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Assessment of Physicochemical, Hygiene Performance and Bacteriological Quality of Stored Water in Selected Hostels in Malete, Kwara State, Nigeria

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ABSTRACT

Water quality assessment is crucial in ensuring the safety and health of individuals, especially in residential areas like student hostels. This study assessed the physicochemical parameters, hygiene performance, and bacteriological quality of stored water in hostels in Malete, Nigeria. Twenty different water samples were collected and analyzed for key physicochemical properties and hygiene practices related to water storage and handling. Membrane filtration technique was employed for the bacteriological estimation and identification of the isolates were carried out using standard methods. Hygiene performance indices ranged from 40 - 80 % of the stored water samples. The findings revealed varying levels of physicochemical properties; Temperature oscillated from (26.0 - 28.4 °C), TDS (48.0 – 690.0 mg/L), pH (5.44 -7.61), EC in µS/cm (96.0 – 689.0), salinity (0.0 -0.01%) and resistivity (1.170 – 4.910 MΩ/cm). Total Bacterial Count ranged from 80.0 ±0.5.77 - 200±20.0 CFU/100ml, Total Coliform Count (0.0 - 100±10.00 CFU/100ml), Total Faecal Coliform Count (0.0 – 10.0±0.0 CFU/100ml), Total Salmonella- Shigella (0.0 - 100±26.45 CFU/100ml) and Total Pseudomonad Count (0.0 - 100±20.00 CFU/100ml). Poor hygiene practices, such as inadequate container cleaning and direct hand contact, contributed to bacterial contamination. The presence of coliforms in almost all the samples indicated potential health risks. This study highlights the need for improved water management practices and regular monitoring to ensure safe drinking water for hostel residents in Malete, Kwara State. Implementing proper hygiene education and water treatment methods is recommended.

Keywords: Water Quality, Student Hostels, Proper Hygiene, Bacteriological Estimation, Malete.

INTRODUCTION

Access to clean and safe drinking water is a fundamental human right and a crucial element for maintaining public health. However, in many developing regions, including Nigeria, ensuring the availability of safe drinking water remains a significant challenge (Okafor *et al.,* 2024). In particular, students residing in hostels often depend on stored water sources, which may be prone to contamination. Malete, a rapidly growing community with a burgeoning student population, exemplifies such a scenario where the quality of stored water in hostels warrants thorough investigation. Ensuring the sanitary and bacteriological safety of these water supplies is essential for preventing waterborne diseases and safeguarding the health of the residents (Aregu *et al*., 2021).

Despite the critical importance of clean water, stored water in hostels within Malete has been observed to suffer from sanitary and bacteriological deficiencies. Preliminary observations and anecdotal reports suggest the presence of contaminants, potentially leading to waterborne diseases among the student population. The lack of routine water quality assessments and inadequate sanitation

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practices exacerbate the risk of microbial contamination (Jimoh *et al.,* 2024). This situation poses a serious public health threat, as contaminated water can harbor pathogenic bacteria, leading to outbreaks of diseases such as diarrhea, cholera, and typhoid fever. Thus, a comprehensive evaluation of the sanitary and bacteriological quality of stored water in these hostels is urgently needed.

While numerous studies have examined water quality issues in various parts of Nigeria, there is a notable lack of focused research on the sanitary and bacteriological evaluation of stored water in student hostels, particularly in Malete. Previous research has primarily concentrated on urban areas and municipal water supplies (Agbabiaka and Sule, 2010; Adesakin *et al*., 2020), leaving a gap in understanding the specific challenges faced by hostel residents in semi-urban and rural settings. Conducting a sanitary and bacteriological evaluation of stored water in Malete hostels is crucial for several reasons. Firstly, it will provide empirical data on the current status of water quality, identifying potential health risks associated with its consumption. Secondly, this study will raise awareness among hostel residents and administrators about the importance of maintaining proper water storage and handling practices. Thirdly, the findings will inform local health authorities and policymakers, guiding interventions to improve water safety and public health outcomes. By addressing the water quality issues in Malete hostels, this research aims to contribute to the broader goal of enhancing environmental health standards in Nigerian educational institutions. This study aimed to assess this gap by providing a detailed analysis of the water quality in Malete hostels, through determination of physicochemical properties, hygienic and bacteriological qualities thereby informing the development of targeted strategies to ensure safe drinking water in educational institutions across Nigeria.

