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Evaluation of physico-chemical and microbial quality of bottled drinking water marketed in Tripoli city , Libya.

Fatma Abolgasem [1,*] , Sundus Almontasir,[1], Fatma Elhabeshi [1], Hajer Elgheriani [2] , Fauzia Abuhtna[2] and Mohamed Salem[2].

[1]Department of Environmental , Food and Biological Applications, Libyan Biotechnology Research Center.
[2]Department of Microbiology, Libyan Biotechnology Research Center.

[*]Corresponding Author: fatma. s.m.a.b@gmail.com

ABSTRACT

This study aimed to assess the physicochemical and microbial quality of 30 brands of bottled drinking water available in Tripoli, Libya. The results of the analyses were compared with both Libyan standards and world Health Organization (WHO) guidelines. The investigated parameters were mainly pH, Electrical conductivity (EC), Total dissolved solids (TDS), Total hardness (TH) as $CaCO_3$, Bicarbonate (HCO_3^-), Chloride (Cl^-), Iron (Fe^{2+}), and Magnesium (Mg^{2+}) using standard analytical techniques available in the laboratory. The results showed that EC, $CaCO_3$, HCO_3^-, Fe^{2+}, Cl^-, and Mg^{2+} were within the acceptable range of Libyan and WHO standards, whereas TDS levels in all samples were below the WHO's permissible limits, and 11 samples had TDS levels below the Libyan minimum standard for drinking water set by Libyan regulations. Microbiological analysis confirmed the absence of harmful microorganisms in all samples, indicating that the bottled water brands analyzed are safe for human consumption.

Keywords: bottled water, physic-chemical, microbial quality, Tripoli.

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INTRODUCTION

Water is a critical natural resource, fundamental to all forms of life, and essential for a wide range of domestic, agricultural, and industrial purposes **(Chimtali et al., 2023; Alam et al., 2017)**. Despite covering over 71% of the Earth's surface, only about 3% of global water resources are freshwater, with the majority existing as saline water in oceans and seas **(Salehi et al., 2014; Zeber-Dzikowska et al., 2022)**. This limited availability of drinkable water has made the quality of accessible freshwater a matter of global concern. The consumption of bottled water has increased in recent years; reports indicate that over 89 billion liters of bottled water are consumed globally each year **(Salehi., et al 2014)**. Customers are increasingly choosing bottled drinking water over tap water because it is safer and healthier. The definition of safe water is that it needs to be free from pathogenic organisms, toxic substances, and an excess of organic materials and minerals, and it should be palatable (free of taste, odor, color, and turbidity) **(Abouglaida et al., 2022 ; Kiric, 2020)**. Bottled water is preferred over tap water for a variety of reasons, including fear of biological or mineral contamination, the unpalatable taste of chlorinated tap water, and the quality of bottled water **(Najah et al., 2021)**. Various contaminants, such as physical, chemical, and microbiological contaminants, can have a significant negative influence on the safety of drinking water and can lead to serious problems. A large number of waterborne diseases cause millions of deaths every year, according to the World Health Organization (WHO); Diarrhea, cholera, typhoid, bacillary, and paratyphoid are just a few of the many diseases that can be brought on by poor water quality **(Mustafa et al., 2024 ; Singla et al., 2014)**. Several common techniques for disinfecting water are employed to kill or remove pathogenic microorganisms, including ultraviolet (UV) disinfection, chlorination, and ozone treatment. Ozone treatment is a powerful oxidation method that works as a strong oxidant, destroying a variety of microorganisms such as bacteria and viruses and aiding in the removal of compounds that give water its color, odor, and taste **(Chimtali et al., 2023 ; Guzzonato et al., 2021)**. Water quality parameters are the physical, chemical, and biological characteristics of water in relation to a set of standards. Many studies have been conducted to evaluate the quality of bottled water in various cities across the world. Recently in Libya, PH, the conductivity, and levels of Na, K, Ca, and Mg in six different brands of bottled water from Alkoms were measured and compared to the World Health Organization's and Libya's drinking water standards. The obtained results showed that the calcium concentration was up to four times higher than WHO and Libyan limits, but the pH values, conductivity, and levels of Na, Mg, Ca, and K were all within an acceptable range **(Najah et al., 2021)**. Study on physical-chemical quality of 18 bottled water samples that are available in Sivas, Turkey. According to national and international standards, the results showed that all of the samples' physicochemical quality parameters were within an acceptable range for human consumption **(Dirican, 2019)**. The quality of drinking water in Riyadh, Saudi Arabia, has also been evaluated through chemical analysis of the various domestic bottled water brands. The distribution of the chemical components is ascertained and contrasted with the WHO, U.S. Environmental Protection Agency, and Saudi Arabian drinking water standards. The results showed that the concentrations of dissolved salts, soluble actions, anions, nitrates, and trace elements in the majority of bottled waters for sale were within the acceptable limits established by the standards used, with the exception of fluoride and bromate **(Al-Omran et al., 2012)**. A microbial study was conducted on 9 samples of various bottled drinking water and 18 samples of reverse osmosis drinking water from different locations in Tripoli, Libya. The domestic bottled waters have bacteriological contents within the accepted ranges based on WHO standards, whereas almost all the reverse osmosis samples have high bacterial counts that can be risky to human health **(Rbeida and Eteer, 2023)**. Libyan markets offer a wide range of bottled water brands from different domestic manufacturers, and Tripoli city is one of the highest consumers of bottled drinking water. The purpose of this study was to evaluate the physical, chemical, and microbial quality of bottled water available in the Tripoli city of Libya.

