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Comparative bacteriological analysis of stored borehole water sources in Oyo town, Oyo State, Nigeria

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Water contamination is one of the leading causes of deaths and diseases worldwide, accounting for the deaths of more than 14,000 people daily, majority being children under 5 years old, therefore periodic monitoring of municipal water supplies are necessary. Comparative bacteriological analyses of twenty five samples of stored borehole water from five hostels in a tertiary institution in Oyo, Oyo State, was carried out using standard microbiological methods between March and April, 2018 to determine their bacteriological content. The hostels were: University Female Hostel (UFH), Diocese of Lagos West Hostel (DLW), Joseph Adetiloye Hostel (JAH), Diocese of Lagos Hostel (LAG) and Peter Jasper Akinola Hostel (IBD). A total of thirteen (13) different bacteria genera were isolated and identified as: *Aeromonas* (17%); *Escherichia* (4%); *Staphylococcus* (9%); *Pseudomonas* (9%); *Lactobacillus* (13%); *Corynebacterium* (27%); *Micrococcus* (6%); *Streptococcus* (3%); *Serratia* (4%); *Klebsiella* (1%); *Citrobacter* (3%); *Shigella* (3%); and *Salmonella* (1%). The total viable count ranged from 5.0×10^3 cfu/mL (IBD) to 1.23×10^5 cfu/mL (DLW). Total coliform bacteria counts of the stored water ranged from 0 to 28 MPN/100 mL. The bacteria load and presence of coliforms and pathogenic organisms raised grave concerns as WHO permissible limits for total viable count and coliforms are 100 cfu/mL and 0 MPN/100 mL, respectively. The organisms isolated are of public health significance as ingestion of water contaminated by them could result in gastroenteritis, especially *Escherichia* that indicates possible fecal contamination.

Key words: Bacteriological investigations, pathogens, groundwater, water quality, Oyo.

INTRODUCTION

The importance of water to human existence and ecological sustainability cannot be overrated as it is essential for life. It is found in virtually all living cells and is paramount to life. Although a human can do without food for up to twenty eight days, man cannot go without water for three days (Ukpong et al., 2013; Akin-Osanaiye

et al., 2018).

Studies have proven that over one billion people in the world lack access to safe drinking water and about 2.5 billion people do not have access to adequate sanitation services at all (Tar et al., 2009). In developing countries such as Nigeria, clean pipe borne water availability is not

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available in almost all the states. Due to the inability of Government to meet the ever increasing water demand, people resort to ground water sources such as shallow wells and boreholes as alternative water resources (LAWMA, 2000). Natural groundwater is usually of good quality but this can deteriorate due to inadequate source of protection and poor resource management (Sadiya et al., 2018).

Groundwater is found beneath the earth's surface where it collects in voids of rocks and soil and it forms the ultimate source of water for springs, wells and boreholes. A borehole is a hydraulic structure which allows the withdrawal of water from an aquifer or groundwater resource (NWRI, 1997). Borehole water serves as the major source of drinking water in the local population of Nigeria (Akpoveta et al., 2011). Unfortunately, borehole water is not entirely pure and its purity depends on the geological conditions of the soil and in particular anthropogenic activities in the area which include: improper waste disposal, close proximity of septic to groundwater supply and leachate from landfills and dumpsites often polluting groundwater supply, thereby resulting in the transmission of bacteria and diseases (Boutaleb et al., 2008; Onwughara, et al., 2010).

Collected and stored borehole water microbial contamination is caused not only by the collection and use of faecally contaminated water that was not safe, to begin with, but also by the contamination of water (that was microbiologically safe initially), during storage. Unhygienic and imperfectly protected (poorly covered or open) water collection and containers for storage, unhealthy means of dispensing water from storage containers, including faecally contaminated dippers, hands, tools, lack of protection against vectors (flies, cockroaches, rodents, etc.) and inadequate cleaning of storage container to prevent biofilm formation and accumulation of sediments and pathogens, all are factors contributing to this problem (Steiner et al., 2006; Onwughara et al., 2010; Akpoveta et al., 2011).

Microorganisms play an important role in water quality and the microorganisms that are concerned with water borne diseases are *Salmonella* species, *Shigella* species, *Escherichia coli* and *Vibrio cholera*. The presence of faecal coliforms of *Escherichia coli* and those listed earlier are indicators of contaminated water (Adetunde and Glover, 2010).

Globally, water related diseases remain a major health concern. 1.8 million children die every year from waterborne diseases (that is to say 1 every 15 s). Worldwide, waterborne diseases are the most implicated killers of children under five years old and more people die annually from unsafe water than from violence (including war). Unsafe or inadequate water, sanitation, and hygiene account for 3.1% of all deaths worldwide. Unsafe water causes 4 billion cases of diarrhea each year, and results in 2.2 million deaths, mostly of children under five; a child dying every 15 s (UNESCO, 2017;

WHO, 2019; Denchak, 2018).