MATERIALS AND METHODS

Study Area

This study was conducted on twenty (20) selected stored water samples from Kwara State University hostels, Malete, Nigeria. Malete is a vibrant town in Kwara state, Nigeria, best known as the home of Kwara State University (KWASU). KWASU is a key feature that significantly shapes the town's identity and development. It is situated in the northern outskirts of the Ilorin metropolitan area, the capital of Kwara State. Malete primarily serves as both an educational and residential hub for the students. Figure 1 illustrates the study area, highlighting the various sampling sites.

Hygiene Condition Ratings of the Stored Water Sampling Sites

An on-site examination of the conditions of individual water source was conducted in order to identify any potential or actual sources of contamination that could compromise the quality of stored water following some of the criteria established by WHO (2013).The sanitary score of each water source was calculated in percentage by dividing the number of 'present' scores by the total parameters evaluated, then multiply the result by 100 (Sule *et al.,* 2020).

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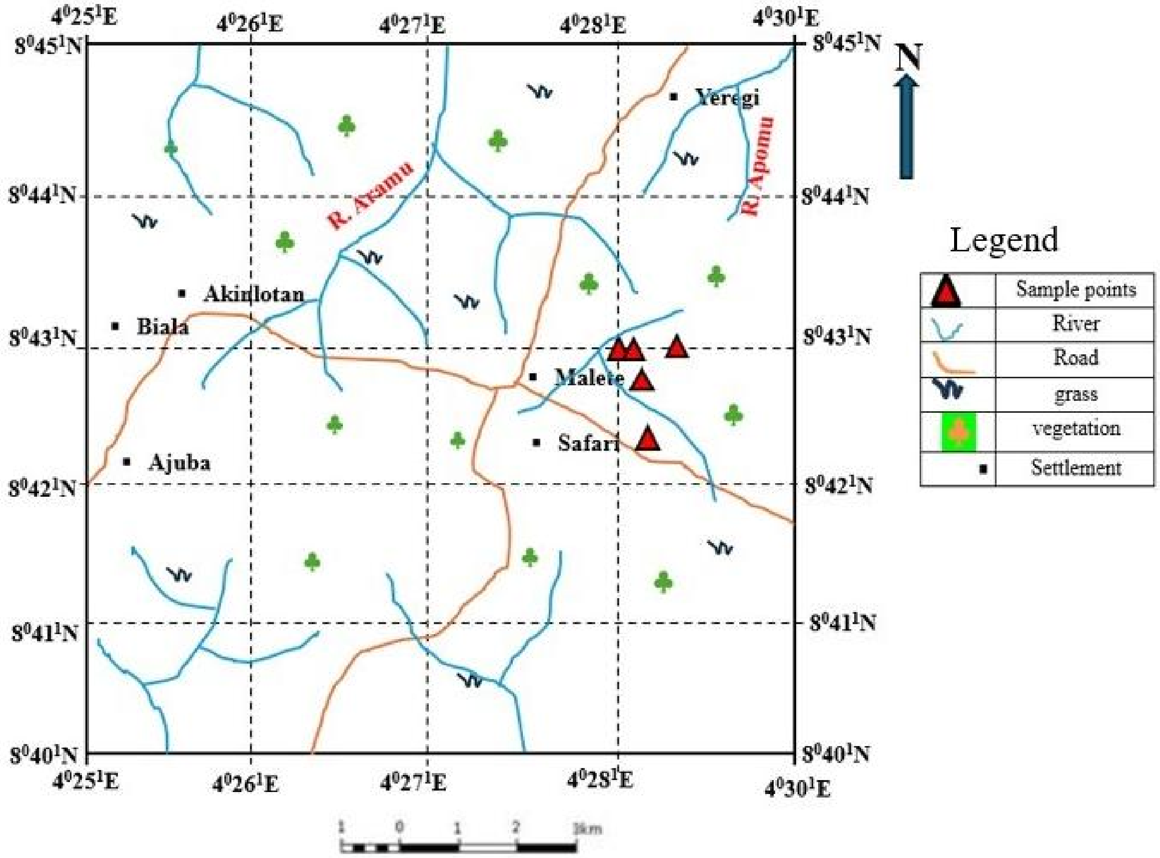

Figure 1: Geographical Location of the Sampling Sites.