MATERIALS AND METHODS

Thirty different samples of bottled water were randomly collected from shops and supermarkets from different locations in Tripoli city**,** Samples were collected during of May to July 2023. Three bottles of water (volume 0.3, 0.5, 1.5, and 7 L) of each brand were used to analyze the selected parameters and all the samples were contained in their original sealed containers . The collected samples were transferred to a laboratory and kept at lab temperature before analysis, Ozone treatment was the sterilization technique applied by the companies. The selected physico-chemical parameters were recorded for their Electrical conductivity (EC), Total dissolved solids (TDS), Total hardness (TH) as $CaCO_3$, Bicarbonate (HCO_3^-), Chloride (Cl^-), Iron (Fe^{2+}), and Magnesium (Mg^{2+}), and each parameter was carried out in triplicate and the mean of each parameter was calculated. Physicochemical and microbial tests were performed in accordance with standard methods. Libyan and WHO standards for bottled water were used as reference values, as shown in Table 1. All selected physico-chemical and microbial analysis for this study were conducted in the laboratories of the Environment, Food and Biological Applications, and Microbiology departments of the Libyan Biotechnology Research Center.

Table 1: Libyan and WHO standards value for commercial bottled water.

Variables	**Standard values**	
	Libyan standards	**WHO standards**
pH	6.5-8	6.5-8.5
TDS	100-500 mg/l	500-1000 mg/l
Electrical Conductivity	1000 µs/cm	2500 µs/cm
Total hardness as $CaCo_3$	200 mg/l	500 mg/l
Fe	0.3 mg/l	0.3 mg/l
Cl	150 mg/l	250 mg/l
Mg	30-150 mg/l	30-150 mg/l
HCo_3	150 mg/l	200 mg/l
Bacterial counts Cfu/ml	50 cfu/ml	50 cfu/ml

TDS and EC were measured using a conductivity meter (JENWAY 4510). The pH values of the bottled water samples were measured using a pH meter (JENWAY 3510). The pH meter was calibrated with buffer solutions of pH 4 and pH 7. Bicarbonate (HCO_3^-) was determined by titration methods. Cl^-, Fe^{2+}, Mg^{2+}, and $CaCO_3$ were measured using water analysis photometer (Palintest-7500). The total viable microbial colonies of the bottled samples were counted by the pour plate method and incubated at 37°C for 24-48 hours. The petri plates of nutrient agar medium were used to determine viable bacterial count. Bacterial load was estimated by counting colony-forming units (CFU) on nutrient agar plates.