The objectives of this study are therefore to determine the bacteriological enumeration, investigate the bacteriological content and compare bacteriological patterns of stored borehole water gotten from five different hostels water supplies in a tertiary institution within Oyo town of Oyo State, Nigeria.

MATERIALS AND METHODS

Study area

The study was carried out in a tertiary institution in Oyo, Oyo State, Nigeria. The institution is located on the Oyo-Ogbomoso road in Atiba Local Government Area (LGA) of Oyo State between longitude 3.9351°E and latitude 7.8371°N. The campus can be reached within 1 h by road from Ibadan and Ogbomoso, in 1.5 h from Ilorin and Ile-Ife and in 2.5 h from Lagos. The institution has five hostels, in which two (2) are allocated to females and three (3) to males. The five hostels are:

- (a) University Female Hostel (UFH);
- (b) Diocese of Lagos West Female Hostel (DLW);
- (c) Joseph Adetiloye Hostel (JAH);
- (d) Diocese of Lagos Hostel (LAG);
- (e) Peter Jasper Akinola / Ibadan Hostel (IBD);

Each of the hostels has a source of borehole from which water is pumped into plastic storage tanks and then to an overhead tank. The hostel residents make use of the stored water for different purposes including drinking, washing and bathing. The water content of the tanks is used up daily due to the population of residents.

Sample collection

Water samples were collected from five (5) different storage tanks, holding water, pumped from individual boreholes of the hostels. The water samples were collected weekly (on Mondays) between the months of March and April 2018 which is a peak period in the use of the hostels. A total of five (5) samples were collected from each storage tank on five respective sampling trips which gave rise to twenty five (25) water samples in all. The average sampling time was 8 am each sampling day. Table 1 shows the description of the sampling areas with their geographical location. Samples were collected into 20 mL sterile sample bottles, screw capped and labeled. Samples were collected and transported using ice bag immediately to the laboratory for analysis.

Media used

Media for the multiple tube fermentation and plate counts were prepared according to the manufacturer's instructions. The media used were Nutrient Agar (Himedia), MacConkey Agar (Himedia), Lactose broth (Lab M), and Eosin Methylene Blue (Himedia) agar. All were prepared according to the manufacturer's instruction and sterilized in an autoclave at 121°C for 15 min.

Bacteriological analysis of water

Using the pour plate method, total heterotrophic bacteria in the water samples were obtained (Dhawale and LaMaster, 2003). Serial

Table 1. Sampling area description.

Sampling location	Identification code	Geographical location
University Female Hostel	UFH	7°51'47 ¹¹ N 3°56'83 ¹¹ E
Diocese of Lagos West Hostel	DLW	7°51'50 ¹¹ N 3°56'43 ¹¹ E
Joseph Adetiloye Hostel	JAH	7°50'50 ¹¹ N 3°56'86 ¹¹ E
Peter Jasper Akinola / Ibadan Hostel	IBD	7°50'49 ¹¹ N 3°56'48 ¹¹ E
Diocese of Lagos Hostel	LAG	7°50'48 ¹¹ N 3°56'50 ¹¹ E

dilution was carried out and 1 mL aliquots of dilutions of 10^{-1} and 10^{-3} of each representative sample were inoculated into sterile Petri dishes. 10 mL of molten Nutrient agar (NA) was then introduced in the Petri dish over the samples. These were then swirled to attain even distribution and incubated at 37°C for 24 h. Petri-dishes from dilutions containing between 30 and 300 discrete colonies were counted and was made in cfu/mL (colony forming unit) (APHA, 2017). The colony forming units per millimeter (cfu/mL) was calculated by dividing the average number of colonies per dilution with the dilution factor.

A sterile inoculating loop was aseptically used to pick a loopful of each water sample. This was then streaked across the already set solid agar surface using the quadrant method of streaking. The inoculating loop was flamed between streaks and eventually after use; the plates were incubated at 37°C for 24 h.

Enumeration of total coliform bacteria

Multiple tube fermentation test

Multiple tube fermentation tests were conducted to enumerate total and faecal coliform (APHA, 2017). Total coliform count was determined with the aid of the three tube assay of the Most Probable Number (MPN) method.

Presumptive test

Presumptive coliform test was carried out using lactose broth. The first set of the three tubes had sterile 10 mL double strength lactose broth (DSLb) and the second and third sets had 10 mL single strength lactose broth (SSLb). Durham tubes were inserted in test tubes prior to sterilization. The three sets of the tubes received 1, 0.1 and 0.01 mL of water samples using sterile pipettes. All tubes were then incubated at 37°C for 24 to 48 h for estimation of total coliforms and examined afterwards for acid and gas production. The MPN was then determined from the MPN table for the three sets of tube (APHA, 2017).

