International Journal of Agriculture Innovations and Research
Volume 7, Issue 6, ISSN (Online) 2319-1473
Manuscript Processing Details (dd/mm/yyyy):
Received: 27/04/2019 | Accepted on: 23/05/2019 | Published: 06/06/2019

Microbiological Quality Assessment of Commercial Bottled Water Marketed in Sana'a City, Yemen

Abdulmageed Bagash Abdullah[1*], Qais Ali Al-Maqtari[1,2] and Waleed AL-Ansi[1,2]
[1] Department of Food Science and Technology, Faculty of Agriculture, Sana'a University, Sana'a, Yemen.
[2] Department of Food Science and Technology, Faculty of Engineering, Jiangnan University, Wuxi, China.
*Corresponding author email id: mageed967@gmail.com

Abstract **– The aim of present study was assessing of microbiological quality for commercial bottled water marketed in Sana'a city, Yemen, through enumerate the Heterotrophic Bacteria count (HBC) and detect the presence or absence of Total Coliform (TC), Faecal Coliform (FC) and *E. coli* from Commercial Bottled water. Samples were collected from five different brands of bottled water (Al-Namudhajia, Qatr Al-Nudaa, Yanabie Azal, Al-Madinatayn and Al-Hikma), Four samples from each type were collected randomly from several shops and supermarkets located in Sana'a City, Yemen. All samples were examined by plate count technique and MPN methods. The result indicated that the HBC for all samples were in the range of 1.44-5.04 Log_{10}/ml at 22˚C, and 1.01-5.21 Log_{10}/ml at 37 ˚C. Approximately 85% and 95% from samples at 22 and 37 ˚C respectively, did not comply with the safety regulation of Codex and UK for drinking water. About 60%, 50% and 25% of samples were contained Total Coliforms, Faecal Coliforms and *E. coli* respectively, higher than the permitted colony count regulated by YSMO, GSO, Codex, UK and WHO.**

Keywords **– Bottled Water, Heterotrophic Bacteria, Coliform, *E. coli*, MPN Technique, Plate Count Technique.**

I. INTRODUCTION

The quality of drinking water is closely associated with human health, and providing of drinking water is one of the important public health priorities **[1]**. So, Access to safe drinking water is key to sustainable development, food production, poverty reduction and quality health **[2]**. It is very abundant in nature as its occupies about 70 % of the earth's crust **[3]**. But, despite its relative abundance, good quality drinking water is unavailable to over one billion of the world population **[4]**. Approximately three out of five persons in developing countries do not have access to safe drinking water and only about one in four has any kind of sanitary facilities **[5]**. Unfortunately, such water sources are scarce and even when they are available; they are seldom safe for consumption. There is therefore a great need for water to be treated effectively in order to make it potable and safe for humans **[6]**.

Safe drinking water is essential for human life. It is generally considered that bottled water is safe for usage by people. Provision of safe drinking water is one of the most essential amenities to be made available for citizens in the modern world **[7]**.

The non-availability of good quality drinking water has resulted into a number of health challenges as water is known to be a primary causative agent of many contagious diseases. In developing countries of the world, 80 % of all diseases and over 30 % of deaths are related to drinking water **[1, 8]**. A review of 28 studies carried out by the World Bank gives the evidence that incidence of certain water borne, water washed, water based and water sanitation associated diseases are related to the quality and quantity of water and sanitation available to users **[9, 10]**. Almost two million people every year, the majority of whom are children die from water-related diseases especially from diarrhea which remains the second leading cause of death among children under five years globally, it is estimated that almost one in five child's death is due to diarrhea, surpassing the death caused by AIDS, Malaria and Measles combined **[11]**.

Research have shown that when clean water and needed hygiene condition are provided, the chances of occurrence of diarrhea, sleeping sickness and guinea worm infestation can be eliminated or prevented by 50, 80 and 100% respectively **[12]**. In the other side, Filtered water is the main source of safe and reliable drinking water **[13]**, because, its pleasant taste, the absence of odor and the belief that it is mostly free of germs **[14]**.