RESULTS AND DISCUSSION

This study investigated the physicochemical and microbiological properties of 30 bottled water brands and assessed their compliance with WHO and Libyan drinking water standards.

Physical and chemical properties

pH

The pH value is a critical parameter in evaluating the suitability of water for human consumption and other uses. Increasing the pH gives the water an intense color and bitter taste, while a low pH may erode the metal containers **(Toma, 2015).** As shown in Table 2, the pH values of the 30 bottled water brands ranged from 5.95 (Bw_{26}) to 8.6 (Bw_8). Thirteen of the 30 bottled water samples were found to be very slightly acidic, with a pH below 7 units. The basicity of water is mostly related to the existence of carbonate and bicarbonate salts, while the acidity of water is mostly related to the solubility of acidic gases such as carbon dioxide, in addition to the existence of basic minerals that are both monovalent and divalent (**Najah et al., 2021; Albaqshi et al., 2017**). From Table 2, it may be seen that the pH value of the ten studied samples is lower than the minimum range of drinking water set by WHO (6.5-8.5) and the Libyan standard (6.5-8), and only one sample with pH 8.6 was over the range recommended by WHO and the Libyan standard. The pH value of all other studied samples was found within accepted limits. The results of this study for pH were in agreement with the study by **Abouglaida et al. (2022)**, who reported the pH value of drinking bottled water marketed in Libya ranged between 5.6-8.4 .

Table 2: The value of physicochemical parameters in the investigated bottled water.

Sample	pH	TDS mg/L	EC μs/cm	$CaCo_3$ mg/L	Mg^{2+} mg/L	Fe^{2+} mg/L	Cl^- mg/L	HCo_3^- mg/L
Bw_1	7.4	127	195.3	21	3	-	14.5	27.45
Bw_2	6.94	132.6	222	12	3	-	38	36.6
Bw_3	7.48	99.1	152.6	16	4	-	72.0	21.35
Bw_4	7.0	128.0	197.0	11	29	0.03	0.3	6.1
Bw_5	7.0	77.0	128.4	11	3	0.01	18	27.45
Bw_6	7.03	73.8	123.4	12	3	0.01	18	18.3
Bw_7	7.4	141	204	16	4	-	34.0	15.25
Bw_8	8.6	82.4	138.7	12	3	-	10.0	12.2
Bw_9	7.33	49.2	82.5	33	8	-	13.5	21.35
Bw_{10}	6.86	94.2	156.7	25	6	-	22.5	24.4
Bw_{11}	7.07	79.5	132.7	4	1.2	0.01	25.5	15.25
Bw_{12}	7.00	120.1	201	29	7	-	30.0	57.95
Bw_{13}	6.46	110.4	184.5	33	8	0.02	14.5	36.6
Bw_{14}	7.5	106.2	163.5	12	3	-	27.5	30.5
Bw_{15}	7.40	81.06	136.3	16	4	0.01	15.5	27.45
Bw_{16}	6.52	100	165.5	21	5	-	30.0	42.7
Bw_{17}	6.32	31.0	51.7	16	4	0.01	6.8	18.3
Bw_{18}	7.0	100	156.5	45	11	-	12.5	39.65
Bw_{19}	7.07	124	210	21	5	-	42.0	21.35
Bw_{20}	7.07	145.6	243	18	1	-	48.0	21.35
Bw_{21}	6.07	107.5	179.3	17.5	2	-	28.0	21.35
Bw_{22}	6.08	101.5	169.4	40	7	-	28.5	30.5
Bw_{23}	7.45	113	141.5	8	2	0.01	34.0	21.35
Bw_{24}	6.30	113.4	189.4	21.0	5	-	19.0	33.55
Bw_{25}	6.35	111.6	185.5	25.0	6	0.01	20.5	36.6
Bw_{26}	5.95	131.6	219	29	7	-	46.0	18.3
Bw_{27}	6.22	82.4	136.6	24	3	-	17.0	21.35
Bw_{28}	7	239	397	16	4	0.01	44	21.35
Bw_{29}	5.97	98.8	164.7	4	1.2	0.01	25.5	15.25
Bw_{30}	6.17	131.6	219	12	3	-	18	18.3