Confirmed test

A loopful of culture was transferred from a positive tube from presumptive test into a tube of Lactose broth with Durham tube to carry out Confirmed test. The tubes were incubated at 37°C for 24 to 48 h for total coliform and 44.5 for faecal coliforms and observed for gas production.

Completed test

For the completed test a loopful of broth from a positive tube is streaked on Eosine Methylene Blue (EMB) agar plate for pure colonies. The plates were incubated at 37°C for 24 to 48 h.

Colonies developing on EMB agar were further identified. Colonies with green metallic sheen were confirmed to be faecal coliform bacteria with rods shape.

Organisms observed with different morphology (mixed growth) were sub-cultured on Nutrient agar and Eosin Methylene Blue agar and incubated at 37°C for 24 h to get pure cultures.

After development of bacterial growth colony on the agar surface, cultural characteristics of the isolates on different solid agar were examined. Growth characteristics including colonial morphology, color pigmentation, form, deviation, margin, surface, and optical characters were recorded, following Bergey's manual of systematic bacteriology (Ryan and Ray, 2008).

Biochemical tests for identification of isolates

Biochemical tests carried out for identification of isolates were: Gram stain, Endospore test, Catalase test, oxidase, Sugar fermentation (TSI), Hydrogen sulphide, motility, Indole test; and Mannitol fermentation test.

RESULTS

The total heterotrophic counts of bacteria from stored borehole water samples of the various hostel ranged from 5.0×10^3 (IBD) to 1.23×10^5 cfu/mL (DLW) while the total coliform count of the stored water samples ranged from 0 (IBD) to 28 (UFH) MPN/100 mL (Table 2). Only Ibadan Hostel recorded 0 total coliform counts all through the study, next in line was Lagos Hostel which recorded low coliform counts on only 2 trips out of 5 UFH; however, had the highest number of coliform counts on four trips out of five as shown in Table 2. A total of 77 bacteria isolates were obtained in this study (Tables 3 to 7), 32 (41.6%) were Gram negative, while 45 of them (58.4%) were Gram positive bacteria. The most number of organisms were isolated from UFH, followed by LAG, next was JAH, then DLW and IBD had the least number of isolates (Tables 3 to 7). The 77 organisms isolated belonged to only 13 different bacterial genera which were characterized and identified as: *Corynebacterium* (27%), *Aeromonas* (17%), *Lactobacillus* (13%), *Escherichia* (4%), *Psuedomonas* (9%), *Staphylococcus* (9%), *Micrococcus* (6%), *Serratia* (4%), *Citrobacter* (3%), *Shigella* (3%), *Streptococcus* (3%), *Klebsiella* (1%), and *Salmonella* (1%) as shown in Figure 1. Table 8 shows a comparative representation of the different isolates from the hostels and reveals that UFH hostel had the most number of isolates, while LAG hostel had the least

Table 2. Total heterotrophic bacterial count and coliform count from the five hostels.

Hostel	Sample trip	Total cfu/mL	Total coliform count (MPN)/100 mL
JAH		3.6×10^4	17
UFH		5.7×10^4	21
LAG	1	3.2×10^4	-
DLW		8.3×10^4	24
IBD		4.1×10^4	-
JAH		2.3×10^4	21
UFH		1.16×10^5	28
LAG	2	3.1×10^4	2.8
DLW		4.3×10^4	24
IBD		2.3×10^4	-
JAH		2.1×10^4	17
UFH		8.6×10^4	24
LAG	3	3.4×10^4	-
DLW		1.23×10^5	17
IBD		4.7×10^4	-
JAH		1.4×10^4	21
UFH		1.6×10^4	28
LAG	4	2.0×10^4	-
DLW		2.5×10^4	17
IBD		5.0×10^3	-
JAH		4.1×10^4	24
UFH		2.8×10^4	28
LAG	5	5.2×10^4	8
DLW		1.96×10^5	21
IBD		1.18×10^5	-

UFH - University Female Hostel; DLW - Diocese of Lagos West Hostel; JAH - Joseph Adetiloye Hostel; LAG - Diocese of Lagos Hostel; IBD - Ibadan / Peter Jasper Akinola Hostel.

number of organisms.

