probable Number (MPN) technique and sterilized MacConkey broth. Fifty (50) mL of water was aseptically dispensed into a sterilized test tube containing 50 mL of double-strength MacConkey broth, 10 mL of water was dispensed into five (5) sterilized test tubes containing 10 mL single-strength MacConkey broth, and 1 mL of water was dispensed into five (5) test tubes containing 5 mL single strength MacConkey broth. All the test tubes employed contained Durham tubes that had been sterilized. The tubes were subsequently incubated at 37 ˚C for 24 hours to estimate total coliforms and at 44 ˚C for fecal coliforms for 48 hours. The incubated test tubes were examined for acid and gas production after the periods of incubation. A change in the color of the broth from reddish-purple to yellow was recorded as acid production while the presence of bubbles and gas entrapment in the Durham tubes was recorded as gas production. The MPN was subsequently determined using the appropriate MPN table presented by Olutiola *et al.* (2000).

2.4.2. Confirmed Test

This test was done following the procedure reported by WHO (2012). This was done by aseptically transferring a loopful of culture from positive test tubes in the presumptive test into Petri dishes containing sterilized Violent Red Bile Agar (VRBA) and test tubes containing sterilized peptone water. The Petri dishes and test tubes were then incubated at 37 °C for 24 hours for total coliforms and 44 °C for 48 hours for fecal coliforms. After respective incubation periods, production of gas and indole in the peptone water was recorded as positive results for *E. coli* presence while the growth of pink colonies with characteristic metallic sheen colonies, and bleaching at the center of the VRBA confirmed the presence of coliforms.

2.4.3. Completed Test

This test was done as reported by WHO (2012). This was done by streaking positive results from the confirmed test on sterilized Eosin Methylene Blue (EMB) agar plates to obtain discrete colonies. The agar plates were successively incubated at 37 °C for 24 hours. The development of green metallic sheen colonies on EMB agar plates was documented as a completed test for further identification of total or fecal coliforms as reported by Adetunde and Glover (2010).

2.4.4. Gram Staining of Bacterial Isolates

This was done following the procedure outlined by Olutiola *et al.* (2000). A smear of the bacterial cell sample to be stained was made. The sample was heat-fixed by putting a drop of sterile water over it and mixing it properly. The slide was then passed through a Bunsen burner three times. The primary stain (crystal violet) was added to the slide and allowed to stay for 1 minute. The slide was rinsed with a gentle stream of water for a maximum of 5 seconds to remove unbound crystal violet. Gram's iodine was added for 1 minute to fix the crystal violet to the bacterial cell wall. The slide was then rinsed with acetone for 3 seconds and was rinsed with a gentle stream of water. The acetone was allowed to remain on the sample for too long as this may also decolorize positive cells. The secondary stain, safranin was then added to the slide and allowed to stay for 1 minute. The slide was finally washed with gentle steam for a maximum of 5 seconds. It was subsequently viewed under an oil immersion microscope (x100).

2.4.5. Biochemical Characterization Tests for the Identification of Coliforms

Biochemical characterization tests ranging from indole, catalase, methyl red, Voges proskauer, citrate, and triple sugar ion were further conducted according to the procedure reported by Cheesebrough (2006); Ochei and Kolhatkar (2008); Hemraj *et al.* (2013); Aryal (2018) to confirm the identity of the bacterial isolates.

2.5. Data Analyses

Most probable number (MPN) analysis reported by Aryal (2018) as a statistical method centered on the arbitrary distribution of microorganisms per volume in any given water sample was used in the analysis of the data recorded from the presumptive test conducted in this study. Data generated on the bacteriological and physicochemical analyses were successively summarized in tables and compared with the allowable standards of the Nigerian Standard for Drinking Water Quality (NSDWQ) and the World Health Organisation (WHO).

3. Results

Sampling points designated as FHA, FHB, FHC, MHA, MHB, and MHC are shown in Table 1.

Table 1

Acronyms ascribed to the sampling points

Sampling point	Acronym
Female Hostel Sample A	FHA
Female Hostel Sample B	FHB
Female Hostel Sample C	FHC
Male Hostel Sample A	MHA
Male Hostel Sample B	MHB
Male Hostel Sample C	MHC

Results obtained from the physicochemical analyses of the sampled water depicted in Table 2 show that the temperature of the water sampled from FHA, FHB, FHC, MHA, MHB, and MHC ranged between 30 ˚C and 34 ˚C.

