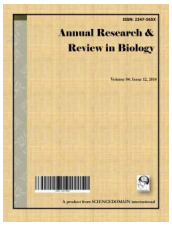

Annual Research & Review in Biology

13(5): 1-12, 2017; Article no.ARRB.33920
ISSN: 2347-565X, NLM ID: 101632869

Bacteriological and Physicochemical Quality of Malabor Hostel Tap Water - University of Calabar, Nigeria

O. A. Mmuoegbulam[1*], I. U. Bassey[1], A. A. Unimke[1] and E. E. Igwe[1]

[1]Department of Microbiology, Faculty of Biological Sciences, University of Calabar, Calabar, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author OAM designed the study, gave the protocol and interpreted the results. Authors IUB and AAU handled the tabulation and arrangement of the results. While authors OAM and EEI conducted the experiment, managed the literature searches and wrote the first draft of the manuscript, author EEI performed the statistical analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2017/33920
Editor(s):
(1) Iskra Ventseslavova Sainova, Institute of Experimental Morphology, Pathology and Anthropology with Museum to Bulgarian Academy of Sciences (IEMPAM - BAS) in Sofia, Bulgaria.
(2) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
Reviewers:
(1) Joseph O. Falkinham, Virginia Tech, Blacksburg, Virginia, USA.
(2) Jorge Hernández Bourdón, Universidad Metropolitana de Puerto Rico, Puerto Rico.
Complete Peer review History: http://www.sciencedomain.org/review-history/19618

Original Research Article

Received 4th May 2017
Accepted 11th June 2017
Published 19th June 2017

ABSTRACT

Tap water samples collected from different halls in Malabor hostel were analyzed for total heterotrophic bacteria count, total and faecal coliform counts using direct plating and membrane filtration methods. Total heterotrophic bacterial counts ranged from 3 to 80 cfu/ml, corresponding to the total heterotrophic bacterial counts obtained from Hall 4 and Hall 9 samples respectively. Total coliform counts ranged from 28 cfu/ml to 126 cfu/ml, corresponding to the total coliform counts obtained from Hall4 and Hall9, respectively. No faecal coliform was detected at 35 – 37℃ in all samples even after 72 hours of incubation. Bacterial isolates identified include: *Listeria monocytogenes*, *Erwinia stewartii*, *Legionella pneumophilia*, *Carnobacterium gallinarum*, *Staphylococcus caseolyticus*, *Enterobacter dissolves*, *Pseudomonas mallei*, *Klebsiella pneumonia*, *Aeromonas media* and *Lactobacillus* sp. *Lactobacillus* sp. had the highest percentage of occurrence (23%). The physicochemical and heavy metal quality of samples were compared with WHO and SON standards for drinking-water, and results showed that samples were too acidic and contained an unhealthy amount of Aluminum ion (Al^{3+}).

**Corresponding author: E-mail: oluchidinma@yahoo.com;*

Keywords: Total heterotrophic bacteria count; total coliform count; faecal coliform count; direct plating; membrane filtration.

1. INTRODUCTION

Water is known to be a very essential commodity in life. Biologically, it is part of the physiological process of nutrition and waste removal from the cells of living things. It remains one of the controlling factors for biodiversity and distribution of earths varied ecosystems. Apart from nutrition, humans need water for other domestic activities. Moreover, quality water is very paramount in ensuring a safe life especially when it has to be taken into the body.

Drinking water is very important in determining the health condition of people in an environment. This is because about 80% of the diseases in developing countries are due to lack of good water quality [1]. According to World Health Organization [2], drinking water quality management has been a pillar of primary disease prevention for over one and half centuries and it continues to be the foundation for prevention and control of water borne diseases. Thus, it is very pertinent to evaluate the quality of every public-water to determine their portability.

Evaluation of water quality has gained worldwide attention as majority of diseases that cause morbidity and mortality are water-related [3]. Over the least past two decades, there has been increased concern regarding the quality of tap water due to pollution and its undesirable taste and odour [4,5].

Water quality refers to the biological, chemical, physical and radiological characteristics of water [6]. It particularly deals with concerned standards that are based on human consumption (nutrition) and domestic use, industrial use, and of course the entire ecosystem. Apparently, the physical and chemical assessments of water quality are collectively regarded as physicochemical evaluation of water quality. The quality of water in the ecosystem depends on human activities such aswaste treatment, sewage disposal as well as industrial pollution. According to [7] and [8], factors contributing to the growth and survival of pathogens in distribution systems include availability of organic and inorganic nutrients in the distribution systems and bacterial resistance to disinfection. Thus, some bacteria cannot be detected by cultivation, but they still present a public health danger [9].

Microbiologically, water may contain microorganisms like bacteria, fungi, viruses, helminthes and protozoa, and these could exist as contaminants in the water. The proportion of waterborne disease outbreaks associated with the distribution system failures has been increasing over the years [10].