Data shown in Table 8 further reveal the following occurrence of organisms according to site of isolation: *Aeromonas* species and *Corynebacterium* species were isolated from all five hostels studied (UFH, DLW, JAH, LAG and IBD). *Staphylococcus* species were isolated from UFH, JAH, LAG and IBD hostels, *Pseudomonas* species from UFH, DLW, JAH, and IBD hostels. *Lactobacillus* species found occurrence in UFH, DLW, and JAH hostels. *E. coli* and *Streptococcus* species were isolated from UFH and JAH hostels, *Micrococcus* species from UFH and DLW hostels, *Serratia* species from UFH and IBD hostels, *Shigella* species from LAG and IBD hostels. *Klebsiella* and *Citrobacter* species each found occurrence only in JAH hostel, while *Salmonella* species was isolated only from LAG hostel.

DISCUSSION

The total heterotrophic bacteria count from the five hostels

indicated that none of the stored water samples fell within the 100 cfu/mL limit allowed by WHO (2006) for potable water. The high viable bacteria count of the stored water can be attributed to lack of water treatment and hygienic care (for example, washing) of the storage tanks. Most of the sampled waters recorded total coliform counts exceeding the WHO recommended standards which stipulate that total coliform counts should not exceed 1-3/100 mL of potable water and 0/100 mL of thermotolerant coliforms (WHO, 2006) and SON standards that recommend 0/100 mL of coliforms in portable water. Coliforms are indicator organisms and their presence is indicative of other disease causing organisms in the sampled water (Bello et al., 2013). The total coliform count obtained implies contamination, possibly from piping leakages within the water system network, unsanitary conditions or groundwater contamination.

Three members of the coliform bacteria group were isolated in this study (*Escherichia*, *Citrobacter* and *Klebsiella*). Coliforms are important markers for bacteriological water quality as they are established

Table 3. Biochemical characteristics and identification of isolates from university female hostel.

Isolate code	Gram staining	Morphology	Catalase	Oxidase	Indole	Motility	H ₂ S	Lactose	Sucrose	Glucose	Gas	Spore forming	Mannitol	Yellow pigment	Organism
UFH 1a	-	Rod	+	+	-	-	-	-	-	-	-	-	-	-	<i>Aeromonas</i> spp.
UFH 1b	-	Rod	+	+	-	+	-	+	+	+	+	-	-	-	<i>Serratia</i> spp.
UFH 1c	+	Rod	+	+	-	-	+	+	+	+	+	-	-	-	<i>Corynebacterium</i> spp.
UFH 1d	+	Rod	-	+	-	-	+	+	+	+	-	-	-	-	<i>Lactobacillus</i> spp.
UFH 1e	+	Rod	+	+	-	+	-	+	+	+	+	-	-	-	<i>Corynebacterium</i> spp.
UFH 1f	-	Short Rod	+	+	-	-	-	-	-	-	-	-	-	-	<i>Pseudomonas</i> spp.
UFH 2a	+	Cocci	+	+	-	+	-	+	+	+	+	-	+	+	<i>Staphylococcus</i> spp.
UFH 2b	+	Cocci	+	-	-	+	-	-	-	-	-	-	+	+	<i>Micrococcus</i> spp.
UFH 2c	+	Cocci	-	-	+	+	-	+	+	+	+	-	+	+	<i>Streptococcus</i> spp.
UFH 2d	+	Rod	+	+	-	+	+	+	+	+	+	-	-	-	<i>Corynebacterium</i> spp.
UFH 3a	-	Short Rod	+	+	-	-	-	+	+	+	-	-	-	-	<i>Aeromonas</i> spp.
UFH 3b	+	Short Rod	-	+	-	+	-	+	+	+	+	-	-	-	<i>Lactobacillus</i> spp.
UFH 3c	-	Rod	+	+	-	-	-	+	+	+	-	-	-	-	<i>Aeromonas</i> spp.
UFH 3d	-	Rod	+	+	-	-	+	-	-	-	-	-	-	-	<i>Pseudomonas</i> spp.
UFH 4a	-	Short Rod	+	+	+	-	-	+	+	+	-	-	-	-	<i>Escherichia coli</i>
UFH 4b	+	Rod	-	+	-	+	-	+	+	+	+	-	-	-	<i>Lactobacillus</i> spp.
UFH 4c	+	Rod	+	+	-	+	-	+	+	+	-	-	-	-	<i>Corynebacterium</i> spp.
UFH 5a	+	Rod	+	+	-	+	-	-	-	-	-	-	-	-	<i>Aeromonas</i> spp.
UFH 5b	-	Rod	+	+	-	-	+	-	-	-	-	-	-	-	<i>Pseudomonas</i> spp.
UFH 5c	-	Short Rod	+	-	-	+	-	-	-	-	-	-	-	-	<i>Serratia</i> spp.