Electrical conductivity (EC)

EC values ranged from 51.7 μs/cm (Bw_{17}) to 397 μs/cm (Bw_{28}), well within WHO and Libyan limits (1000–2500 μs/cm). This indicates low salinity and good mineral balance in all samples **(Najah et al., 2021).** The EC of all samples was found within permissible limits as shown in Fig. 1. Therefore, all the bottled water samples were safe for drinking from the electrical conductivity point of view in the present study. Similar results were obtained by by **Yilkal et al. (2019)** for EC levels in bottled water. **Sasikaran et al. (2014)** has reported electrical conductivity ranged from 19-253 µs/cm. The minimum and maximum value of the EC is lower than the value of this study.

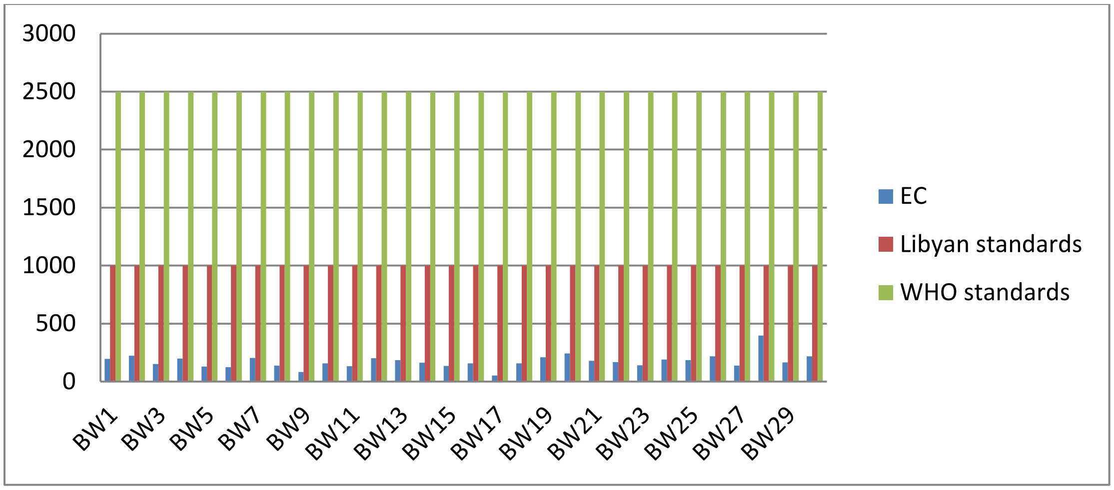

Figure 1: EC values of studied samples compared with WHO and Libyan standards.

Total dissolved solids (TDS)

The concentration of total dissolved solids in the studied bottled water samples ranged from 31 to 239 mg/l (Table 2). The lowest total dissolved solid value was found in Bw_{17}, while the highest total dissolved solid value was found in Bw_{28} bottled water. Total Dissolved Solids (TDS) refers to the combined content of inorganic salt and organic substances, and the taste of water is significantly influenced by the presence of dissolved solids; water with very low levels of dissolved solids can taste flat or bland, while high TDS could impact taste in drinking water **(Chimtali et al ., 2023)**. Eleven samples fell below Libyan guidelines (100–500 mg/L), which may suggest low mineral content as shown in Fig.2. While low TDS is not directly harmful, very soft water may be less palatable and may lack essential minerals **(Almontasir et al., 2024)**. The TDS values were similar to these reported by **Al-omran et al. (2012)** from Riyadh City, Saudi Arabia, and **Ellawala et al. (2017)** from Sri Lanka. TDS values in bottled drinking water obtained in the present study were lower than those obtained by **Salehi et al. (2014)** from Iran.