The pollution of tap water could originate from several sources, including contamination from water pipes and storage tanks [11]. According to [2], human faeces can be a source and major risk for exposure of water to the above mentioned biological agents. Most of these biological agents, especially the bacteria are pathogenic; and faecally derived pathogens known as coliform bacteria have always been the principal concern in setting health based targets for microbiological quality of drinking water. Serious ill health can be caused by water contaminated with faeces being passed or washed into rivers, streams, pools or being allowed to seep into wells or boreholes [1]. Hence, the bacteriological analysis of water quality stands to be very necessary.

In terms of physicochemical analysis, water is assessed for the presence of inorganic chemicals known as heavy metals, biochemical factors and other physical properties that are of importance such as colour, odour, taste, etc. Colour in water can be caused by the presence of metals such as iron and manganese or by substances of vegetative origin such as sea weeds and algae [12]. Colour test usually indicates the efficiency of the water treatment system. Odour and taste are associated with the presence of living microorganisms, or decaying organic matter including weeds, algae, or even industrial wastes containing ammonia, phenols, halogens, hydrocarbons [12]. This is treatable using chlorine.

There are few chemicals that may occur in drinking water, but only a few are of immediate health concerns in any given circumstance [13]. Chemical elements like Zn, Cu, Pb, Fe, Cd, etc may be present in water and can lead to health problems on exposure to concentration above the standard [14]. The health concerns associated with chemical constituents of drinking water differ from those associated with microbial contamination, and arise primarily from the ability of chemical constituents to cause adverse health

effects after prolonged period of exposure [13]. Biochemical properties as biologically dissolved oxygen (BOD) concentration, dissolved oxygen (DO) concentration, pH, temperature and salinity can also contribute to water quality.

2. MATERIALS AND METHODS

2.1 Sampling Site

Water samples were collected from different halls in Malabor Undergraduate hostels, University of Calabar, Calabar- Nigeria in the month of December, 2016. The tap water in the male hostels (Halls 4 and 5) and the female hostels (Halls 8 and 9) were the sampling sites. A total of four (4) water samples collected from the four different halls were analyzed. These sampling sites were the major sources of water used by the students for drinking, cooking, bathing and other domestic activities. About 80% of the undergraduate students living on-campus use this water source. The water source is a motorized-borehole that supplies water to about 1000 students in each of the halls in the Malabor hostel.

2.2 Sample Collection

Water samples were collected for both physiochemical and bacteriological analysis. Samples were collected after allowing the tap to run for about 2 minutes during the day between 10 am and 12 noon. Water samples were collected aseptically in sterile 1 litre containers, and transported to the laboratory for analysis within 4 hours from collection. The sample containers were about 3/4 filled with the sample to allow for proper homogenization of the samples before analysis.

2.3 Isolation and Maintenance of Bacterial Isolates

Bacteriological analyses including heterotrophic plate count (HPC), faecal coliform (FC) and total coliform counts (TCC) were determined using both direct pour plate method and membrane filtration techniques. No serial dilution was carried out.

Nutrient agar medium was used for the heterotrophic bacteria plate count. MacConkey agar (MCA) was used for total coliform counts; whereas Membrane Faecal Coliform (MF-C) agar medium was used for faecal coliform count. The plates were inoculated in triplicates.

Photo 1. Mounted tanks and taps in Malabor hostel halls

Photo 2. Sewage pit for one of the halls in Malabor hostel

Photo 3. An overview of the Malabor hostel water supply

In direct inoculation method for HPC on nutrient agar and total coliform count on McConkey, I ml of samples were added to the plates (for pour plate method of inoculation) while for membrane filtration, 100 ml of each water sample was filtered through a 0.45 µm membrane filters before aseptic transfer of membrane onto membrane faecal coliform (MF-C) agar and MacConkey agar for faecal and total coliform counts respectively. There was no dilution in the two methods. MacConkey agar which was used for isolation of lactose fermenters (coliforms) contains lactose as sugar source with the observation of pink-red colonies indicating lactose fermentation.

The inoculated plates were incubated for 24 hours at 35 – 37℃ and the colonies were thereafter counted for total heterotrophic bacteria and total coliform counts.

Colonies were morphologically characterized and sub-cultured on nutrient agar for further identification. The isolates were Gram stained and biochemically identified based on the Bergey's Manual of Determinative Bacteriology.

2.4 Physicochemical Analyses

Physical parameters including temperature, pH, turbidity, Biological Oxygen Demand (BOD), conductivity and Total dissolved solids (TDS) were determined using their respective instruments (pH, conductivity meter, and BOD meter- HACH products). Chemical parameters and heavy metals such as Iron (Fe), Copper (Cu), Manganese (Mn), Zinc (Zn), Chromium (Cr), Nickel (Ni), Cobalt (Co), Aluminum (Al^{3+}), Phosphate ($PO4^{3-}$), Nitrite (NO_2-N), Nitrate (NO_3-N) and Ammonia (NH_3) were also determined using a spectrophotometer (HACH- DR 5000 model) and their respective chemical reagents.

