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Evaluation of Chemical Quality in Selected Brands of Bottled Drinking Water from Tajura, Libya

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ABSTRACT

In modern society, the consumption of bottled water has become increasingly popular due to concerns over the quality of tap water. In the face of increasing scrutiny over the quality of bottled water and its health implications, the aim of this investigation is to evaluate the chemical quality of collected brands of bottled drinking water available in Tajura, Tripoli- Libya. This research focuses on physicochemical parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS), and the concentrations of essential ions such as sodium (Na^{+}), potassium (K^{+}), calcium (Ca^{2+}), magnesium (Mg^{2+}), bicarbonate (HCO_3^{-}), and sulfate (SO_4^{2-}), using standard techniques in laboratory.The electrical conductivity (EC) measurements ranged from 114 µs/cm to 193 µs/cm, while the total hardness varied between 16.03 mg/L and 60.01 mg/L. The pH levels were found to be between 6.01 and 7.16. Potassium concentrations ranged from 0.47 to 2.02 mg/L, calcium levels from 3.21 to 9.61 mg/L, and magnesium content from 0.94 to 11.6 mg/L. Additionally, bicarbonate levels ranged from 17.1 to 30.6 mg/L, and sulfate concentrations varied from 5.1 to 10.2 mg/L.The findings were meticulously compared to both Libyan specifications and standards and World Health Organization (WHO) guidelines to determine compliance and safety standards.The results of all parameters indicated that every bottled water brand complied with safety standards established for public health regulations and policies. This study will contribute to the development of effective strategies aimed at ensuring that all individuals have access to clean and safe drinking water.

Evaluation of Chemical Quality in Selected Brands
of Bottled Drinking Water from Tajura, Libya

منصور بوفارس نور علي

ازداد في العصر الحديث استهلاك المياه المعبأة وأصبح هو الشائع وذلك بسبب المخاوف من جودة مياه الصنبور، وفي مواجهة التدقيق المتزايد على جودة المياه المعبأة وتداعياتها الصحية، فإن الهدف من هذا البحث هو تقييم المياه المعبأة لبعض العلامات التجارية في السوق الليبي بمنطقة تاجوراء. وركز هذا البحث على الخواص الفيزيائية والكيميائية للعينات المختبرة، وهي الرقم الهيدروجيني، والتوصيل الكهربائي(EC) ، وإجمالي المواد الصلبة الذائبة (TDS)، وتركيزات الأيونات الموجبة مثل الصوديوم(Na^{+}) ، والبوتاسيوم(K^{+}) ، والكالسيوم(Ca^{2+}) ، والمغنيسيوم(Mg^{2+}) ، والبيكربونات(HCO_3^{-}) ، والكبريتات(SO_4^{2-}) ، باستخدام الطرق الكيميائية القياسية في المختبر، تراوحت قياسات التوصيل الكهربائي (EC) من 114 ميكروثانية/سم إلى 193 ميكروثانية/سم، بينما تراوحت الصلابة الكلية بين 16.03 مجم/لتر و60.01 مجم/لتر. ووجد أن مستويات الرقم الهيدروجيني تتراوح بين 6.01 و7.16. وتراوحت تركيزات البوتاسيوم من 0.47 إلى 2.02 مجم/لتر، ومستويات الكالسيوم من 3.21 إلى 9.61 مجم/لتر، ومحتوى المغنيسيوم من 0.94 إلى 11.6 مجم/لتر. بالإضافة إلى ذلك، تراوحت مستويات البيكربونات من 17.1 إلى 30.6 مجم/لتر، وتراوحت تركيزات الكبريتات من 5.1 إلى 10.2 مجم/لتر. وتمت مقارنة النتائج مع كل من المواصفات الليبية ومنظمة الصحة العالمية والتي اظهرت أن مياه الشرب التي تم جمعها من علامات تجارية مختلفة كانت أكثر ملائمة للاستهلاك البشري من المياه الجوفية ومطابقة للمواصفات الليبية والعالمية.

INTRODUCTION

Water is vital for human life, and its quality greatly affects health and well-being. Increased awareness about taps water quality and concerns over plastic bottles have boosted the demand for bottled drinking water, although the quality of different brands varies significantly (Goncharuk, 2014).