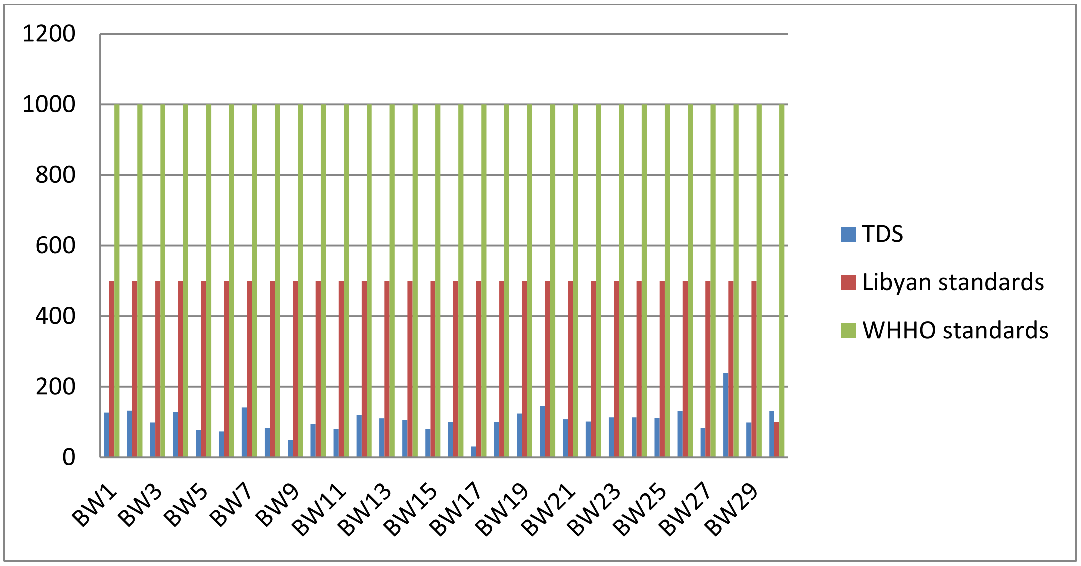

Figure 2: TDS values of studied samples compared with WHO and Libyan standards.

Total hardness (TH)

Water hardness is mainly determined by the concentration of Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) ions, which are found in the forms of carbonate and bicarbonate **(Toma, 2015)**. From Table 2, it may be seen that the values of total hardness of the studied samples ranged from 4 to 40 mg/l as calcium carbonate, and the lowest concentration was found in Bw_{11} while the highest concentration was found in $Bw_{18.}$ The maximum acceptable level of total hardness in bottled and drinking water according to WHO guidelines and Libyan standards is 500 mg/l and 200 mg/l as $CaCO_3$, respectively. Thus, TH values were within the permissible level as shown in Fig. 3.