3. RESULTS AND DISCUSSION

All the samples showed presence of microbes with a total of 10 genera of bacteria obtained from both nutrient and MacConkey agar plates. However, no faecal coliform bacteria were found in all the samples. This is in agreement with [13] standards of zero faecal coliform in drinking water. Although, groundwater is often less vulnerable to the immediate influence of contamination sources due to the barrier effects provided by the overlying soil and its unsaturated zone, its contamination is more frequent where these protective barriers are breached, allowing direct contamination. This may occur through contaminated or abandoned wells or underground pollution sources, such as latrines and sewer lines [13].

3.1 Bacterial Counts in Samples

Heterotrophic plate count was expressed in colony forming unit per millilitre (cfu/ml). This is because samples were not diluted.

3.2 Heterotrophic Plate Count

Table 1 displays the results of the colony counts of total heterotrophic bacteria using direct plating on nutrient agar. Results were reported in cfu/ml.

Table 1. Heterotrophic bacterial count from nutrient agar

Samples	Total colony count (cfu/ml)
Hall4 Tap water	3
Hall5 Tap water	21
Hall8 Tap water	35
Hall9 Tap water	80

3.3 Total Coliform Count

Total coliform count was analyzed using both direct plating and membrane filtration methods. The results displayed in Table 2 shows that no coliform count was recorded for water samples from halls 4 and 5 using the direct plating method while confluent growth was observed on the membrane filters for halls 8 and 9 water samples. However, halls 4 and 5 gave a TCC of 28 and 65 cfu/ml respectively on MacConkey agar plates using the membrane filtration method while halls 8 and 9 gave a TCC of 90 and 126 cfu/ml respectively on the MacConkey agar plates. The presence of coliform organisms in water samples from halls 8 and 9 suggests that there was a fault in the treatment process in the distribution system.

3.4 Faecal Coliform Count

No faecal coliform was observed in both the membrane filtration and direct plating methods. This suggests that the water samples were safe when compared with the WHO and Standard Organization of Nigeria (SON) water quality standards on faecal coliform bacteria.

Table 2. Total coliform bacterial count from Mac Conkey agar

Samples	Membrane filtration count (cfu/100 ml)	Direct plating count (cfu/ml)
Hall4 tap water	28	No growth
Hall5 tap water	65	No growth
Hall8 tap water	Confluent growth	90
Hall 9 tap water	Confluent growth	126

Table 3. Bacterial isolates from samples

Samples	Isolate codes	Probable organisms
Hall4 tap water	IH4	*Listeria monocytogenes*
Hall5 tap water	$IH5_1$	*Erwinia stewartii*
	$IH5_2$	*Legionella pneumophilia*
	$IH5_3$	*Carnobacterium gallinarum*
	$IH5_4$	*Staphylococcus caseolyticus*
Hall 8 tap water	$IH8_1$	*Enterobacter dissolves*
	$IH8_2$	*Pseudomonas mallei*
Hall 9 tap water	$IH9_1$	*Klebsiella pneumonia*
	$IH9_2$	*Aeromonas media*
	$IH9_3$	*Lactobacillus* spp

Key: I: Isolate, IH4: Isolate from Hall 4, $IH5_1$: 1st isolate from Hall5, $IH5_2$: 2nd isolate from Hall 5, $IH5_3$: 3rd isolate from Hall 5, $IH5_4$: 4th isolate from Hall 5, $IH8_1$: 1st isolate from Hall 8, $IH8_2$: 2nd isolate from Hall 8, $IH9_1$: 1st isolate from Hall 9, $IH9_2$: 2nd isolate from Hall 9, $IH9_3$: 3rd isolate from Hall 9

Results showed that there was more heterotrophic bacterial load in Hall 9 water sample (80 cfu/ml), followed by water samples from Hall 8 sample (30 cfu/ml) and then Hall 5 sample (21 cfu/ml). Hall 4 water sample had the least heterotrophic bacterial load (3 cfu/ml). These counts comply with WHO standards of <500 cfu/ml heterotrophic bacteria count. Six of the isolates were obtained through the heterotrophic bacteria count cultured on nutrient agar. Hall 5 had three (i.e. 50%) of the total number of heterotrophic bacterial isolates which include: *Legionella* sp., *Carnobacteruim* sp. and *Staphylococcus* sp.