Ultimately, the quality of a brand of bottled drinking water depends on a range of factors, including its source, how it is treated, and what kind of container it is stored in. By considering these factors, consumers can choose a brand that meets their individual needs and preferences. When looking for a reliable and high-quality brand, it is crucial (Hussein, Mohammed (2020). The industry of bottled water is a significant advocate for our natural resources and the environment. Companies in this sector utilize resources wisely by putting funds into technologies and methods that enhance water quality while safeguarding water resources. Among all bottled beverages, bottled water boasts the smallest environmental footprint. Research indicates that bottled water is the most eco-friendly option available among bottled drinks (Grebitus et al., 2020).

Moreover, the industry is dedicated to minimizing plastic waste through the adoption of sustainable packaging solutions and the promotion of recycling initiatives. By collaborating with local communities and conservation groups, bottled water companies aim to safeguard and maintain the water sources of our planet for generations to come. A simple method for initiating a lifestyle change is opting for water in place of sugary beverages. In our fast-paced society, where many drinks come in packages, choosing bottled water is a wise decision to cut down on or remove calories, sugar, caffeine, artificial flavors and colors, along with other additives from your diet. Following a natural disaster or other catastrophic event, access to clean and safe water is essential for both citizens and first responders. Sadly, public water systems frequently experience disruptions in water delivery during these situations. In such instances, the most effective solution for swiftly supplying clean, safe drinking water to impacted regions is bottled water (Pacheco-Vega 2019).

Consumers opt for bottled water due to its safety, reliability, and convenience for healthy hydration. Bottled water, whether sourced from protected aquifers or municipal supplies, is produced to meet high safety and quality standards (Valavanidis, 2020). The multi-barrier process utilized in production prevents contamination from harmful microorganisms and includes source protection, monitoring, and various purification methods such as reverse osmosis and UV light. This ensures that bottled water remains a trusted option for hydration at home, work, or during emergencies) Treacy, 2019).

Materials and METHODS

Water samples

Nine different samples of bottled water (0.50 L) were collected from the local markets of Tripoli, Libya (Bs1, Bs2, Bs3, Bs4, Bs5, Bs6, Bs7 Bs8, Bs9) and the bottles were closed tightly and kept in a dry and cool place before analysis.The study was conducted over a week (5/2024). The bottled water samples were taken to Advanced Laboratory of Chemical Analysis Tajura, Tripoli- Libya. The study will analyze bottled water qualitatively, examining chemical and physical properties such as pH, electrical conductivity (EC), total dissolved solids, calcium, sodium, total hardness, bicarbonate, sulfate, and potassium. The findings will be compared against Libyan specifications and standards and World Health Organization limits.

Various physical parameters such as pH (measured with HANNA HI 8314), TDS, and EC were determined using a digital multiparameter device (HACH HQ 40D). Calcium (Ca2+), magnesium (Mg2+), chloride (Cl-), bicarbonate (HCO3-), and sulfate (SO42-) were determined by volumetric titration method, while sodium (Na+) and potassium were determined by flame photometry as following the standard protocols and procedures of American Public Health Organization (APHA, 2017)

The experiments were performed in triplicate, and means with standard deviation were calculated using standard statistical procedures. Statistical analysis was performed on the data, and the coefficient of determination (R) was calculated using Microsoft Exce

RESULTS AND DISCUSSION

The permissible pH range for drinking water is between 6.5 and 8.5. Data from Table 1 shows that pH levels in the samples ranged from 6.01 (Bs6) to 7.15 (Bs1). All samples met Libyan specifications and standards (Libyan National Center, 1992) and World

Health Organization (6.5-8.5) (World Health Organization, 2017), except for sample Bs1. The study found that the pH value of water sample Bs1 was below the Libyan specifications and standards of 6.01, indicating it is too acidic for safe consumption. This acidity can cause tooth decay, hinder calcium absorption, and lead to bone loss and heavy metal accumulation. Alkalinity in water, caused by carbonates and minerals, can affect taste, color, and metal corrosion. Water is considered alkaline if its pH reaches 9.0 for extended periods, potentially harming biodiversity and organ health. Additionally, a significant correlation (r = 0.63) was observed between electrical conductivity (EC) and pH levels.