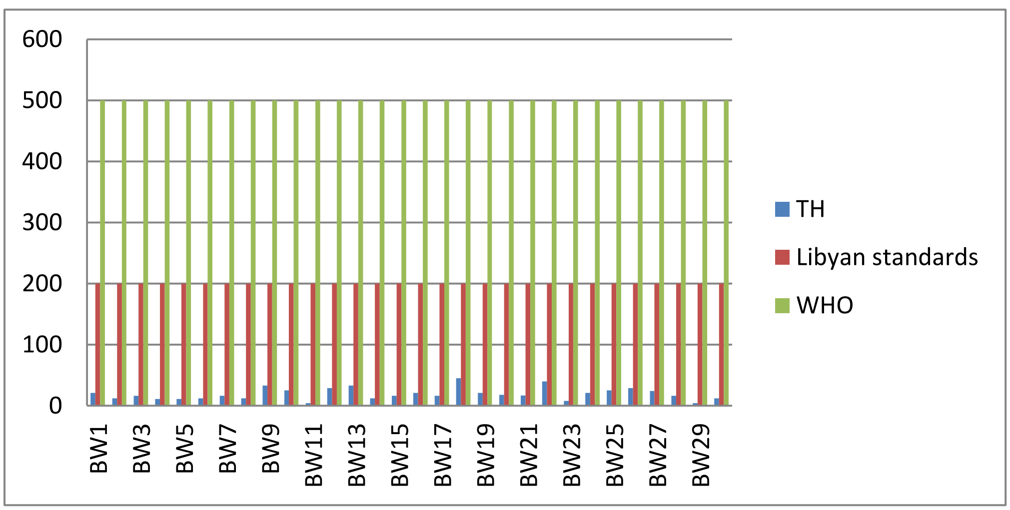

Figure 3: TH values of studied samples compared with WHO and Libyan standards.

Magnesium (Mg^{2+})

Magnesium is a main hardness component of water and plays a vital role in human health **(Hussein, 2014)**. excessive consumption of this component causes various illnesses such as kidney stones and osmotic diarrhea, while insufficient consumption of this component can harm health and has been linked to increased risks of hypertension, osteoporosis, colorectal cancer, stroke, coronary artery disease, obesity, and insulin resistance **(Alam et al., 2017).** From the results shown in the Table 2 , Magnesium concentrations ranged from 1 mg/l (Bw_{20}) to 29 mg/l (Bw_4), all within the WHO limit of 150 mg/L as shown in Fig. 4. These findings align with **Hussein (2014),** suggesting safe levels for human consumption.

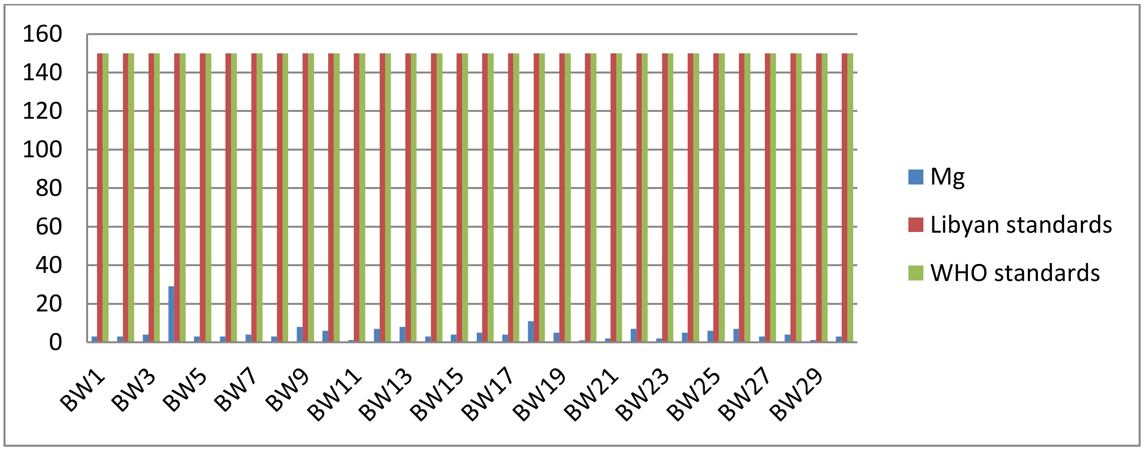

Figure 4: Magnesium concentration in studied samples compared with WHO and Libyan standards.