Among the four (4) isolated Gram-positive organisms which were *Listeria* sp, *Carnobacterium* sp, *Staphylococcus* sp and *Lactobacillus* sp., only *Listeria* sp. was isolated from Hall 4. This organism is known to form biofilms on stainless steel coupons in tap water at any temperature including 4℃ [15]. This literature revealed that *L. monocytogenes* could form biofilms in tap water and that sessile cells could remain viable and cultivatable in some conditions for at least 48 hours, but could remain undetected using traditional culture recovery techniques. This may be the reason for the few counts observed in the water sample.

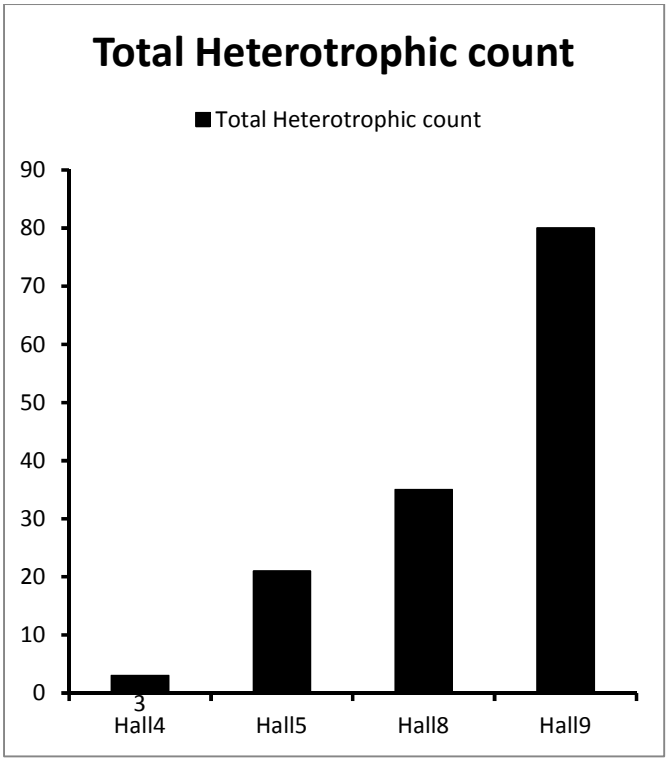

Fig. 1. Bar chart of total heterotrophic count

Corynebacterium spp are widely distributed in nature and are commonly found in soil and water. *Carnobacterium gallinarum* isolated from Hall5 was also too few to be counted. This organism, like *Tsukamurella* spp. exist primarily as environmental saprophytes in soil, water and is represented in HPC populations in drinking-water. *Tsukamurella* organisms have been detected in drinking-water supplies, but the significance is unclear, and their biochemical characterizations are not far fetch from that of the *Carnobacterium* spp. This probably suggests the reason for their microbial distribution in water samples.

Lactobacillus sp. had the highest percentage of occurrence (23%) in the samples analyzed (including Halls 4, 5 and 9 tap water samples) out of all the identified isolates. This organism expressed a good level of microbial distribution in Malabor tap water than the other isolates. The aquatic environments were favourable to the microbe.

Microorganisms, including *Legionella* spp. form biofilms as a mechanism to withstand adverse conditions, such as limited nutrients or temperature extreme. Legionellae are found in sources such as distributed drinking-water supplies, and the major risk factor for Legionellae proliferation appears to be neglect or insufficient maintenance. A significant proportion of outbreaks of Legionnaires' disease in these systems have been attributable to the start-up of stagnant systems without adequate chemical treatment [16].

Coliforms isolated on MacConkey agar were only four (4); with Hall 9 water sample having two (i.e. 50%) of the total coliform bacteria. This insinuates that the environment in Hall 9 was favourable for the growth of coliforms than that of other tap water in other halls in Malabor hostel as shown by the result. Natural waters contain a myriad of different bacterial species, many of which have not been cultured, much less identified. The methods used widely in water microbiology tend to favour the detection of mesophilic bacteria that are able to grow on nutrient-rich media [17]. However, this does not comply with the WHO standards of 0 cfu/100 ml coliform or SON standards of 10 cfu/ml coliform bacteria.

All the coliforms isolated from the samples were majorly members of the Enterobacteriaceae family and include *Klebsiella* sp., *Enterobacter* sp., *Aeromonas* sp. and *Erwinia* sp. However, Gram-negative bacteria population in Malabor tap water was very poor compared to that of Gram-positive bacteria population. This is also reflected in the absence of faecal coliforms in the water sample.

Aeromonas sp. had the highest frequency of occurrence in all the samples analyzed. It was detected in samples from Halls 4, 5 and 9. Typically, *Aeromonas* in drinking-water in distribution systems has been con-trolled by increased disinfection, and it appears that free cells of *Aeromonas* are relatively susceptible to the common chlorine-based disinfectants. A key mechanism for the control of aeromonads in drinking-water is therefore the removal of biodegradable compounds (i.e. improving the biostability of the water). Such measures would also help to control the re-growth of heterotrophic bacteria and the proliferation of invertebrates within the distribution system.