UFH-University Female Hostel, 1-Sample trip 1, 2-Sample trip 2, 3-Sample trip 3, 4-Sample trip 4, 5-Sample trip 5; a, b, c, d, e, respective isolates; spp.-Species, H₂S-Hydrogen Sulphide.

causes for human gastroenteritis and their presence in potable water makes it unsafe for consumption. The most implicated coliform, *E. coli* indicates recent faecal contamination. *E. coli*, a normal intestinal gut flora, is found in the gut of humans and animals, where it is harmless (WHO, 2017). However, in other parts of the body, *E. coli* can cause serious disease. Two particular pathogenic serotypes of *E. coli* namely *E. coli* O157:H7 and *E. coli* O104:H4 are known causes of diseases in humans (Ateba and Bezeuidenhout, 2008). A severe outbreak of

illness caused by *E. coli* O157:H7 was recorded in Walkerton community, Ontario, Canada resulting in 7 deaths and over 2300 cases of illness (Aboh et al., 2015). Coliforms have been isolated from soil and water and their presence in the samples tested suggests possible breakage of the piping system. Moreover, the presence of coliforms in tested water samples implies a failure to meet up with WHO standards.

Worldwide, 80 to 165 million cases of infection from *Shigella* are reported, causing 600,000 deaths annually largely in developing countries,

the most vulnerable group being children below 10 years (WHO, 2017), which makes the presence of *Shigella* unacceptable among others. The incidence of high numbers of *Pseudomonas* in potable water often elicits foul odour, taste, and high turbidity levels. *Salmonella* also isolated in this study clinically manifests in gastroenteritis in humans and one of its serotype-*typhi* causes typhoid fever with devastating public health implications (WHO, 2017). These organisms are commonly found in the environment with some species being host specific particularly in animals

Table 4. Biochemical characteristics and identification of isolates from Joseph Adetiloye Hostel.

Isolate code	Gram staining	Morphology	Catalase	Oxidase	Indole	Motility	H ₂ S	Lactose	Sucrose	Glucose	Gas	Spore forming	Mannitol	Yellow	Organism
JAH 1a	+	Rod	+	+	-	+	-	+	+	+	+	-	-	-	<i>Lactobacillus fermentii</i>
JAH 1b	+	Rod	+	+	-	-	-	+	+	-	-	-	-	-	<i>Corynebacterium</i> spp.
JAH 1c	-	Rod	+	+	-	-	-	-	-	-	-	-	-	-	<i>Pseudomonas</i> spp.
JAH 2a	+	Cocci	-	-	-	-	-	-	-	-	-	-	+	+	<i>Streptococcus</i> spp.
JAH 2b	+	Cocci	+	+	+	+	-	-	-	-	-	-	+	+	<i>Staphylococcus</i> spp.
JAH 2c	+	Rod	+	-	-	+	-	+	+	+	+	-	-	-	<i>Lactobacillus fermentii</i>
JAH 2d	+	Rod	-	+	-	-	-	+	+	+	+	-	-	-	<i>Lactobacillus fermentii</i>
JAH 2f	+	Rod	-	+	+	+	+	+	+	+	+	-	-	-	<i>Lactobacillus fermentii</i>
JAH 3a	+	Rod	+	+	-	-	-	+	+	+	+	-	-	-	<i>Klebsiella</i> spp.
JAH 3b	+	Rod	+	+	-	+	-	-	-	+	-	-	-	-	<i>Corynebacterium</i> spp.
JAH 3c	-	Rod	+	+	+	-	-	+	+	+	+	-	-	-	<i>Escherichia coli</i>
JAH 3c	-	Rod	+	+	-	-	-	+	+	-	-	-	-	-	<i>Pseudomonas</i> spp.
JAH 4a	-	Rod	+	+	-	+	+	+	+	+	+	-	-	-	<i>Aeromonas hydrophilic</i>
JAH 4b	-	Rod	+	+	-	+	+	+	+	+	+	-	-	-	<i>Citrobacter</i> spp.
JAH 4c	+	Rod	+	+	+	+	+	+	+	+	+	-	-	-	<i>Escherichia coli</i>
JAH 4d	-	Rod	+	+	-	-	-	+	+	+	-	-	-	-	<i>Aeromonas veronii</i>
JAH 5a	-	Rod	+	+	-	+	+	+	+	+	+	-	-	-	<i>Citrobacter</i> spp.

JAH-Joseph Adetiloye Hostel, 1-Sample trip 1, 2-Sample trip 2, 3-Sample trip 3, 4-Sample trip 4, 5-Sample trip 5; a,b,c,d,e, respective isolates; spp.-Species, H₂S-Hydrogen Sulphide.

and also humans. Their presence in tested samples suggest possible compromise of nearby sewage system, water piping leakages and They are opportunistic pathogens that are known to induce chronic diarrhea in humans when water polluted by them is ingested (Igbiosa et al., 2012; Pavan et al., 2013). There is a possibility that the storage tanks were not properly covered or covers may have depreciated due to weathering.