Chloride (Cl^-)

Chloride content of 30 brands of bottled water ranged from 0.3 to 72.0 mg/l. The lowest mean concentration of chloride was found in Bw_4 , while the highest mean concentration of chloride was found in Bw_3 bottled water (Table 2). Chloride in natural water sources is typically present in low concentrations, but various human activities can lead to increased levels, such as rock waste water from industries and waste water from treatment plants. Although the presence of chloride is required to eradicate many illnesses, including cholera, typhoid, and amoebic dysentery, the rate of increase has led to health problems for the user, particularly when the rate is increased by approximately 100 mg/l, and the concentration of more than 250 mg/l alters the taste of water **(Dirican, 2019)**. In comparison with WHO and Libyan limits, all the bottled water samples were safe for drinking from the chloride point of view as shown in Fig. 5. These results are similar to **Abouglaide et al. (2022)**, who found that the chloride concentration of bottled water available in the Libyan market ranged between 0.47 and 71.5 mg/l.

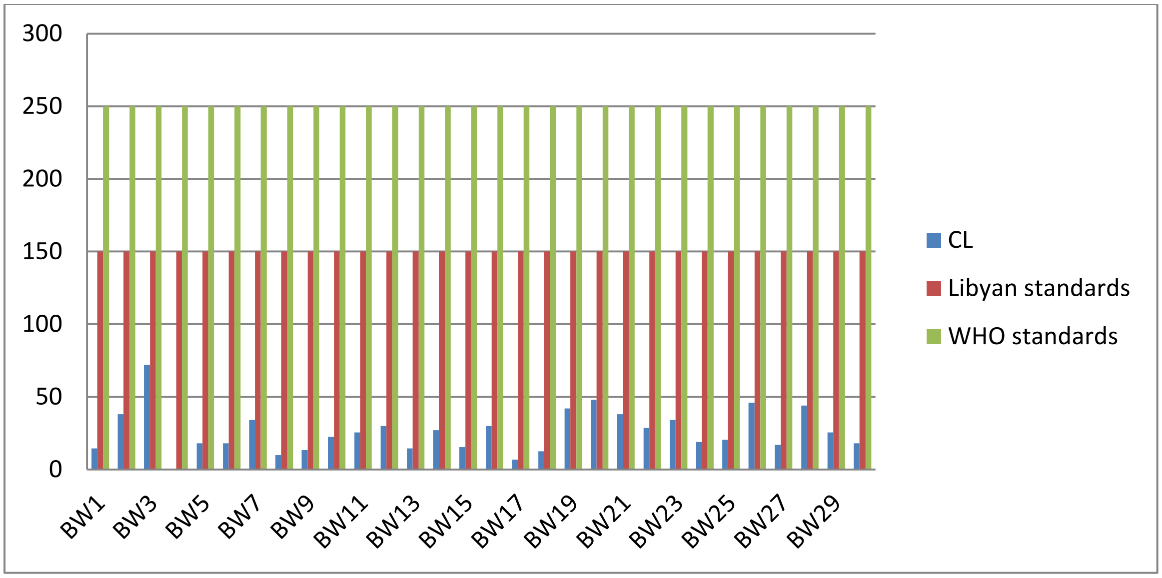

Figure 5: Chloride concentration in studied samples compared with WHO and Libyan standards.

Iron (Fe^{2+})

Iron is a necessary component of water and is involved in many physiological functions. However, too much iron can cause a number of problems, especially when it comes to food preparation and drinking water. Iron gives the water a bitter, undesirable taste that could ruin the majority of tap water-based beverages **(Alam et al., 2017)**. Eleven of the 30 samples contain iron, and these values ranged from the lowest 0.01 mg/l to the highest 0.03 mg/l ; the other samples did not contain iron (Table 2). Comparing with WHO and local standards, all samples were found to have low values, and the level of iron was within the permissible limits as shown in Fig. 6. The iron concentration of bottled water reported by **Alam et al. (2017)** ranged from 2.25 to 3.2mg/l in different bottled drinking water, whereas the concentration of iron in this study is lower than the reported value of Alam.