In terms of physical parameters, there is no significant difference in the mean physical quality within samples, unlike within the parameters per se. At 95% confidence interval, Fcal (2.4) is less than Fcrit. (4.5) while Fcal. (92.1) is greater than (3.8), respectively within the columns and rows of the Two-factor ANOVA analysis.

Comparing physical results with standards, samples were assessed for safety using WHO and SON standards. Table 5 shows the comparison and inferences.

Table 4. Physical quality of Malabor tap water

S/N	Physical parameters	Hall4	Hall5	Hall8	Hall9
1	Temperature (℃)	29.300	29.200	29.000	29.100
2	pH	3.970	3.950	3.800	3.830
3	Turbidity (NTU)	0.768	0.776	0.801	0.891
4	BOD	6.690	6.890	6.990	7.010
5	Conductivity (µS/cm)	72.500	99.400	138.60	135.00
6	TDS (mg/L)	43.500	59.640	83.160	81.000

Table 5. Physical quality compared with WHO and SON standards

S/N	Physical parameters	Unit	Maximum permitted		Health impact	Fata of sample			
			SON	WHO		H4	H5	H8	H9
1	Temperature	℃	Ambient		None	S	S	S	S
2	pH	-	6.5-8.5	6.5-9.5	None	U	U	U	U
3	Turbidity	NTU	5	-	None	S	S	S	S
4	BOD	-	-	-	-	-	-	-	-
5	Conductivity	µS/cm	1000	1000	None	S	S	S	S
6	TDS	mg/L	500	600	None	S	S	S	S

[18]: Nigerian Standard for Drinking Water Quality; [13]: Guidelines for Drinking-water Quality
Key: S: safe, U: unsafe, H4: Hall 4 sample, H5: Hall 5 sample, H8: Hall 8 sample, H9: Hall 9 sample

Physical parameters like temperature and pH follow a similar trend of variation within samples, in that samples with high temperature had high pH also. Similarly, BOD, turbidity, TDS and conductivity to some extent follow the trend in all the samples. Moreover, values obtained for Halls 4 and 5 water samples were very similar; two factor ANOVA between these sample revealed Fcal=2.29 and Fcrit=6.61 at p=0.19, which implies that there is no significant difference in the mean physical quality of the samples. The same scenario is observed between Halls 8 and 9 water samples, with Fcal=2.02 and Fcrit=6.61 at p=0.21. This may be due to the fact that the corresponding sites were in very close locations.

However, compared with World Health Organization standards for drinking-water, all the samples were acidic. And this was reflected in the presence of *Lactobacillus* sp. (an acid-loving microbe) and its percentage of occurrence. Similarly, the fact that Legionellae are found in hot-water tanks or thermally polluted rivers emphasize that water temperature is a crucial factor in the colonization of water distribution systems [16]. For instance, *L. pneumophila* has been shown to be able to withstand temperatures of 50℃ for several hours, but does not multiply below 20℃. Thus, the presence of *Legionella* in an aquatic environment and warm temperature are two factors that can increase the risk of Legionnaires' disease

Lactobacilli are much better adapted to grow in an acidic environment created by lactic acid bacteria [13]. Thus because of the acidic metabolites produced by these lactic acid bacteria, other bacterial genera that cannot withstand acidic environment tend to be inhibited thus accounting for the prevalence of *Lactobacillus* sp in such acidic water. According to [19], a research on effects of adding *Lactobacillus plantarum* I-UL4 metabolites in drinking water of rats has shown that water containing lactic acid bacterial metabolites have a slightly lower faecal coliform counts than those of the control after two weeks of the experiment, this could be explained by the present of antibacterial agents (organic acids, peroxides or bacteriocins) that are produced and secreted which have an inhibitory effect on controlling pathogenic micro flora. Results of the experiment showed that the addition of UL4 metabolite in the drinking water reduced the growth rate of rats, especially those treated with 70% UL4, increased the lactic acid bacterial counts, reduced coliform counts and pH. The prevalence of lactic acid bacteria in drinking water reinforces the need to examine the health risk of this water-borne pathogen to better define the quality guidelines for drinking water [19].

Furthermore, according to [13], it is necessary to know the pH of water, because more alkaline water requires a longer contact time or a higher free residual chlorine level at the end of the contact time for adequate disinfection (0.4–0.5 mg/litre at pH 6–8, rising to 0.6 mg/litre at pH 8–9) and chlorination may be ineffective above pH 9. Also, turbidity adversely affects the efficiency of disinfection and enhances the growth of microbes in water and thus must be measured to determine what type and level of treatment needed.

Results from chemical analysis, heavy metals and physicochemical parameters are displayed in Table 6 while individual parameters were represented in Figs. 2-5.