So, the insufficiency of water supply has given rise to the involvement of private individuals in the production of packaged drinking water (pure water) **[15]**. And it led to increasingly high demand for bottled water during the last decade due to the fact that people living in both developed and some developing countries have no suitable water supply around their homes **[16]**. But, there is still a debate on the efficiency of filtration system to comply with the regulations as water that physically looks colorless, odorless and even tasteless is not sufficient to determine that the water is safe for consumption, So, the drinking water should be examined on microbiological and physicochemical quality **[13]**. Because the quality of drinking water can deteriorate by microbial and toxic chemicals during transportation, storage, packaging and handling before reaching the final consumer. Also, Distribution systems, service lines and home devices could influence the quality of drinking water **[17]**. As well, Biofilms (an aggregate of microorganisms in which cells adhere to each other on a surface) affect water quality and they are widely spread in the nature. These biofilms are a major problem in many environmental, industrial and medical settings **[6]**. The hygiene of the environment and conditions under which majority of brands of packaged water are produced and stored are faced with a number of uncertainties **[18]**. In addition, Variations in the number of bacteria in the bottle after storage, depending on the type of bottle used (PVC or glass), have been observed. Where, the bacterial numbers in glass less than in PVC bottles.

On the other hand, concerns have been raised about the microbial quality of bottled water marketed worldwide with several studies have documented the detection of Coliform

and heterotrophic bacteria in bottled water **[19]**. Therefore, Constant and periodic assessment of packaged drinking water is needed to satisfactorily enlighten the consumers about quality **[12]**.

The provision of drinking water of acceptable microbiological quality and low infectious disease risk requires a number of essential elements within a Water Safety Plan. Thus, within any water safety plan emphasis is placed on controlling and detecting faecal contamination of drinking water and its sources **[20]**. So, the National and international organizations standards have been explicitly developed for safe drinking water quality. Virtually all the available standards have upper limits for physical, chemical and microbiological properties which when exceeded are dangerous and have the potential of been harmful to the end users **[3]**.

Although, the direct isolation of intestinal pathogens is impractical **[21]**. Where, many potential pathogens could be associated with water; it is thus impractical to screen samples for all possible pathogens **[22]**. Instead, various indicator organisms have been used as surrogate markers of risk **[21]**. Most waterborne disease is related to faecal pollution of water sources, therefore water microbiology is largely based on the need to identify indicators of faecal pollution such as coliforms and *E. coli*, but the use of enterococci and *Clostridium perfringens* is increasing. In addition, the less specific term 'faecal coliforms' (which includes species of *Klebsiella*, *Enterobacter*, and *Citrobacter*) is used in recreational water testing because the examination of large numbers of colonies to identify *E. coli* is labor intensive **[22]**. Also, the heterotrophic plate count is a parameter that could be used to reflect the biofilm formation in water systems. It is the basic standard technique for microbiological testing of drinking water. In addition, the most dangerous microorganisms are the coliforms which are part of the normal flora of the gut of warm blooded animals. The presence of contamination with any of these organisms and others can be tested using various indicators. However, the development of such indicators has never been such an easy job and up to date, there still remains considerable arguments about the best indicators for testing microbial contamination **[6]**.

Generally**,** the bottled drinking water should supply by modern techniques such as ozone disinfection, membrane filtration, UV disinfection to reach the maximum standard of water safety before refilling the bottles and distributing to the consumers **[19]**. Then, Regular examination of water quality for the presence of organisms, chemicals, and other physical contents provides information on the level of the safety of water. Frequent examinations of faecal indicator organisms remain the most sensitive way of assessing the hygienic conditions of water. Indicator organisms of faecal pollution include the coliform group as a whole and particularly *Escherichia coli, streptococcus feacalis* and some thermo tolerant organisms such as *clostridium perfringens*. The overall concepts adopted for microbiologi--cal quality is that no water intended for human consumption shall contain *E coli* in 100 ml sample. Treated water entering the distribution system should be 0 faecal coliforms and 0 coliform organisms per 100 ml of water **[5].** The standards for indicator organisms, other than colony counts, apply up to the point of sale. The standard for total colony counts applies only within 12 h of bottling. Under the new regulations water offered for sale in bottles or containers will have to undergo check sampling, which will include testing for coliforms and *E. coli, Pseudomonas aeruginosa*, and colony bacterial counts at 22°C and 37°C **[23]**.

Therefore, the present study was aimed to evaluate the microbiological quality of drinking water and check it compliance with (national or/and international) standards through isolating Heterotrophic bacteria count, total coliform, faecal coliform and *E. coli* in bottled water marketed of Sana'a city.

II. Materials and Methods

Study Area

The study was carried out in Sana'a city, that is one of the governorates of the Republic of Yemen.