Most of the organisms isolated are important human pathogens associated with variety of infectious diseases and outbreaks including: gastroenteritis, typhoid fever, dysentery, cholera, urinary tract infection among others, especially

perhaps questionable personal hygiene of the operators.

Micrococcus and *Aeromonas* are known water where such bacteria possess virulence factor genes (Orji et al., 2006; Uzoigwe and Agwa, 2012; Bello et al., 2013). They belong to the family of Enterobacteriaceae, and members of this family are generally spread via the faecal-oral route, and their presence in the samples indicates contamination of the water supplies. If such water is consumed without treatment, it poses grave health hazards to humans (WHO, 2006; SON, 2015).

This study also reveals disparities in organisms

contaminants that easily proliferate in waters exposed to contaminated air, dust and where water holding vessels are not cleaned regularly. isolated from the different hostels. This indicates differing sanitary and environmental conditions of the storage tanks in the various hostels. It also implies that the contamination source is peculiar to prevailing conditions of the respective sampling sites.

Conclusion

This study isolated pathogenic organisms from stored borehole water supplies in a tertiary

Table 5. Biochemical characteristics and identification of isolates from Diocese of Lagos West Hostel.

Isolate code	Gram staining	Morphology	Catalase	Oxidase	Indole	Motility	H ₂ S	Lactose	Sucrose	Glucose	Gas	Spore forming	Mannitol	Yellow	Organism
DLW 1a	-	Short Rod	+	+	-	+	-	+	+	+	+	-	-	-	<i>Aeromonas veronii</i>
DLW 1b	+	Short Rod	+	-	-	-	-	+	+	+	+	-	-	-	<i>Corynebacterium</i> spp.
DLW 1c	+	Cocci	+	+	-	-	-	-	-	-	-	-	+	+	<i>Micrococcus</i> spp.
DLW 1d	-	Rod	+	+	-	+	+	-	-	-	-	-	-	-	<i>Pseudomonas</i> spp.
DLW 1e	+	Cocci	+	-	-	+	-	+	+	+	-	-	+	+	<i>Micrococcus</i> spp.
DLW 1f	+	Cocci	+	-	-	+	-	+	+	+	+	-	+	+	<i>Micrococcus</i> spp.
DLW 2a	+	Rod	-	+	-	+	+	+	+	+	+	-	-	-	<i>Lactobacillus fermentii</i>
DLW 2b	-	Rod	+	+	-	+	+	+	+	+	+	-	-	-	<i>Corynebacterium</i> spp.
DLW 2c	-	Rod	+	+	+	+	-	-	-	+	+	-	-	-	<i>Aeromonas veronii</i>
DLW 2d	-	Short Rod	+	+	-	+	+	+	+	+	+	-	-	-	<i>Aeromonas hydrophila</i>
DLW 3b	+	Rod	+	-	+	+	-	-	-	-	-	-	-	-	<i>Corynebacterium</i> spp.
DLW 4a	-	Rod	-	+	-	+	-	+	+	+	-	-	-	-	<i>Lactobacillus delbrueckii</i>
DLW 4b	+	Rod	-	+	-	+	+	+	+	+	+	-	-	-	<i>Lactobacillus fermentii</i>
DLW 5a	-	Rod	+	+	-	+	-	+	+	+	-	-	-	-	<i>Aeromonas veronii</i>
DLW 5b	+	Cocci	+	+	-	-	-	+	+	+	+	-	+	+	<i>Micrococcus</i> spp.

DLW-Diocese of Lagos West Hostel; 1-Sample trip 1, 2-Sample trip 2, 3-Sample trip 3, 4-Sample trip 4, 5-Sample trip 5; a,b,c,d,e, respective isolates; spp.-Species, H₂S-Hydrogen Sulphide.

Table 6. Biochemical characteristics and identification of isolates from Peter Jasper Akinola Hostel (IBADAN).