Table 1: Hygiene condition percentage rating and status of water.

Hygiene Condition Ratings	Hygiene Status
0≤25	Very good
25≤50	Good
51≤75	Poor
76≤100	Very poor
>100	Not fit

Water Sample Collection

One thousand mL of stored water sample were aseptically collected in sterile containers to prevent contamination of the sample by microorganisms from external sources. Twenty (20) different water samples were collected between February and June 2023. The samples were kept in ice packs and transported immediately to the Microbiology Laboratory in Kwara State University for analyses which was done within 6 hours of collection.

Physicochemical Characteristics of Stored Water Samples

The following Physicochemical parameters such as pH, temperature, total dissolved solids (TDS), electrical conductivity (EC), salinity and resistivity were assessed using hand held multi- parameter probe for water analysis as outlined in the work of Abiy *et al.* (2024).

Bacteriological Estimation of the Water Samples

Membrane filtration technique was employed in this study to detect and estimate Total Bacterial Count, Total Coliform Count, Faecal Coliform Count, Total *Salmonella Shigella* Count in accordance with APHA 9222A,

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9222D and 9260F. A sterile millipore filter of 0.45µm pore size (47mm in diameter) was placed on the filtration unit support. One hundred mL of sampled stored water was aseptically filtered and with the aid of a sterile forceps the millipore filter was transferred to the Petri dish containing solidified media for various parameters: MacConkey agar for Total Coliform, Eosin Methylene Blue Agar for Faecal Coliform, Nutrient Agar for Total Bacterial counts and *Salmonella Shigella* Agar for *Salmonella* and *Shigella* Counts. All plates were incubated at 35±2°C for 18-24 hours. Bacterial colonies were counted and expressed in CFU/100 mL ((Liu *et al.,* 2017; Jimoh *et al.,* 2025).

Purification of Microbial Isolates

The bacterial colonies obtained were sub-cultured into already solidified nutrient agar medium and the plates were incubated at 37 degree Celsius for 18- 24 hours. The purified isolates were kept in 3 % glycerol at 0◦C for future use (Sule *et al.,* 2023).

Biochemical Characterization of the Isolated Bacteria

The morphological and biochemical characterization of the bacterial isolates was done using standard methods. Morphology of the bacterial colonies, Gram staining and biochemical tests including methyl-red, Voges-proskaeur, indole, citrate, catalase, oxidase, urease, triple salt iron (TSI) and sugar fermentation tests. Advanced bacterial identification software online, ABIS, was used for the bacterial identification (Jimoh and Kolawole, 2021).

Statistical Analyses

The results obtained were subjected to one-way analysis of variance (ANOVA) to evaluate the physicochemical and bacterial quality variance of the selected hostel water samples using SPSS package 16.

RESULTS

Hygiene Condition Ratings of Sampling Sites

Based on the assessed parameters, the level of risk and hygiene status of the stored water varied between 40% and 80%. The stored water from S7 had a better hygiene performance index than other sampling sites. Stored water from site S7 demonstrated a higher hygiene performance index compared to the other sampling sites as presented in Table 2.

Table 2: Level of risk and hygiene condition ratings of the stored water sampling sites of the school hostels.