Sample Collection

Five different brands of bottled water (Al-Namudhajia, Qatr Al-Nudaa, Yanabie Azal, Al-Madinatayn and Al-Hikma), Four samples from each type were collected randomly from several shops and supermarkets located in Sana'a city of Yemen. The collected water samples were transported to the microbiology laboratory *in Department of Food Science and Technology, Faculty of Agriculture, Sana'a University* on ice parks and immediately stored at 4°C. The microbiological tests were carried out within 24 hours after collection. The parameters tested were, Heterotrophic bacteria count, Total coliforms, Faecal coli and *E. coli.*

Heterotrophic Bacteria Count (HBC)

The plate count technique for the enumeration of microorganisms is one of the oldest and most widely used techniques in microbiology. The HBC test is one method for monitoring the overall bacteriological quality of drinking water and was done according to International Standards Organization for bottled water **[24]**. The collec--ted water sample made diluted up to 10^{-4} by serial dilution method in Peptone salt solution. The pour plate technique was employed. One milliliter of each water sample and dilute was poured with a sterile nutrient agar medium (three replicates of petri dish for each dilution). Two sets were done. Allowed the medium to set then inverted the plates and incubated one set at (36 ± 2) °C for (44 ± 4) h and the other set incubated at (22 ± 2) °C for (68 ± 4) h. after which the bacterial colonies that developed were counted and the result recorded as the number of colony-forming units per milliliter (cfu/ml) of the sample for each temperature of incubation and were expressed as (Log_{10}/ml).

Detection and Enumeration of Escherichia coli and Coliform Bacteria

Most probable number (MPN) technique are considered as statistical best estimates obtained by culturing a number (usually five tubes) of sample volumes and/or dilutions of such samples **[25]**. MPN method was used for enumeration of Total coliform, faecal coliform and *E. coli* according to BAM, (2001) as follows **[26]**:

Presumptive test: 10 ml, 1 ml and 0.1 ml (1 ml of the 1:10 dilution) of water samples were inoculated into three sets of sterilized test-tubes. Each set contains five test tubes with an inverted Durham tube and 9 ml of lauryl tryptose (LST) broth and then incubated at 35°C for 24-48 h. After incubation, each test tube was examined for gas production (coliform bacteria produce gas from the lactose which was trapped in the inverted Durham tube).

Confirmed test: Gently agitated each gassing LST tube and transferred loopful of suspension to three tube, two of them contain 9 ml from BGLB (Brilliant Green Lactose 2% Bile) broth with an inverted Durham tube to enumeration of total and feacal coliform and third tube contain 9 ml from EC (*Escherichia coli*) broth with an inverted Durham tube to detection of *E. coli.* Then, the tubes that used to enumeration of total coliform were incubated at 35°C for 24-48 h and the tubes that used to detect of feacal coliform and *E. coli* were incubated at 44.5°C for 24-48 h. After incubation, each test tube was examined for gas production. The positive tubes with gas production were counted and MPN determined from standard table.

Completed test: loopful from positive tubes (with gas production) in confirmed test was streaked on the MacConkey agar plate to enumeration of total coliform and Eosin methylene blue agar to detection of feacal coliform and *E. coli*. The plates were incubated at 35°C for 24-48 h. After incubation, the colonies were further examined for their colony morphology on MacConkey agar and Eosin methylene blue (EMB) plates for presumptive identification of coliform and *E. coli*. Differential stains (Gram stain) for typical colonies were carried out to confirm that the bacteria are gram negative, rode shape and then its tested to ability to produce gas from lactose after incubation for 24-48 h by test tubes with an inverted Durham tube and 9 ml of lauryl tryptose (LST) broth.

Identification of E. coli by Biochemical Test

Besides IMViC which stands for Indole, Methyl red, Voges–Proskauer and Citrate tests, four other biochemical tests, i.e. catalase, gelatin liquefaction, starch hydrolysis and sugar fermentation were performed to confirm the identity of *E. coli* according to standard method **[26]**.

Statistical Analysis

All the data were subjected to a one-way analysis of variance (ANOVA) to determine the significant differences ($p \leq 0.05$) between means and were evaluated by Duncan's. All the statistical procedures were performed using SPSS software version 20.0 (Chicago, Illinoi, USA).