Isolate code	Gram staining	Morphology	Catalase	Oxidase	Indole	Motility	H ₂ S	Lactose	Sucrose	Glucose	Gas	Spore forming	Mannitol	Yellow	Organism
IBD 1a	+	Rod	+	-	-	-	-	-	-	-	-	-	-	-	<i>Corynebacterium</i> spp.
IBD 1b	-	Rod	+	-	-	+	-	-	-	-	-	-	-	-	<i>Serratia liquefaciens</i>
IBD 2b	+	Cocci	+	-	-	-	-	-	-	-	-	-	+	+	<i>Staphylococcus</i> spp.
IBD 3a	+	Long Rod	+	-	-	+	-	+	+	+	-	-	-	-	<i>Corynebacterium</i> spp.
IBD 3b	-	Short Rod	+	+	-	+	+	+	+	+	+	-	-	-	<i>Aeromonas veronii</i>
IBD 4a	+	Cocci	+	+	+	+	-	+	+	+	+	-	+	+	<i>Staphylococcus</i> spp.
IBD 4c	-	Short Rod	+	+	-	+	-	+	+	+	+	-	-	-	<i>Pseudomonas</i> spp.
IBD 4d	+	Rod	+	+	-	+	-	+	+	+	+	-	-	-	<i>Corynebacterium</i> spp.
IBD 5a	-	Short Rod	-	-	-	-	-	-	-	-	-	-	-	-	<i>Shigella</i> spp.
IBD 5b	+	Rod	+	+	-	-	-	+	+	-	-	-	-	-	<i>Corynebacterium</i> spp.
IBD 5c	+	Rod	+	-	-	+	-	+	+	-	-	-	-	-	<i>Corynebacterium</i> spp.

IBD-Peter Jasper Akinola / Ibadan Hostel; 1-Sample trip 1, 2-Sample trip 2, 3-Sample trip 3, 4-Sample trip 4, 5-Sample trip 5; a,b,c,d,e, respective isolates; spp.-Species, H₂S-Hydrogen Sulphide.

Table 7. Biochemical characteristics and identification of isolates from Diocese of Lagos Hostel.

Isolate code	Gram staining	Morphology	Catalase	Oxidase	Indole	Motility	H ₂ S	Lactose	Sucrose	Glucose	Gas	Spore forming	Mannitol	Yellow	Organism
LAG 1a	+	Rod	+	+	-	-	-	+	+	+	-	-	-	-	<i>Corynebacterium</i> spp.
LAG 1b	+	Rod	+	+	-	+	-	+	+	+	-	-	-	-	<i>Corynebacterium</i> spp.
LAG 1c	+	Rod	+	+	-	+	-	-	-	-	-	-	-	-	<i>Corynebacterium</i> spp.
LAG 1d	+	Rod	+	+	-	+	-	-	-	-	-	-	-	-	<i>Corynebacterium</i> spp.
LAG 2a	+	Cocci	+	+	-	+	-	-	-	-	-	-	-	-	<i>Staphylococcus</i> spp.
LAG 2b	-	Rod	+	-	-	-	-	-	-	+	-	-	-	-	<i>Shigella</i> spp.
LAG 2c	-	Short Rod	+	-	+	+	+	+	+	+	-	-	-	-	<i>Samonella</i> spp.
LAG 2d	-	Rod	+	+	-	-	+	+	+	+	-	-	-	-	<i>Aeromonas hydrophila</i>
LAG 3a	-	Rod	+	+	-	+	+	+	+	+	+	-	-	-	<i>Aeromonas hydrophila</i>
LAG 3b	+	Long Rod	+	+	-	+	-	-	-	-	-	-	-	-	<i>Corynebacterium</i> spp.
LAG 4a	+	Cocci	+	+	-	-	-	-	-	-	-	-	+	+	<i>Staphylococcus</i> spp.
LAG 5a	-	Rod	+	-	-	+	+	+	+	+	+	-	-	-	<i>Aeromonas hydrophila</i>
LAG 5b	+	Cocci	+	+	-	+	-	+	+	+	+	-	+	+	<i>Staphylococcus</i> spp.
LAG 5c	+	Rod	+	+	-	+	-	-	-	-	-	-	-	-	<i>Corynebacterium</i> spp.
LAG 3b	+	Long Rod	+	+	-	+	-	-	-	-	-	-	-	-	<i>Corynebacterium</i> spp.
LAG 4a	+	Cocci	+	+	-	-	-	-	-	-	-	-	+	+	<i>Staphylococcus</i> spp.
LAG 5a	-	Rod	+	-	-	+	+	+	+	+	+	-	-	-	<i>Aeromonas hydrophila</i>
LAG 5b	+	Cocci	+	+	-	+	-	+	+	+	+	-	+	+	<i>Staphylococcus</i> spp.
LAG 5c	+	Rod	+	+	-	+	-	-	-	-	-	-	-	-	<i>Corynebacterium</i> spp.

LAG-Diocese of Lagos Hostel, 1-Sample trip 1, 2-Sample trip 2, 3-Sample trip 3, 4-Sample trip 4, 5-Sample trip 5; a,b,c,d,e, respective isolates; spp.-Species, H₂S-Hydrogen Sulphide.

institution. These findings prove that all the stored water tested failed to meet up with approved SON and WHO standards for portable water. Consumption of water from these supplies without treatment may pose serious health risks to the consumers.