Table (1): Chemical and physical composition of bottled water samples (mean ±SD

Sample	PH	COND	TDS	T.H
Bs1	7.16	246	160	20.02
	±0.58	±0.29	±0.50	±0.44
Bs2	6.36	163	106	16.03
	±0.85	±0.35	±0.50	±0.55
Bs3	6.85	167	108	24.02
	±0.79	±0.51	±0.38	±0.60
Bs4	6.09	153	100	20.02
	±0.66	±0.45	±0.57	±0.79
Bs5	7.09	193	126	28.03
	±0.39	±0.78	±0.78	±0.50
Bs6	6.01	129	84	16.01
	±0.41	±0.77	±0.81	±0.58
Bs7	6.65	170	111	36.03
	±0.89	±0.83	±0.63	±0.37
Bs8	6.52	193	125	60.00
	±0.70	±0.70	±0.77	±0.80
Bs9	6.72	114	75	20.02
	±0.88	±0.55	±0.85	±0.20
Libyan Standards	**6.5. – 8.5**	**400**	**≤ 500**	**200**
WHO	**6.5-8.5**	**450-1500**	**500-1000**	**500**

Table (2): Chemical composition of bottled water samples (mean ±SD

Sample	Ca.H	Ca	Mg	HCO_3^-
Bs1	8.00	3.21	2.92	25.1
	±0.48	±0.75	±0.45	±0.45
Bs2	8.00	3.21	1.94	17.2
	±0.80	±0.54	±0.45	±0.52
Bs3	16.01	6.41	1.94	22.3
	±0.72	±0.70	±0.75	±0.68
Bs4	12.01	4.81	1.94	29.2
	±0.77	±0.58	±0.55	±0.42
Bs5	24.02	9.62	0.97	31.01
	±0.55	±0.47	±0.85	±0.52
Bs6	8.02	3.21	1.94	20.05
	±0.69	±0.70	±0.77	±0.68
Bs7	20.02	8.15	3.89	28.09
	±0.54	±0.48	±0.65	±0.70
Bs8	12.01	4.81	11.66	24.07
	±0.87	±0.55	±0.35	±0.77
Bs9	16.14	6.41	0.94	30.06
	±0.57	±0.60	±0.61	±0.54
Libyan Standards		**200**	**-**	**150**
WHO		**30-200**	**10-50**	**200**

Table (3): Chemical composition of bottled water samples (mean ±SD

Sample	SO4	Na	K
Bs1	9.1	17.73	1.06
	±0.66	±0.68	±0.56
Bs2	7.2	17.10	0.47
	±0.71	±0.71	±0.70
Bs3	8.1	11.83	0.57
	±0.54	±0.46	±0.69
Bs4	6.3	18.21	0.78
	±0.77	±0.59	±0.58
Bs5	6.1	15.71	0.76
	±0.35	±0.63	±0.75
Bs6	10.2	16.81	0.55
	±0.56	±0.80	±0.60
Bs7	7.3	15/78	0.80
	±0.78	±0.80	±0.79
Bs8	5.1	0.36	0.87
	±0.77	±0.78	±0.50
Bs9	8.1	5.37	2.06
	±0.66	±0.76	±0.58
Libyan Standards	**150**	**100**	**12**
WHO	**400**	**30-200**	**12**

pH concentrations of samples in the literature have been reported to be in the ranges: 6.69 to 7.73 (Dirisu et al., 2016), 6.43 to 7.69 (Najah et al., 2021), 6.2 to 6.6 (Yilkal et al., 2019), 6.92 to 7.45 (Chimtali et al., 2023), 6 to 8 (Fhelboom et al., 2020), 7.3 to 7.49 (Brika et al., 2022), respectively. The pH results of all samples were in agreement literature.

Electrical conductivity (EC) measures water's capacity to conduct electric current, which is directly linked to the concentration of ions from dissolved salts and inorganic substances like alkali metals, chlorides, sulfides, and carbonate compounds. The conductivity values of the tested samples ranged from 114 to 246 µs/cm, with sample Bs1 having the highest value and sample Bs9 the lowest, as shown in Table 1.

EC values exceeding the allowed values increase the salinity of the water, making the taste of the water unacceptable. According the Libyan specifications and standards the maximum acceptable concentration of sodium in drinking water is 500 μs/cm (Libyan National Center, 1992) and the World Health Organization (450-1500 μs/cm) (World Health Organization, 2017). In this study, there was a strong correlation (r = 0.99) between EC and TDS.