III. Result and Discussion

Sana'a city is a highly urbanized area and Capital of Yemen where many brands of bottled water are marketed. Therefore, this study was undertaken to assess the bacteriological quality of bottled water from markets and to check their compliance with the standard regulations. According to the guidelines of national and international recommendations, all the samples were checked for the following parameters: Heterotrophic Bacteria count (HBC), Total Coliform (TC), Faecal Coliform (FC) and detection of presence or absence of *E. coli.*

Heterotrophic bacteria count total coliform, Faecal Coliform and *E. coli* have been used widely as a basis for controlling the bacterial quality of drinking water **[27]**. In this study, most of samples were exceeding above the standard regulations (**Tables 1**) and Study results clearly indicate that most of the bottled water are highly contaminated.

Table 1. Microbiological guidelines and standards for drinking water.

Characteristics		YSMO	GSO	Codex	EC	UK	WHO
Total bacteria count	colony count 22°C colony count 37°C	n/s	n/s	100/ml 20/ml	10/ ml	100/ml 20/ml	n/s
Total coliforms		0/100 ml	0/100 ml	0/100 ml	0/100 ml	0/100 ml	0/100 ml
Faecal coliforms		0/100 ml	0/100 ml	0/100 ml	0/100 ml	0/100 ml	0/100 ml
E. coli		0/100 ml	0/100 ml	0/100 ml	0/100 ml	0/100 ml	0/100 ml

n/s: not stated.
Source: [13, 28, 29, 30]

Heterotrophic Bacteria Count (HBC)

This microbial group was included in the analysis because its presence could indicate poor hygiene conditions during the processing of the bottled water.

However, HBC analysis at 22°C (**Table 2**), indicate that 50% and 25% of Al-Namudhajia and Qatr Al-Nudaa samples respectively were lower than the limit of 2 Log_{10}/ml at 22˚C while the rest of the samples were generally higher than the standard limit for heterotrophic count of drinking water. This results were confirmed with many authors that attributed the high level of HBC either to the presence of bacteria in the water source or contamination during bottling processes **[31, 32]**.

Table 2. Mean of Heterotrophic bacteria count (as Log_{10}/ml) at 22 ºC

	Source/ Sampling site				
No.	**Al-Namudhajia**	**Qatr Al-Nudaa**	**Yanabie Azal**	**Al-Madinatayn**	**Al-Hikma**
1	$2.76 \pm 0.01^{c*}$	1.44 ± 0.01^{a}	3.51 ± 0.01^{c}	3.93 ± 0.01^{b}	4.11 ± 0.01^{c}
2	4.15 ± 0.03^{d}	4.82 ± 0.02^{d}	3.82 ± 0.02^{d}	2.45 ± 0.01^{a}	3.47 ± 0.01^{b}
3	1.90 ± 0.02^{b}	2.90 ± 0.01^{b}	2.04 ± 0.01^{a}	5.04 ± 0.01^{d}	4.20 ± 0.01^{d}
4	1.63 ± 0.01^{a}	4.30 ± 0.01^{c}	2.49 ± 0.04^{b}	4.30 ± 0.01^{c}	2.11 ± 0.01^{a}
Mean	2.60 ± 1.03	3.36 ± 1.3	2.97 ± 0.76	3.93 ± 0.99	3.47 ± 0.87

*Same letters in the same Colum mean significant different ($p \leq 0.05$)

Generally, the lowest value for HBC was 1.44 Log_{10}/ml in Qatr Al-Nudaa samples and the highest was 5.04 Log_{10}/ml in Al-Madinatayn samples as shown in **Table 2**. And overall 85% of the tested samples were out of the standard limit as shown in **fig. 1.**

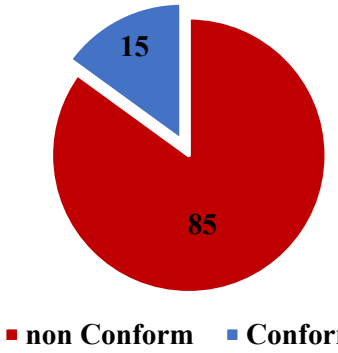

Fig. 1. Percentage of samples conforming to a standard for Heterotrophic bacteria count at 22 °C

While, (HBC) at 37 ˚C, 25% of Qatr Al-Nudaa samples were lower than the limit of 1.3 Log_{10}/ml and the rest of samples were higher than the limit, which was Al-Madinatayn samples the highest 5.21 Log_{10}/ml as shown in **Table 3**. And overall 95% of the tested samples were out of the standard limit as shown in **fig. 2.**