Sites	Hygiene indicators					Hygiene performance indices (%)
	A	B	C	D	E	
S1	1	0	0	1	1	60
S2	1	0	0	1	1	60
S3	1	0	0	1	1	60
S4	1	0	0	1	1	60
S5	1	0	0	1	1	60
S6	1	0	0	1	1	60
S7	1	0	0	0	1	40
S8	1	0	0	1	1	60
S9	1	0	0	1	1	60
S10	1	0	0	1	1	60
S11	1	1	0	0	1	60
S12	1	0	0	1	1	60

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S13	1	0	0	1	1	60
S14	1	0	0	1	1	60
S15	1	1	0	1	1	80
S17	1	1	0	1	1	80
S18	1	0	0	1	1	60
S19	1	1	0	1	1	80
S20	1	1	0	1	1	80

Key: A: Stagnation of water near the sampling sites; B: Dumpsite near the sampling sites; C: Sampling sites close to a septic tank; D. Sampling sites close to an unclear bush;

E: Poor waste management practices around the sites; S1- S20: Sampling sites; Present = 1;

Absent = 0

Physicochemical Qualities of Stored Water

Most of the physicochemical parameters of the analyzed stored water were within WHO and EPA standards. All samples fell within the WHO/EPA acceptable temperature range (25–30°C), ranging from 26.0°C (S12) to 28.4°C (S17 and S18). Most samples had TDS values well below the WHO/EPA limit of 500 mg/L except in sites S11, S12 and S15 with high TDS values. The pH values ranged from 5.44 (S18) to 7.61 (S20) while low pH in S18 (5.44) indicates acidity of the water. All samples had EC values well below the 1000 µS/cm limit of 1000 µS/cm. Salinity values were generally low (0.00% to 0.03%) while resistivity ranged from 1.170 MΩ·cm (S19) to 4.910 MΩ·cm (S15) (Table 3).

Table 3: Physicochemical qualities of stored water samples from selected hostels in Malete.

Source	Temp (°C)	TDS (mg/L)	pH	EC (µS/cm)	Salinity (%)	Resistivity (MΩ/cm)
S1	27.4	145.0	7.45	293.0	0.01	2.720
S2	27.5	117.0	7.26	235.0	0.01	3.293
S3	27.6	161.0	7.03	321.0	0.01	2.491
S4	27.5	140.0	7.45	281.0	0.01	2.820
S5	27.6	150.0	7.22	301.0	0.01	2.663
S6	27.5	203.0	7.57	400.0	0.02	2.062
S7	27.7	310.0	7.35	630.0	0.03	1.485
S8	27.3	304.0	7.21	612.0	0.03	1.535
S9	27.5	197.0	6.97	396.0	0.01	1.544
S10	27.8	210.0	7.44	414.0	0.01	1.397
S11	27.0	550.0	6.00	312.0	0.00	1.570
S12	26.0	610.0	6.66	297.0	0.00	3.285
S13	27.0	128.0	6.50	208.0	0.00	2.945
S14	27.0	106.0	6.40	228.0	0.00	1.290
S15	27.0	690.0	7.00	135.0	0.00	4.910
S16	28.0	73.0	6.15	146.0	0.00	4.820
S17	28.4	87.0	6.90	174.0	0.00	2.550
S18	28.4	48.0	5.44	96.0	0.00	3.290
S19	27.9	342.0	6.95	689.0	0.03	1.170
S20	28.0	104.0	7.61	209.0	0.01	2.310
WHO	25-30	500.0	6.5-8.5	1000	NA	NA
EPA	30	500.0	6.5-8.5	1000	NA	NA

key: TEMP: Temperature (°C); TDS: Total Dissolved solids; pH: Potential of Hydrogen; EC: Electrical conductivity; WHO: World Health Organization; EPA: Environmental Protection Agency; NA: Not Available; S1- S20: Sampling Sites

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Bacteriological Parameters of the Samples

Total Bacterial Counts (TBC) ranged from 80 to 200 CFU/100mL, Total Coliform Counts (TCC) were detected in 19 out of 20 samples ranging from 0.0 – 100 CFU/100mL (except in S12), far exceeding the EPA and WHO limits. Faecal Coliforms (TFC) were generally absent in analyzed stored water, except in S13 (10 CFU/100mL), breaching the WHO guideline that requires zero thermotolerant coliforms in any 100 mL sample. Staphylococcal Count (TSS) varied, with values between 0 and 100 CFU/mL, and was absent in samples S7 and S8, while Total Pseudomonas Count (TPC) ranged from 0 to 100 CFU/mL as observed in Table 4.