Table 2

Physiochemical parameters recorded from the sampling points

Parameters	FHA	FHB	FHC	MHA	MHB	MHC
pH	7.2	7.7	7.4	7.8	7.3	7.6
T (˚C)	32	33	31	34	30	32
TH (mg/L)	46.8	67.8	64.5	102.4	84.2	96.8
EC (µS/cm)	402	456	426	585	507	499
Sulphate (mg/L)	28	37	24	40	39	27
Nitrite (mg/L)	0.02	0.01	0.01	0.06	0.03	0.02

Note: T= Temperature; TH= Total hardness; EC= Electrical conductivity

The recorded temperature range (30-34 ˚C) of the water sampled from the storage tanks depicted in Table 2 can be said to be ambient as recommended by NSDWQ (Table 3). EC ranged from 402 to 456 µS/cm in the water sampled from FH while it ranged between 499 and 585 µS/cm in the water sampled from MH (Table 2).

Table 3

Comparison of mean values of physicochemical properties recorded in the sampled water with acceptable standards

Parameters	Mean FH	SD MH	Mean MH	SD MH	NSDWQ	WHO
pH	7.4	0.25	7.6	0.25	≥ 6.5 to ≤ 8.5	≥7 to ≤9.2
T (˚C)	32	1.0	32	2.0	Ambient	NSS
TH (mg/L)	59.7	11.29	94.47	9.32	150	150 to 500
EC (µS/cm)	428	27.06	530.3	47.51	1000	1000
Sulphate (mg/L)	29.67	6.66	35.33	7.23	100	500
Nitrite (mg/L)	0.01	0.01	0.04	0.02	0.2	50

Note: SD= Standard deviation; FH= Female hostel; MH= Male hostel; T= Temperature; TH= Total hardness; EC= Electrical conductivity; NS= No standard set; NSDWQ= Nigerian Standard for Drinking Water Quality; WHO= World Health Organization

Results derived from the water assay for determining the presence of coliforms in the water samples are depicted in Table 4. It can be observed that all the samples (FHA, FHB, FHC, MHA, MHB, and MHC) across all the dilution strengths employed for water assay recorded substantial growth of total and fecal coliforms at 37 ˚C for 24 hours and 44 ˚C for 48 hours respectively. These results have clearly suggested that all the assayed water samples harbored total and fecal coliforms during the conduct of this study.

Table 4

Water assay results for all the sampling points

Sample	Growth			Acid Production			Gas Production		
	50 mL	10 mL	1 mL	50 mL	10 mL	1 mL	50 mL	10 mL	1 mL
FMA	Yes	Yes	Yes	+	+	+	+	+	-
FMB	Yes	Yes	Yes	+	+	+	+	+	+
FMC	Yes	Yes	Yes	+	+	+	+	+	+
MHA	Yes	Yes	Yes	+	+	+	+	+	+
MHB	Yes	Yes	Yes	+	+	+	+	+	-
MHC	Yes	Yes	Yes	+	+	+	+	+	+

Key: + = Positive; - = Negative

With respect to acid production by the total and fecal coliforms that grew in the water samples, all recorded positive results across the dilution strengths employed (Table 4).

The quantification of the coliform bacteria presents in the water samples assayed in this study through the employment of the most probable number (MPN) table is depicted in Table 5. It can be seen that the MPN values ranged from 4-12 mL across the six sampling points (Table 5). Samples

from GHC (4 mL) and GHA, GHB, and BHB (12 mL) recorded the lowest and highest MPN/100 mL respectively.

Table 5: MPN values for the water samples collected from the sampling points

Sample	Ratio	MPN Values (MPN/100 mL)
FHA	1:2:3	12
FHB	1:2:3	12
FHC	1:0:2	4
MHA	1:1:3	9
MHB	1:2:3	12
MHC	1:1:2	7

K**ey:** MPN = most probable number. The MPN table presented by Olutiola *et al.* (2000) was adopted to generate the MPN values depicted above.

Identification of the possible bacteria detected in the water samples was done and the results are depicted in Table 6. It can be observed that all the bacterial isolated appeared Gram-negative in rod shape with pink color under the microscope (Table 6).