Table 3. Mean of Heterotrophic bacteria count (as Log_{10}/ml) at 37°C

	Source/ Sampling site				
No.	Al-Namudhajia	Qatr Al-Nudaa	Yanabie Azal	Al-Madinatayn	Al-Hikma
1	$3.11 \pm 0.03^{c*}$	1.01 ± 0.02^{a}	1.93 ± 0.05^{a}	4.00 ± 0.01^{b}	4.30 ± 0.00^{c}
2	4.60 ± 0.05^{d}	4.92 ± 0.02^{d}	4.04 ± 0.00^{c}	2.51 ± 0.03^{a}	3.86 ± 0.05^{b}
3	2.23 ± 0.03^{a}	2.01 ± 0.02^{b}	2.31 ± 0.02^{b}	5.21 ± 0.01^{d}	4.40 ± 0.01^{d}
4	2.74 ± 0.04^{b}	4.16 ± 0.02^{c}	2.35 ± 0.03^{b}	4.24 ± 0.21^{c}	2.71 ± 0.01^{a}
Mean	3.17 ± 0.92	3.02 ± 1.65	2.66 ± 0.85	3.99 ± 1.01	3.82 ± 0.70

*Same letters in the same colum mean significant different ($p \leq 0.05$)

From all the samples there were 85% and 95% samples at 22 and 37˚C respectively still not able to comply with the standard for microbial quality of water for human consumption given by Codex and UK regulations as shown in **Table 1**, that only allowed not more than 2 Log_{10}/ml and 1.3 Log_{10}/ml at 22 and 37˚C respectively in bottled drinking water. However, Poor sanitation, water scarcity, inferior water quality and inappropriate hygiene behavior are may be the main reasons for the high microbial load in bottled water samples in this study.

In the other side, the high contamination in bottled water in this case attributed to the poor microbiological quality of the source. In addition, the potential for water contamination during packaging and transport from the source and subsequent storage makes the challenge of providing "safe drinking water" even greater.

Therefore, point of use treatment systems is seen as providing "safe drinking water" to communities, households and individuals who are in desperate need for clean water.

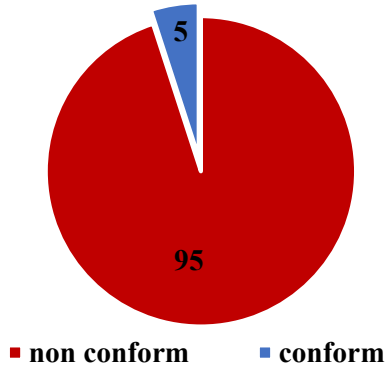

Fig. 2. Percentage of samples conforming to a standard for Heterotrophic bacteria count at 37 °C

Total and Faecal Coliforms

Most coliforms are present in large numbers among intestinal flora of humans and other warm-blooded animals, and are thus found in faecal wastes **[33]**. As a consequence, coliforms detected in higher concentrations are used as an index of the potential presence of entero pathogens in water environments **[34]**.

The result of TC showed that all Al-Namudhajia samples in the accepted range of the standard limit. While 75%, 75%, 100% and 50% of Qatr Al-Nudaa, Yanabie Azal, Al-Madinatayn and Al-Hikma respectively resulted positively for the presence of TC.

However, the highest value for TC was in Qatr Al-Nudaa which was 170 MPN/100ml as shown in **Tables 4**.

Table 4. Mean of Total coliform count (as MPN/100 ml)

	Source/ Sampling site				
No.	Al-Namudhajia	Qatr Al-Nudaa	Yanabie Azal	Al-Madinatayn	Al-Hikma
1	< 1.8	< 1.8	< 1.8	6.8	4.5
2	< 1.8	170	26	25	< 1.8
3	< 1.8	26	6.1	94	9.3
4	< 1.8	70	4.0	24	< 1.8

From all samples 40% was in the accepted range according to the standard regulations for TC and 60% was out of the range and unaccepted as shown in **fig. 3**.

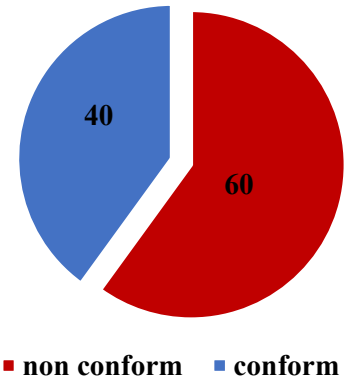

Fig. 3. Percentage of samples conforming to a standard for Total Coliform

Coliforms are also routinely found in diversified natural environments, as some of them are of telluric origin, but drinking water is not a natural environment for them. As a result, their presence in drinking water must be considered as a harm to human health. Positive presence of coliforms in treated water which is usually coliform-free may indicate treatment ineffectiveness.