The findings presented in the literature have been reported to be in the ranges:20.30 to 228.50 (Dirisu et al., 2016), 9.87 – 266 (μs/cm) (Najah et al., 2021) ,6.54–90.15 μs/cm (Yilkal et al., 2019),1.43–4.17 μs/cm (Brika et al., 2022), respectively. The EC results of all samples were in agreement literature. there are currently no health guidelines for minimum permissible conductivity in drinking water.

Total Dissolved Solids (TDS) in bottled water measures the combined inorganic and organic substances in water, indicated in parts per million (ppm) or milligrams per liter (mg/L). TDS includes inorganic salts like calcium, potassium, magnesium, sodium, and small organic matter (Imneisi , 2023). Results are shown in Table 1, TDS readings from 75 mg/L(Bs9) to 160 mg/L(Bs1), all below the accepted parametric values set by Libyan specifications and standards (<200 mg/L) (Libyan National Center, 1992) and the World Health Organization (<500 mg/L) (World Health Organization, 2017).

The mean concentration of total dissolved solids of samples in previous studies have reported to be in the ranges: 63-102 (mg/L) (Najah et al., 2021), 6.54–90.15 (Yilkal et al., 2019),45.5 –89.9 mg/L [13], 13–122 mg/L (Chimtali et al., 2023), respectively. The pH results of all samples were in agreement literature.

The mean concentration of total hardness mg/L in the literature have been reported to be in the ranges:4.00 to 97.3 (Najah et al., 2021). In this paper, there was a high correlation (r =0.97) between T.H and K.

Calcium hardness (CaCO3) is a common measure of water hardness and mineral content in bottled water. The level of calcium and magnesium in water determines its hardness, usually measured in terms of CaCO3. Water with less than 60 mg/L of calcium carbonate is typically considered to be soft. In the bottled water sample, the average calcium hardness ranged from 8.0 to 24.02 mg/L (Table 2). The lowest magnesium concentration was observed in samples Bs1 and Bs2, while the highest was found in sample Bs7, as indicated in .

The mean concentration of calcium hardness mg/L in the literature has been reported to be in the ranges:70 to 330 (Islam, 2017). In this paper, there was a high correlation (r =0.99) between Ca and Ca.H.

Studies have generally found that calcium and magnesium in drinking water have positive effects on cardiovascular health (Abd El-Salam et al., 2008). Adequate calcium intake is essential for achieving peak bone mass and preventing osteoporosis (Furtado et al., 2008).

Calcium is an essential mineral found in various bottled water brands, contributing to the overall mineral content and health benefits of the water (Pop et al., 2008). The mean calcium concentration was found in the range of 3.21-9.62 mg/L., and the results are summarized in Table 2. The highest concentration of calcium was found in Bw5 bottled water samples while the lowest values were found in Bs1, Bs2, and Bs6. All the bottled water samples are below the World Health Organization permissible limit (200 mg/L) and all bottled water is safe to drink. Although for all the bottled water samples the calcium is below the Libyan specifications and standards (<200 mg/L) (Libyan National Center, 1992)

The mean concentration of calcium of samples in several studies have documented have been reported to be in the ranges: 12.15–89.34.15 [12], 4.5 – 7 mg/L [13], 0–13 mg/L [14], respectively. The mean calcium of all samples was in agreement literature.

Magnesium is essential for the synthesis and stability of nuclear DNA and for the mineralization of bone (Vitoria et al., 2014). All sampling in the current investigation had magnesium readings that ranged between 0.943228 mg/L (Bs 7) and 3.892031 mg/L (Bs 9), according to Table 2. The results of the magnesium are presented.

The results indicated that the mean concentration of magnesium of samples were less than World Health Organization (10-50 mg/L) (World Health Organization, 2017). Several reports have shown the mean of magnesium mg/L has been reported to be in the ranges: 0.69-7.91 mg/L (Yilkal et al., 2019), 5-100 mg/L) (Fhelboom et al., 2020), the mean of magnesium (mg/L) results of all samples were in agreement literature. In this paper, there was a high correlation (r =0.99) between Mg with So4, K and Ca.