Table 6: Morphology and biochemical identification of the bacterial isolates

Isolates	FHA	FHB	FHC	MHA	MHB	MHC
Gram's Reaction	-	-	-	-	-	-
Shape	RSPC	RSPC	RSPC	RSPC	RSPC	RSPC
Indole	+	+	+	+	+	+
Catalase	+	+	+	+	+	+
Methyl red	+	+	+	+	+	+
Voges-Proskauer	-	-	-	-	-	-
Citrate	-	-	-	-	-	-
Triple sugar ion	-	-	-	-	-	-
Identity	*E. coli*	*E. coli*	*E. coli*	*E. coli*	*E. coli*	*E. coli*

Key: + = positive; - = negative; RSPC= Rod shape with pink colour

4. Discussion

Similar temperature ranges as seen in Table 3 have been previously reported by Bamigboye and Amina (2018); Adeleye *et al.* (2020); Amoo *et al*. (2021) in their respective examination of drinking water quality. The mean values of total hardness, pH, EC, nitrate, and sulfate fell below the allowable standards set by NSDWQ (Table 3). Analogous findings had been submitted by Amoo *et al.* (2018) who assayed similar physicochemical parameters of borehole water in the same study area. These findings are in agreement with the report of Adeleye *et al.* (2020) regarding the physicochemical attributes of borehole water assayed in Sabon Gari quarters, Ringim, Northwest Nigeria.

The results seen in Table 4 indicate the presence of total and fecal coliforms in all the water samples as indicator organisms have been implicated by Ochei and Kolhatkar (2008) as having the ability to produce acid when incubated at the afore-indicated temperature ranges employed in this study. Again, the detection of gas in all the Durham tubes employed in this study indicates the presence of total and fecal coliforms in all the water samples assayed. These results are in agreement with the submission of Willey *et a*l. (2009) about the ability of total and fecal coliforms to produce gas if their presence is detectable in any water sample. These results are similar to the submissions of Adetunde and Glover (2010); Onuorah *et al*. (2019) that reported a breach in the sanitary reliability of the boreholes assayed in their respective study areas owing to the detection of total coliforms and fecal coliforms in substantial numbers. Again, the detection of total coliform in the water samples assayed in this study conforms to the submissions of Mustafa *et al*. (2013); Ngele *et al.* (2014) about the

presence of total coliform in the boreholes they assayed in their respective study areas. The variations observed as depicted in Table 5 regarding the total and fecal coliforms present in the study area may be a result of different sources and the proximity of pollutants responsible for each sampling point. Similar detection of total coliform and fecal coliform in the water meant for human consumption has been reported by Haile *et al.* (2014); Milner *et al.* (2016); Eboh *et al.* (2017); Bisiriyu *et al.* (2020); Adeleye *et al.* (2020); Amoo *et al.* (2021); Sitotaw *et al.* (2021); Adeleye *et al*. (2022) in similar studies conducted in their respective study areas.

However, the results of the biochemical characterization tests conducted on all the bacterial isolates confirmed they're being positive for catalase, indole, and MR tests while they were negative for VP, citrate, and TSI (Table 6). These results have confirmed the presence of *E. coli* in all the sampling points assayed in this study. As recorded in this current study, detection of *E. coli* in the water meant for human consumption has been equally reported by Okareh *et al.* (2018); Adeleye *et al.* (2020); Amoo *et al.* (2021); Sitotaw *et al.* (2021); Raji *et al.* (2021); Falnyi *et al.* (2022); Adeleye *et al*. (2022). *E coli* is one of the pathogens linked with the storage of water in tanks (Slavik *et al*., 2020). According to Chalchisa *et al.* (2018), the presence of coliforms in water obtainable from storage tanks can be largely attributed to the leakage of the tanks' valve seals which was evident during the conduct of this study.

5. Conclusion

The results obtained in this study have revealed that the water in the storage tanks present in the students' (female and male) hostels in Federal University Dutse recorded the presence of *E. coli* that was found to be beyond the permissible limit set by NSDWQ and WHO as it all recorded the presence of total and fecal coliforms. This strongly implies that the water obtainable from all the storage tanks during sampling was not fit for human consumption. Consequently, water stored in storage tanks may not always be of primeval quality as it ought to be.

Owing to the results obtained in this study, it is recommended that the water stored in the storage tanks must be treated before final consumption. The water storage tanks should be sealed tightly to avert animals' or birds' feces gaining entry therein. The water storage tanks should equally be cleaned regularly to avert possible physical and microbial contamination. Installation of membrane filters in the water outlet of the tanks should be ensured to effectively filter water meant for human consumption. The storage tanks should be inspected promptly for the presence of accumulated sediments and onward removal. Again, routine monitoring and assessment of the source of water being pumped into the tanks are highly recommended. The need to increase the frequency of sampling and quality assessment of the water in the tanks is also desirable with a view to effectively monitoring its potability. Finally, early detection of possible groundwater pollution can enhance faster employment of remedial measures to avert public health crises.

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