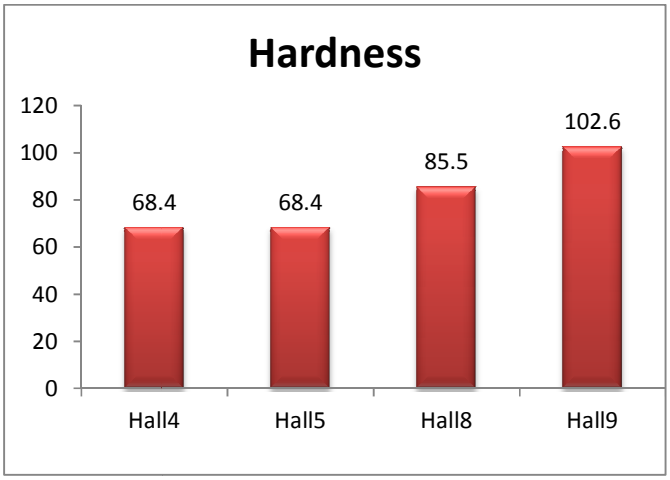

Fig. 2. Comparison of hardness of samples

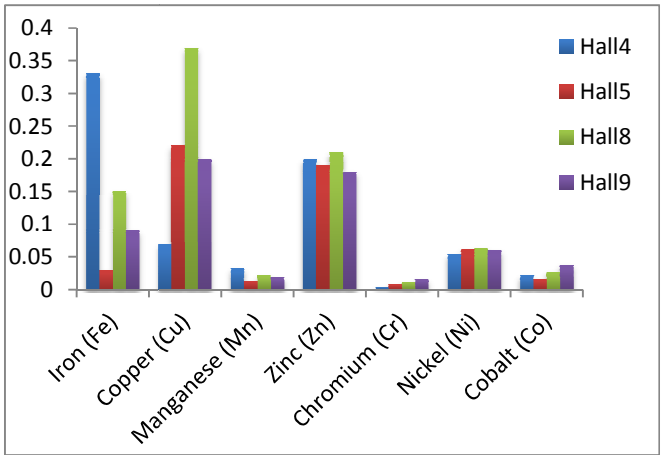

Fig. 3. Comparison of heavy metal concentrations

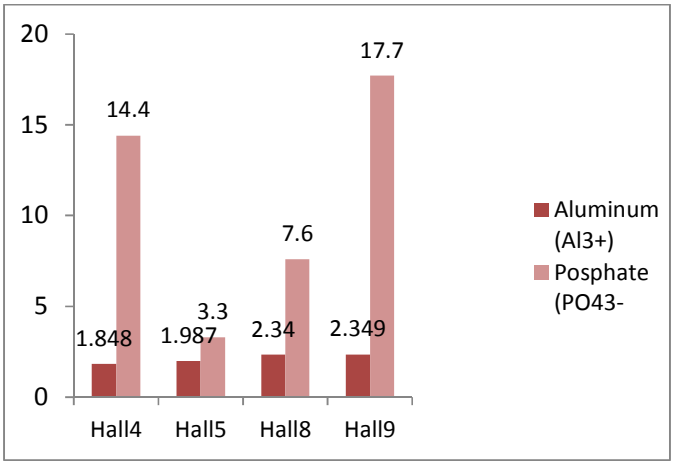

Fig. 4. Comparison of ions in samples

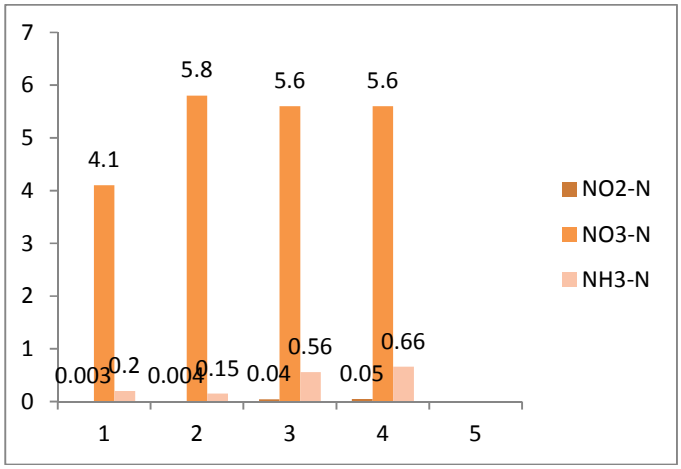

Fig. 5. Comparison of Nitrogen compounds

Table 6. SON and WHO interpretative standards for chemical quality of samples

S/N	Chemical analysis	Unit	Maximum permitted		Health Impacts	Fata of sample			
			SON	WHO		H4	H5	H8	H9
1	Hard-ness	mg/l	150	200	Gastrointestinal disorder	S	S	S	S
2	Fe	mg/l	3.0	0.3	None	S	S	S	S
3	Cu	mg/l	-	1.0	None	S	S	S	S
4	Mn	mg/l	0.2	0.1	Neurological disorder	S	S	S	S
5	Zn	mg/l	3.0	0.05	None	S	S	S	S
6	Cr	mg/l	0.05	0.07	Carcinogenic	S	S	S	S
7	Ni	mg/l	0.02	-	Possibly carcinogenic	U	U	U	U
8	Co	mg/l	-	-	-	-	-	-	-
9	Al^{3+}	mg/l	0.2	0.1	Potential Neuro-degenerative Disorders	U	U	U	U
10	PO_4^{3-}	mg/l	-	-	-	-	-	-	-
11	$NO_{2-}N$	mg/l	0.2	-	Cyanosis and asphyxia in infants under 3months	S	S	S	S
12	$NO_{3-}N$	mg/l	50	50	Cyanosis and asphyxia in infants under 3months	S	S	S	S
13	$NH_{3-}N$	mg/l	-	-	-	-	-	-	-

[18]: Nigerian Standards for Drinking Water Quality; [13]: Guidelines for Drinking-water Quality.
Key: S: safe, U: unsafe

In terms of chemical parameters, there is no significant difference in the mean chemical quality within samples, unlike within the parameters. At 95% confidence interval, Fcal (1.09) is less than Fcrit. (3.44) while Fcal. (5.99) is greater than (2.26), respectively within the columns and rows of the Two-factor ANOVA analysis. Also, values obtained for Halls 4 and 5 samples were very similar; two factor ANOVA between these sample reveal Fcal=0.7 and Fcrit=4.7 at p=0.4, which implies that there is no significant difference in the mean chemical quality of the samples. The same scenario is observed between Hall 8 and 9 samples, with Fcal=2.0 and Fcrit=4.7 at p=0.18. However, Hall9 had the highest and most extreme hardness

result. Also, the aluminum concentration of samples compared with WHO standards is not safe for the water sources.

Nitrogen containing compounds in water samples follow a trend of conversion. For instance, nitrate could be present as a result oxidation of other forms of nitrogen, including nitrite, ammonia, and other organic nitrogen compounds such as amino acids. Ammonia and organic nitrogen can enter water through sewage effluent and runoff from land where manure has been applied or stored. Nitrate can get into water directly as the result of runoff of fertilizers containing nitrate. Some nitrate enters water from the atmosphere, which carries nitrogen-containing compounds derived from automobiles and other sources. The most effective strategy is prevention by keeping chemicals that contain or can generate nitrate out of the water.