Table 4: bacteriological parameters of stored water in the school Hostels.

Source	TBC	TCC	TFC	TSS	TPC
S1	100±0.00	80±20.0	0.00±0.00	80±10.0	100±10.00
S2	100±10.00	95±20.0	0.00±0.00	100±26.45	100±00.00
S3	180±17.32	100±10.0	0.00±0.00	100±0.00	5±00.00
S4	200±20.0	100±00.0	0.00±0.00	100±10.00	90±00.00
S5	100±10.0	60±00.0	0.00±0.00	100±20.00	60±10.00
S6	80±5.77	70±10.00	0.00±0.00	90±17.32	10±0.00
S7	110±10.00	100±14.52	0.00±0.00	0.00±0.00	100±5.77
S8	150±5.77	100±17.32	0.00±0.00	0.00±0.00	100±15.27
S9	100±0.00	100±5.77	0.00±0.00	100±5.77	10±1.54
S10	120±17.32	100±10.00	0.00±0.00	100±0.00	100±15.24
S11	80±0.5.77	50±11.54	0.00±0.00	10±0.00	90±5.77
S12	90±10.00	0.00±0.00	0.00±0.00	50±11.54	10±0.00
S13	100±11.54	100±5.77	10.0±0.0	100±5.77	100±10.00
S14	110±10.00	100±11.54	0.00±0.00	80±5.77	50±0.00
S15	180±17.32	100±5.77	0.00±0.00	80±20.0	50±11.54
S16	100±0.00	100±10.00	0.00±0.00	100±0.00	100±17.32
S17	150±10.00	100±17.32	0.00±0.00	100±10.00	100±0.00
S18	160±14.30	100±14.30	0.00±0.00	20±0.00	0±0.00
S19	100±10.00	97±10.00	0.00±0.00	60±0.00	100±20.00
S20	100±11.00	100±20.00	0.00±0.00	100±30.00	80±43.90

Key:TBC: Total Bacterial Count (CFU/100 mL); TCC: Total Coliform count (CFU/100 mL); FCC: Feacal Coliform count (CFU/100 mL); TSS: Total *Salmonella Shigella* (CFU/100 mL); TPS: Total Pseudomonas Count (CFU/100 mL); CFU: Colony forming unit; WHO: World Health Organization; EPA: Environmental Protection Agency; S1-S20: Sampling sites

DISCUSSION

The findings in the present study based on hygiene performance ratings, indicate a high level of contamination risk in stored water supplies. Hence, the need for effective hygiene practices and water quality safety measures. The assessment of hygiene ratings of the studied sites revealed that contamination of source water is attributable to various environmental hygiene indicators including poor waste management practices, refuse dumpsites proximity to water sources, poor environmental hygiene, and stagnant water in surrounding areas. These parameters require immediate attention to ensure the safety and quality of the stored water supplies in the school hostels. Hygiene performance indices of the sampling sites ranged from 40 to 80 % indicating poor sanitary conditions in most of the sampling sites except the S7 (40 %) with a

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good hygiene performance index. A strong connection exists between the hygiene performance indices and faecal coliforms as well as *Salmonella-Shigella* count. Strong hygiene practices reduce microbial contamination levels. This is evident by the absence of faecal coliforms and *Salmonella - Shigella* count in a site with a good hygiene performance rating. This finding conforms the study of Abdulsalam and Sule (2020), who reported the correlation between the sanitary scores and total bacterial load of the water samples, underscoring not only the predictive power of hygiene scores for microbial risk but also the critical impact of targeted environmental health interventions on safeguarding stored water quality.