On the other hand, the result of FC showed that all Al-Namudhajia samples in the accepted range of the standard limit. While 50%, 75%, 100% and 25% of Qatr Al-Nudaa, Yanabie Azal, Al-Madinatayn and Al-Hikma respectively resulted positively for the presence of FC. While the highest value for FC was in Qatr Al-Nudaa which was 94 MPN/100ml as shown in **Tables 5**.

Table 5. Mean of Feacal coliform count (as MPN/100 ml)

	Source/ Sampling site				
No.	Al-Namudhajia	Qatr Al-Nudaa	Yanabie Azal	Al-Madinatayn	Al-Hikma
1	< 1.8	< 1.8	< 1.8	2.0	< 1.8
2	< 1.8	94	9.3	5.6	< 1.8
3	< 1.8	< 1.8	4.0	24	4.5
4	< 1.8	4.5	4.0	17	< 1.8

Fig. 4 is shown the results of FC in accepted and unaccepted range according to the regulations which 50% of all the samples were in the accepted range.

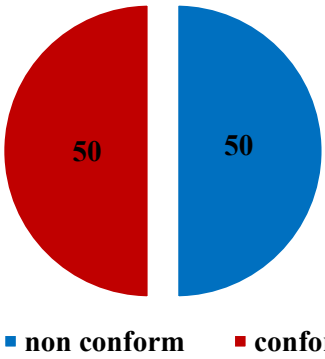

Fig. 4. Percentage of samples conforming to a standard for Feacal Coliform

The presence of faecal coliform in water is often associated with contamination by faecal matter which occurs when faecal matter from a nearby septic tank infiltrates into the borehole chambers and introduces bacteria or other pathogenic microorganisms into such water drawn from the borehole.

However, the high contamination by total and faecal coliform in our samples may be due to the poor quality of water, sanitation, sources and hygiene during the production of water or may be due to the lack of cleanliness of the containers and periodic maintenance of the filters. We also suspect lack of personal hygiene among the personnel involved in the operations in some of the bottling facilities as indicated by the incidence of fecal coliforms as one of the predominant genera encountered in the samples.

E. *coli*

The absence of *E. coli* mainly due to the pore sizes (0.3-0.7 micron) of the ceramic filters in all the water filter systems, which enable to filter *E. coli* with the size of 1.0 - 1.5 micron from the water. Furthermore, the chlorination process also able to kill and injured most of the *E.* coli **[13]**.

The results of *E. coli* are presented in **Table 6**. Al-Namudhajia and Al-Hikma samples showed negative presence of *E. coli*, this indicates that the all water samples were free from faecal contamination as *E. coli* is one of the indicators for faecal contamination in drinking water **[35]**. Furthermore, the *E. coli* were present in 25%, 50% and 50% of Qatr Al-Nudaa, Yanabie Azal, and Al-Madinatayn samples respectively, that were unacceptable according to the UK regulations (1999).

Table 6. Detection of *E. coli* from Bottled Water / 100ml

	Source/ Sampling site				
No.	Al-Namudhajia	Qatr Al-Nudaa	Yanabie Azal	Al-Madinatayn	Al-Hikma
1	-	-	-	-	-
2	-	+	+	-	-
3	-	-	-	+	-
4	-	-	+	+	-

In **fig. 5** it's clear that from all the samples 75% were in the accepted range and 25% were higher and in the unaccepted range according to the regulations mentioned in **Table 1**.

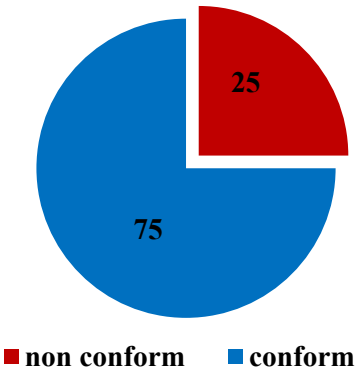

Fig. 5. Percentage of samples conforming to a standard for *E. coli*

The specific presence of *E. coli* indicates faecal contamination and possible occurrence of enteric pathogens **[36],** and water borne diseases such as *Salmonella sp, Shigella sp, Vibrio cholerae, Entamoeba histolytica, Giardia lamblia, Balantidium coli, Cryptococcus parvum* and Entero viruses of various clinical ailments which include *Poliovirus, Rotavirus, Hepatitis A virus and Hepatitis E virus* **[4]**. So, The *E. coli* remains the most widely recognized indicator used to assess drinking water quality, and public health and food safety authorities recommend that drinking water should always be free of *E. coli* **[37]**. Thus, the presence of this bacterium in bottled water or on water processing equipment is generally an indication of faecal contamination because the poor sanitation or poor manufacturing techniques and handlers with poor personal hygiene.