Bicarbonate is one of the elements that may naturally occur in water. Bicarbonate mineral water can neutralize stomach acid, increase the pH level in the gastric lumen, and stimulate the release of digestive hormones, which can improve gastric function and potentially relieve acid reflux (Kinney et al., 1998).
Bicarbonate levels in drinking water can significantly influence its taste and mouthfeel. Higher bicarbonate concentrations can impart a slightly salty taste and a smoother mouthfeel, which some consumers may find more pleasant (Quattrini et al., 2016).
The mean concentration of bicarbonate ranged from 17.02 to 30.06 mg/L in Bw2 and Bw9, respectively (Table 2; 8). The maximum concentration limit of bicarbonate set by the World Health Organization (WHO) is 200 mg/L (World Health Organization, 2017). For all bottled water samples, the calcium content is below the Libyan specifications and standards values (<150 mg/L) (Libyan National Center, 1992). The concentration of bicarbonate found in this study is acceptable for drinking purposes. The study also found a high correlation (r = 0.99) between HCO3, K, and SO4.
The concentrations of bicarbonate in imported brands, Zamzam water, and tube-well water were found to be 395 mg/L, 217.47 mg/L, and 293.91 mg/L, respectively (Whelton et al., 2007).

Sulfate is a substance that occurs naturally in drinking water. Health concerns regarding sulfate in drinking water have been raised because of reports that diarrhea may be associated with the ingestion of water containing high levels of sulfate (Backer et al., 2005). In the study, the mean sulfate concentration ranged from 5.1 to 10.2 mg/L in Bw8 and Bw6, respectively (Table 3.). The concentrations of sulfate in this study are below in Libyan specifications and standards (150 mg/L) (Libyan National Center, 1992) and World Health Organization limit. (400 mg/L) (World Health Organization, 2017). High levels of sulfate in drinking water have been linked to various health effects, including potential impacts on gastrointestinal health and an increased risk of developing kidney stones (Kozisek, 2005).

This indicates that sulfate levels in bottled water are consistently low and well within the recommended range of 250 mg/L to 400 mg/L, as per standard guidelines. Furthermore, laboratory tests on various bottled water brands have revealed sulfate concentrations ranging from 0 to 10 mg/L, providing further evidence of the low sulfate levels in bottled water (Kozisek ,2005). The study also found a strong correlation (r = 0.99) between sulfate and calcium, as well as between sodium, potassium, and sulfate.

The mean concentration of sodium in all samples from 0.36 to 18.21 mg/L as Table(3), that the values are in accordance with values given by Libyan specifications and standards (100 mg/L) (Libyan National Center, 1992) and World Health Organization (200 mg/L) (World Health Organization, 2017). The mean of sodium concentration in the literature have been reported to be in the ranges: 2.7 to 4.5 (mg/L), (Dirisu et al., 2016), 6 to 32 mg/L (Fhelboom et al., 2020),13.6 to 34.8 mg/kg (Chimtali et al., 2023), the mean concentration of sodium results of all samples was in agreement literature.

Potassium is an important component of cellular fluid, and along with Sodium, it plays an important role in regulating osmosis, as well as an important base in the conduction of nerve impulses (Pohl et al., 2013).

The experimental results are presented in Table 3, found that sample Bs4 has the lowest concentration of potassium (0.30 ppm) while sample Bs9 recorded highest concentration (2.06 ppm). The permissible value of Mean potassium concentration by Libyan specifications and standards (10 mg/L) (Libyan National Center, 1992) and World Health Organization (10 mg/L) (World Health Organization, 2017).

The mean concentration of potassium concentration in the literature have been reported to be in the ranges: 0.7 to 1.4 mg/L (Dirisu et al., 2016), 0.11– 0.92 mg/L (Yilkal et al., 2019), 0.0 –0.3 mg/L (Chimtali et al., 2023), respectively. The mean of Potassium results of all samples was in agreement literature. In this paper, there was a high correlation (r =0.99) between K with So4 and Ca.

Conclusion:

- The study indicates that the bottled drinking water available in Tajura, Tripoli- Libya., maintains high compliance with both Libyan specifications and standards and World Health Organization.
- The evaluated brands displayed pH, electrical conductivity, and concentrations of key ions – Na, K, Ca, Mg, HCO_3, and SO_4 – all within acceptable ranges. This comprehensive quality assessment supports the safety and reliability of these bottled water brands for daily consumption.
- Implications for Public Health: Given the outcomes, consumers can be assured of the chemical safety of bottled waters in Tajura, Tripoli- Libya, enhancing public confidence and potentially guiding policy decisions for further monitoring and quality control by regulatory agencies.
- Future Research: Continuous and more extensive monitoring, encompassing a broader spectrum of chemical and microbiological parameters, is recommended to sustain public trust and uphold water quality standards amid changing environmental and industrial conditions.

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