The bacterial and physicochemical qualities of the water samples from twenty selected hostels in Malete community assessed in this study were compared with the Environmental Protection Agency (EPA) and World Health Organization (WHO) standards acceptable guidelines for drinking water (Adesakin *et al.,* 2020). The pH plays an important role in the survival rate of microorganisms, and a neutral pH will support the growth of a large number of bacteria (*Madigan et al.,* 2015). The pH of the water samples analyzed ranged between 5.44 and 7.61, with the lowest obtained from S18 and the highest recorded at S20. This report is different from the finding of Abiy *et al.* (2024).The minimum and maximum values of the pH recorded in this study indicated acidity and slight alkalinity of the stored hostel water. The high pH in the range of alkalinity during storage could be due to the activities of the autochthonous flora or their decay due to death, which result in the release of inorganic substances such as ammonia (*Salle et al.,* 2015). The lowest pH recorded in the present study was below the standard range of EPA and WHO for drinking water and, this could be due to the high amount of dissolved carbon (IV) oxide forming carbonic acid in stored water. Acidic water is unsafe for drinking and is known to support the solubility of heavy metals which places the consumer of such water at a greater risk of several health problems, including organ damage and suppression of the immune system (Singh *et al.*, 2022).

The total dissolved solids of the water samples ranged between 48.0 and 690 mg/L which was above the limit set by WHO. The maximum TDS obtained at S15 is an indication of poor water quality and impairs the aesthetic values of water, thereby affecting its colour. However, water with total dissolved solids (TDS) values less than 100 mg/L is considered palatable and pleasant to drink (WHO, 2014). High dissolved solids obtained in some of the stored water samples could be due to the age of the tanks and source of the water (well and bore hole) pumped into the tanks (Nunes *et al.*, 2018). Constant stirring of the sediments of the well water especially during pumping, could also introduce particles into the storage. This report is in contrary to the report of Mengstie *et al.* (2023), who reported a lower TDS value of 67.30 mg/L in reservoir water. Electrical conductivity is an important physicochemical parameter used to determine the quality of water. It ranged between 96.0 and 689.0 (µS/cm), which is within the guidelines of the World Health Organization for drinking water. Electrical conductivity and total dissolved solids (TDS) are measures of the water's mineral content. High levels of conductivity and TDS may indicate the presence of dissolved salts, which can affect the taste and potability of water for drinking and other purposes.

Temperature is an important physicochemical parameter that can influence the proliferation of microorganisms. The temperature of the stored water samples in this study ranged between 26.0 and 28.4◦C. Maximum temperature values were obtained at sites S17 and S18. The water temperature obtained in this study were within the limit of the WHO and EPA standards and also within the temperature range of 24.9 - 28.3◦C reported by Adesakin *et al.* (2020) from domestic water. High temperature and longtime exposure to sunlight has a direct influence on the amount of dissolved solids and trace elements as well as the palatability of the water. Proper temperature control is therefore essential in ensuring the microbiological safety of stored water (Okoro *et al.,* 2023).

Across global guidelines, salinity is managed primarily for palatability rather than direct health effects. The salinity of the stored water presented ranged between 0.01 and 0.03 ppm. The lowest recorded values compromise water palatability and usability for household purposes. The values obtained in this study were higher than the permissible limits of good water quality highlighting significant concerns about the suitability of the water for domestic use. A similar report by Adepoju *et al.* (2018) examined the quality of stored water in urban areas of Nigeria, and their findings revealed that the salinity levels of stored water exceeded the recommended limits for various domestic applications, raising concerns about the acceptability and safety of these water sources.

The findings of this study make a significant contribution by providing empirical evidence of microbial contamination levels in stored water sources, particularly within student environments where water safety is crucial. The total bacterial count in this research for stored water samples revealed to be 80 and 200 CFU/ 100 mL, minimum and maximum level respectively. The lowest value was recorded at S6 and the highest value at S4. The total heterotrophic bacterial count in many of the sites in this study was generally high and exceeded the WHO and EPA standards of bacterial count for drinking water. This elevated level of total bacterial count in most of the water sources may have been as a result of stagnation around the piped distribution system, poor waste management practices, improperly maintained storage tanks and seepage of contaminants into the water sources potentially affecting the quality and safety of the water for consumption (Shah *et al.*, 2023). This study offers a practical framework for students and institutional stakeholders to understand how infrastructural factors directly influence the safety of the water supply, prompting the need for targeted interventions to reduce microbial risks and safeguard public health on campus.