IV. Conclusion

The study conducted showed that the HBC for 85% and 95% of samples at 22 and 37 ˚C respectively were did not comply with the safety regulation from Codex and UK for drinking water. While, about 60%, 50% and 25% of Total Coliforms, faecal coliforms and *E. coli* respectively were higher than the permitted count regulated by National and international organizations standards. In conclusion, the high values of HBC, Total Coliforms, faecal coliforms and *E. coli* in the bottled waters detected in this study seem to fully justify the need for reevaluation of the current microbiological water quality guidelines in Yemen regarding the use of HBC and faecal contamination.

Furthermore, Additional examinations could be taken in order to ensure low values of microorganism and its variation during storage, among these we mentioned protection of sources, stringent hygienic-sanitary care with the personnel and the equipment involved in the production and cleaning of containers, care hygienic-sanitary with caps and bottles and appropriate cleaning and disinfection of the returnable bottles.

Also, if the sources of contamination are known, the problem will decrease as concerned health authorities can work to solve the problem by spreading awareness among people regarding using simple and effective methods of cleaning the filtration system regularly to keep the water quality safe.

Moreover, Adherence to good manufacturing practices (GMPs), strict process control and personal hygiene should be maintained at the processing facility and sanitation practice that must be employed by the manufactures for safety and quality water.

As well, Proper treatment of the water samples before bottling, bottling in hygienic environment as well as adequate post-bottling handling are recommended.

References

[1] Sarker, A., et al., Assessment of microbial quality of water in popular restaurants in Sylhet city of Bangladesh. Bangladesh Journal of Agricultural Research, 2016. 41(1): p. 115-125.

[2] Adekunle, L., et al., *An assessment of the health and social economc implications of satchet water in Ibadan, Nigeria: A public health challenge.* African Journal of Biomedical Research, 2004. 7(1).

[3] Ibrahim, M., M. Umaru, and A. Akinsoji, *Qualitative assessment of sachet and bottled water marketed in Bauchi Metropolis, Nigeria.* Chemical and Process Engineering Research, 2015. 37: p. 11-23.

[4] Samuel, O., N. Florence, and O. Ifeanyi, *Microbial Quality assessment of Commercial Bottled Water Brands in Major Markets in Awka, Nigeria.* Universal Journal of Microbiology Research, 2016. 4: p. 1-5.

[5] Mengesha, A., W. Mamo, and G. Baye, *A survey of bacteriological quality of drinking water in North Gondar.* Ethiop J Health Dev, 2004. 18(2): p. 112-5.

[6] Micheni, L.N., et al., *Research Article assessment of the microbiological quality of bottled water and protected spring water in Bushenyi district, Uganda.*

[7] Joseph, N., et al., *Bacteriological assessment of Bottled Drinking Water Available at Major Transit Places in Mangalore City of South India.* Journal of environmental and public health, 2018. 2018.

[8] Onweluzo, J. and C. Akuagbazie, *Assessment of the quality of bottled and sachet water sold in Nsukka town.* Agro-Science, 2010. 9(2).

[9] Howard, J. and J. Howard, *The Development of a Site Sanitation Planning and Reporting Aid (SSPRA) for the Selection of Appropriate Sanitation Technologies for Developing Communities: Report to the Water Research Commission*. 2001: Water Research Commission.

[10] Abebe, L., *Hygienic water quality; its relation to health and the testing aspects in tropical conditions.* Department of Civil Engineering, University of Tempere, Finland, 1986.

[11] Organization, W.H., *Global water supply and sanitation assessment 2000 report*. 2000: World Health Organization.

[12] Alhassan, M.M. and F. Ujoh, *Assessment of the chemical quality of potable water sources in Abuja, Nigeria.* British Journal of Applied Science & Technology, 2012. 2(2): p. 146.

[13] Chan, C.L., M. Zalifah, and A. Norrakiah, *Microbiological and physicochemical quality of drinking water.* Malaysian Journal of Analytical Sciences, 2007. 11(2): p. 414-420.