These nitrogenous compounds originated from accumulation of biodegradable organic compounds in the soil and aquatic environment. Report by [16] suggested limiting the concentrations of biodegradable compounds in anaerobic groundwater source, by aeration. And that such measure would also help to control the re-growth of heterotrophic bacteria and the proliferation of invertebrates within the water distribution system.

It is also worthy of note that so far, Hall 4 was the hall with the sample with the fairest physicochemical and bacteriological water quality as compared with WHO and SON standards for drinking-water quality, whereas Hall9 had the worst water quality. Isolation of pathogenic and potentially pathogenic microorganisms such as *Salmonella* spp, *Staphylococcus* spp, *Aeromonas* spp, *Streptococcus* spp and *Pseudomonas aeruginosa* is of high importance and according to [20] it indicates that the tap water is unsafe.

The isolation of *Pseudomonas aeruginosa* and *Areomonas* spp indicates water quality deterioration and that immuno-compromised people are at risk and suggestes that there may be connection between the high cases of reported diarrhea and the isolated organisms [21].

4. CONCLUSION

Irrespective of the poor sewage management processes, Malabor tap water can be considered to be safe for consumption since there was no faecal contamination of the water from the source. However there is need for treatment of the water before distribution due to the total coliform count which was above the WHO regulatory standard of 0 coliform (cfu/100 ml) in all the halls and above the SON standard of 10 coliforms (cfu/ml) in halls 8 and 9. Moreover, since most of the coliform organisms are opportunistic pathogens that can cause serious healthy problems, it suggests that the safety of the consumers of water from these sources is not guaranteed. However, we observed in our antibiotic susceptibility study that antibiotic chemotherapy will go a long way in controlling the bacterial infections resulting from the pathogens (including the opportunistic pathogens) isolated in this study. Also, the presence of acidic metabolites which led to low pH levels of the water samples was found to favour the growth of *Lactobacillus* sp- an acid-loving bacteria.

5. RECOMMENDATIONS

It is pertinent that the Malabor water distribution systems (being a groundwater source) undergoes necessary water treatments especially chlorination and aeration as this will help to contribute to the safety of the water source. This is very necessary especial for Halls 8 and 9 water supplies. According to [22], groundwater extracted from well protected aquifers is usually free from pathogenic microorganisms, and the distribution of such groundwater without treatment is common practice in many countries. However, the catchment area must be protected by effective regulatory measures and the distribution system adequately protected against secondary contamination of the drinking-water. If the water, in its passage from source to consumer, cannot be protected at all times, disinfection and the maintenance of adequate chlorine residuals are imperative [22].