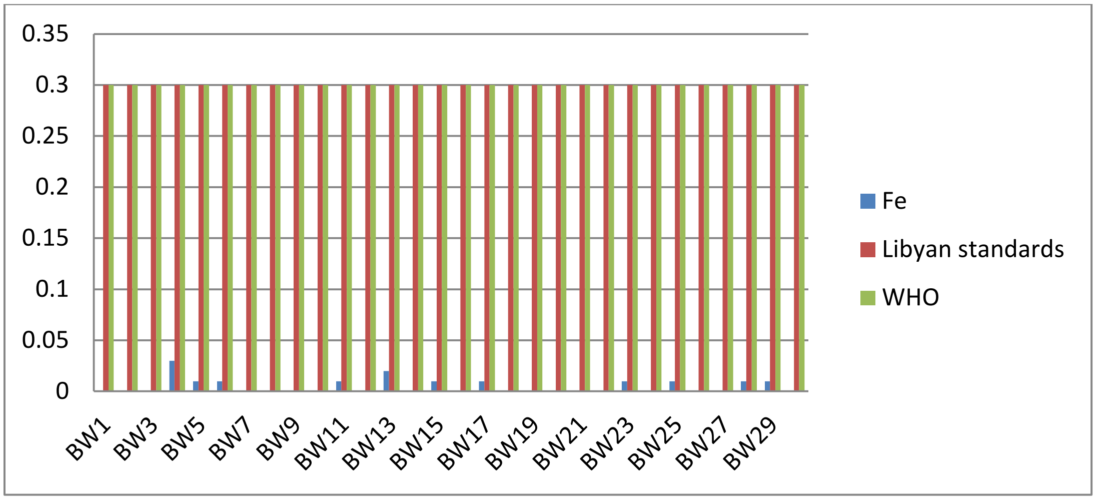

Figure 6: Iron concentration in studied samples compared with WHO and Libyan standards.

Bicarbonate (HCo_3^-)

The mean concentration of bicarbonate ranged from 6.1 mg/l to 42.7 mg/l, and the maximum concentration limit of bicarbonate set by. Libyan standards and WHO guidelines is 150 and 200 mg/l respectively. The results were within the permissible values as shown in Fig. 7. According to a study conducted by **Alfazani et al. (2017),** the minimum and maximum levels of bicarbonate were 20 and 65 mg/l, respectively, in which the concentration of bicarbonate was higher than in the present study.

Figure 7: Bicarbonate concentration in studied samples compared with WHO and Libyan standards.

Microbial properties

The total viable count for each drinking water sample collected from different Tripoli locations was determined and it was observed that the viable microbial counts of all tested bottled water samples were not detected , and all the bottled water was considered safe for drinking purposes. No microbial contamination was detected in any of the bottled water samples, indicating effective sterilization methods such as ozonation. This is consistent with previous studies from Tripoli (**Rbeida & Eteer, 2023**), suggesting adherence to safe processing practices. This situation indicates that the techniques applied by companies for disinfection are high quality and practical. However, the study by **Malik et al. (2020)** in Dehradun City, India, reported that the total viable count in drinking water of various areas ranges from 1.2×105±0.267 to 4.0×104±0.140 cfu/ml in ten types of bottled water, and according to **Sosikaran et al. (2014)** in the Jaffna Peninsula, the total aerobic count of the 22 bottled drinking waters varied from 0 to 800 cfu/ml with a mean of 262.6 (± 327.50) cfu/ml.

CONCLUSION

Bottled water consumption is steadily rising as a results of public concerns about palatability and microbial and chemical contaminants in tap water. However, the quality of bottled water may vary significantly among brands. This study investigated the physicochemical and microbial quality parameters of 30 brands of bottled water marketed in Tripoli city. The results of this study indicate that all physicochemical quality parameters of bottled water were within acceptable rang of the national and international standards, whereas TDS levels in all samples were below the WHO's permissible limits, and 11 samples that were analyzed had TDS levels below the minimum range for drinking water determined by Libyan regulations. The results of the biological analysis showed that every sample of tested bottled water was free of harmful microorganisms, and consuming this kind of bottled drinking water would not present any risk to the humans, health.

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