Recommendations

There is a need to sensitize operators of boreholes and end users of the stored water on the importance of maintaining clean and hygienic environmental conditions around the borehole and

water storage tanks to prevent contamination. Further investigation of the waste disposal system of hostels where coliforms were isolated from samples is necessary, together with proper monitoring of environmental conditions of the water systems in all hostels. Adequate water disinfection and treatment of

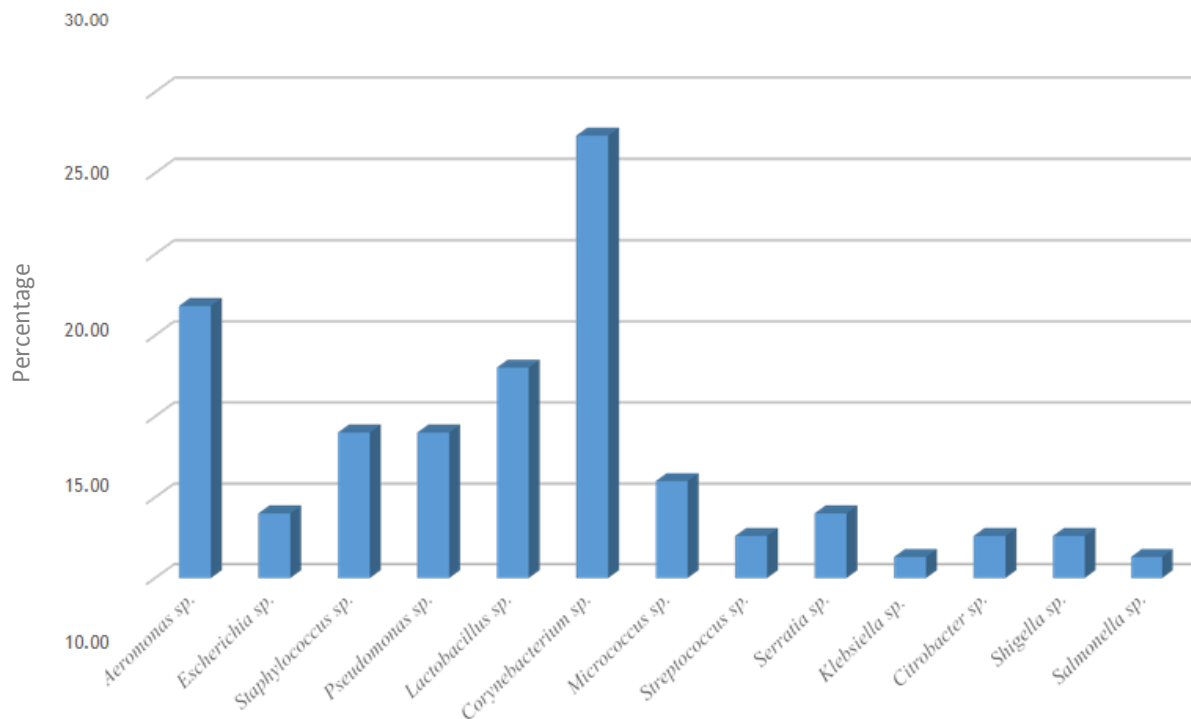


Figure 1. Frequency (%) of occurrence of bacteria isolated from stored borehole water.

Table 8. Comparative frequency of occurrence of organisms.

Isolate	UFH (%)	DLW (%)	JAH (%)	LAG (%)	IBD (%)
<i>Aeromonas</i> spp.	20	23.5	11.8	21	9
<i>Escherichia coli</i> .	5	AB	11.8	AB	AB
<i>Staphylococcus</i> spp.	5	AB	6	21	18
<i>Pseudomonas</i> spp.	15	6	11.8	AB	9
<i>Lactobacillus</i> spp.	15	17.6	23.5	AB	AB
<i>Corynebacterium</i> spp.	20	17.6	17.6	43	45
<i>Micrococcus</i> spp.	5	23.5	AB	AB	AB
<i>Streptococcus</i> spp.	5	AB	6	AB	AB
<i>Serratia</i> spp.	10	AB	AB	AB	9
<i>Klebsiella</i> spp.	AB	AB	6	AB	AB
<i>Citrobacter</i> spp.	AB	AB	11.8	AB	AB
<i>Shigella</i> spp.	AB	AB	AB	7	9
<i>Salmonella</i> spp.	AB	AB	AB	7	AB

AB-Absent, UFH-University Female Hostel, DLW-Diocese of Lagos West Hostel, JAH- Joseph Akitiloye Hostel, LAG-Diocese of Lagos Hostel, IB-Peter Jasper Akinola Hostel (Ibadan).

all storage water tanks is advocated to prevent any adverse effect to end users of the water supplies. Regular water system monitoring and analysis will be instrumental in ensuring water supplies fall within approved limits.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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