It is also recommendable that water quality in Malabor tap water be assessed regularly so as to control possible seepage and contamination of Malabor water as a result of poor sewage management. This is because it may take several decades say 100-150 years for this process to be completed; and then the presence of coliform in this ground water sources will make it unsafe for consumption.

Limiting the concentrations of biodegradable compounds in Malabor groundwater sources, by

aeration may be the preferred option in controlling the microbial quality. Such measures would also help to control the re-growth of heterotrophic bacteria and the proliferation of invertebrates in the distribution systems.

Furthermore, antibiotic chemotherapy against possible infections from the isolated genera of bacteria has to be carefully used in order to avoid the development of bacterial resistance to subsequent antibiotic therapy.

Finally, it is of great importance for further researches to be done on the antibiotics required to control *Erwinia* sp. in Malabor water in other to control possible prevalence and disease condition of this organism. Antibiotic synergism will go a long way to proffer a solution.

ETHICAL APPROVAL

As per international standard or university standard, written ethical approval has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Cheesbrough M. District laboratory practice in tropical countries. Part 2. Cambridge University Press. 2006;143-157.
2. WHO. Guidelines for drinking-water quality. World Health Organization Recommendation, Geneva. 2010;1-6.
3. Shayo N, Chove B, Gidamis A, Ngoma O. The quality of water in small community supplies of Kingolwira village, Morogoro, Tanzania. Tanzania Journal of Health Research. 2007;9:56-60.
4. Saleh M, Ewane E, Jones J, Wilson B. Chemical evaluation of commercial bottled drinking-water from Egypt. Journal of Food Composition and Analysis. 2001;14:127-152.
5. Ikem A, Odueyungbo S, Egiebor N, Nyavor K. Chemical quality of bottled waters from three cities in Eastern Alabama. Science of the Total Environmen. 2002;285:165-175.
6. Diersing N. Water quality: Frequently asked questions. Florida Books National Marine Sanctuary, Keywest, FL; 2009.
7. Le Dante C, Duguet JP, Montiel A, Dumoutier N, Dubrou S, Vincent V. Chlorine disinfection of atypical Mycobacteria isolated from a water distribution system. Applied Environmental Microbiology. 2002;68(3):1025-1032.
8. Goel S, Bouwer EJ. Factors influencing inactivation of Klebsiella pneumonia by chlorine and chloramines. Water Res. 2014;38(2):301-308.
9. Mouna H, Ahmed A, Omar A. An evaluation of environmental factors affecting the survival of Escherichia coli in coastal area, Oualidia Lagoon. International Journal of Current Microbiology and Applied Science. 2014;3(10):710-721.
10. Moe C, Rheingans R. Global challenges in water, sanitation and health. Journal of Water Health. 2006;4:41-57.
11. Parag Y, Roberts J. A battle against the bottles: Building, claiming, and regaining tap-water trust worthiness. Society and Natural Resources. 2009;22:625-636.
12. Sciortino AJ, Ravikumar R. Fishery harbour manual on the prevention of pollution-bay of Bengal Programme. BOBP for Fisheries Management, BOBP/MAG/22; 1999.
13. WHO. Guidelines for drinking-water quality. World Health Organization Recommendations. 3rd Ed. 2004;1:107-142.
14. WHO. Europe. Health risks of heavy metals from long-range transboundary air pollution; 2007.
15. Gião MS, Keevil CV. Listeria monocytogenes can form bioflms in tap water microbial and enter into the viable but non-cultivatable state. Microbial Ecology. 2014;67:603-611.
16. WHO. Legionella and the prevention of legionellosis. Asian Network for Scientific Information. 2007;15-33.
17. WHO. World Health Report. Shaping our future. World Health Organisation; 2003.
18. SON. Nigerian standard for drinking water quality. Nigerian Industrial Standard (NIS). 2007;554:15-22.
19. Foo HL, Loh TC, Lai PW, Lim YZ, Kufli CN Rusul G. Effects of adding Lactobacillus plantarum I-UL4 metabolites in drinking water of rats. Pakistan Journal of Nutrition. 2003;2(5):283-288.
20. Kurup R, Persaud R, Caesar J, Raja V. Microbiological and physiochemical

analysis of drinking-water in Georgetown, Guyana. Nature and Science. 2010;8(8): 261-265.

21. Yagoub SO, Ahmed RY. Microbiological evaluation of the quality of tap water distributed at Khartoum State. Research Journal of Microbiology. 2009;4:355-360.

22. World Health Organization- WHO. Health guidelines for drinking-water quality criteria and other supporting information. World Health Origination, Gevena. 1996;2(2).

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/19618