The total coliform bacteria have been used over the years as the primary indicator of the pathogens' presence in drinking water. It serves as the crucial indicator of the potability of water for consumption (Meride and Ayenew, 2016). A total coliform count of 0 - 100 CFU/100 mL was obtained in this research. No coliform was detected at S16 indicates that the water from this source meets the recommended standards for potable water. High total coliform counts obtained in other sites studied strongly suggest that other harmful bacteria may exist in the water samples, as total coliforms are used as indicators of water quality and the possible presence of disease-causing microorganisms. Total coliforms greater than 0 - 10 CFU/100 mL are not acceptable in drinking water supplies. There is critical need for regular monitoring and maintenance of water storage systems to ensure water safety and public health.

Faecal coliforms were not detected in the samples from all studied sites S17 with the value of 10 CFU/100 mL, indicating 5 % prevalence of faecal contamination among the

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analyzed samples. This research finding is in line with the study of Alem (2020). The presence of *Escherichia coli* in water serves as critical indicator of recent faecal contamination or pollution because these organisms cannot survive for extended periods outside the intestinal tract of warm-blooded animals, including human, which is their natural habitat. Their presence in water suggests that the water has been contaminated with faecal matter, which can contain harmful pathogens (Koju *et al.,* 2015). It has been recommended by the standard guidelines that both treated and untreated water should have no *E. coli* (faecal coliforms) in it. The spread of diseases through the contamination of water sources, particularly in developing country like Nigeria is a common phenomenon (Odonkor and Addo, 2013).

Salmonella - *Shigella* count (TSS) obtained in the present study ranged from 0 to 100 CFU/100 mL with the minimum value of zero and the maximum level of 100 CFU/100 mL. Salmonella and Shigella were not detected at S7, suggesting that proper maintenance and hygiene practices can effectively mitigate contamination risks. Although, *Salmonella* species and *Shigella* species are intestinal pathogens which are not common in potable water except when contaminated. They can be introduced into the drinking water systems via environmental factors such as storm water runoff, poor handling, sewage overflow or animal waste contamination resulting in waterborne diseases (Politi *et al.,* 2024).

The *Pseudomonas* count (TPC) oscillated between 0.0 and 100.0 CFU/100 mL during this study. As reported in the scientific literature, *Pseudomonas aureginosa* is ubiquitous and can be found in the soil and aquatic environments. A meta-analysis by Crone *et al*. (2020) showed that its prevalence increases in contaminated soil and water, suggesting a potential indicator of environmental pollution. European Union guidelines (98/83/EC) governing water quality for human consumption required that potable water should be Pseudomonas aureginosa free. Their presence is unacceptable in drinking water (Wei *et al.,* 2020). The presence of this bacterium in drinking water systems can be introduced through environmental factors such as stormwater runoff, inadequate handling, sewage overflow, or contamination from animal waste, leading to waterborne diseases

Bacterial species obtained during this study belong to nine different genera including; *Pseudomonas, Escherichia, Salmonella, Shigella, Staphylococcus*, *Proteus*, *Enterococcus*, *Aeromonas* and *Citrobacter.* The high occurrence of bacterial species observed during the present study may be influenced by favourable temperature, oxygen availability as well as dissolved minerals inside the storage containers (Adesakin *et al.,* 2022). These conditions can promote the growth and proliferation of various bacterial pathogens, posing significant risks to water quality and public health.

The present findings revealed that some of the stored hostel water samples exhibited substantial deterioration in terms of physical and chemical properties. Furthermore, it was also found that the analysed water samples were heavily contaminated with bacteria. It was however observed in this study that absence of total coliforms and faecal coliforms does not mean complete absence of pathogens in water, indicating the need for additional parameters are needed for a more comprehensive approach to assessment of water quality. Covering of the tanks and regular cleaning can significantly enhance the bacteriological and physicochemical qualities of the stored water. Therefore, it is imperative to implement regular monitoring, boiling before consumption and maintenance

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protocols to ensure the safety and health of students relying on these stored water supplies.

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