[14] Güler, C. and M. Alpaslan, *Mineral content of 70 bottled water brands sold on the Turkish market: assessment of their compliance with current regulations.* Journal of Food composition and Analysis, 2009. 22(7-8): p. 728-737.

[15] Dada, A., *Sachet water phenomenon in Nigeria: Assessment of the potential health impacts.* African Journal of Microbiology Research, 2009. 3(1): p. 15-21.

[16] Hu, Z., L.W. Morton, and R. Mahler, *Bottled water: United States consumers and their perceptions of water quality.* International Journal of Environmental Research and Public Health, 2011. 8(2): p. 565-578.

[17] Lee, E.J. and K.J. Schwab, *Deficiencies in drinking water distribution systems in developing countries.* Journal of water and health, 2005. 3(2): p. 109-127.

[18] Ndinwa, C., et al., *Physio-chemical and bacteriological characteristics of bottled and sachet brand of packaged water in Warri and Abraka, Southern Nigeria.* Journal of Environmental Management and Safety, 2012. 3(2): p. 145-160.

[19] Al Moosa, M.E., et al., *Microbiological quality of drinking water from water dispenser machines.* International Journal of Environmental Science and Development, 2015. 6(9): p. 710.

[20] Jain, A., A. Khatri, and A. Siddiqui, *Tap water quality assessment of some selected regions of Mhow, District Indore India.* Bioscience Biotechnology Research Communications, 2018. 11(3): p. 512-517.

[21] Parvez, A., et al., *Bacteriological quality of drinking water samples across Bangladesh.* Arch. Clin. Microbiol, 2016. 7(1).

[22] Barrell, R., P. Hunter, and G. Nichols, *Microbiological standards for water and their relationship to health risk.* Commun Dis Public Health, 2000. 3(1): p. 8-13.

[23] Jukes, D., *Natural mineral water, spring water and bottled drinking water regulations.* British Food Journal, 1999. 101(1).

[24] Standardization, I.O.f., *Water Quality: Enumeration of Culturable Micro-organisms: Colony Count by Inoculation in a Nutrient Agar Culture Medium*. 1999: ISO.

[25] Bumadian, M.M., et al., *Detection and Enumeration of Coliform Bacteria in Drinking Water at Hospital of Benghazi /Libya.* Jour-

-nal of Experimental Biology, 2013. 1: p. 6.
[26] Feng, P., et al., *BAM: Enumeration of Escherichia coli and the Coliform Bacteria.* Bacteriological analytical manual, 2002. 13.
[27] Pavlov, D., et al., *Potentially pathogenic features of heterotrophic plate count bacteria isolated from treated and untreated drinking water.* International Journal of Food Microbiology, 2004. 92(3): p. 275-287.
[28] GSO (Gulf Cooperation Council Standardization Organization). Microbiological criteria for foodstuffs. 2014. GSO/FDS 1016.
[29] Codex. Working paper on elaboration of a regional standard for microbiological levels in food. Preparaed by Egypt. Agenda item 13. 2003. CX/NEA 03/16. Y8278a.
[30] YSMO. (The Yemen Standardization, Metrology and Quality Control Organization). Microbiological criteria for foodstuffs. 2002. Part 1
[31] Falcone-Dias, M.F. and A. Farache Filho, *Quantitative variations in heterotrophic plate count and in the presence of indicator microorganisms in bottled mineral water.* Food Control, 2013. 31(1): p. 90-96.
[32] Kassenga, G.R., *The health-related microbiological quality of bottled drinking water sold in Dar es Salaam, Tanzania.* Journal of water and health, 2007. 5(1): p. 179-185.
[33] Dorothy, A. and R. Philip, *Technology of Bottled Water*. 1998, USA: Sheffield Academic Press.
[34] Rompré, A., et al., *Detection and enumeration of coliforms in drinking water: current methods and emerging approaches.* Journal of microbiological methods, 2002. 49(1): p. 31-54.
[35] Warburton, D.W., J.K. McCormick, and B. Bowen, *Survival and recovery of Aeromonas hydrophila in water: development of methodology for testing bottled water in Canada.* Canadian journal of microbiology, 1994. 40(2): p. 145-148.
[36] Bharath, J., et al., *Microbial quality of domestic and imported brands of bottled water in Trinidad.* International Journal of Food Microbiology, 2003. 81(1): p. 53-62.
[37] Organization, W.H., *Microbial aspects: in Guidelines for drinking-water quality*. 2011, WHO, Geneva, Switzerland.