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Comprehensive Safety and Quality Profiling of Bottled Drinking Water in Tripoli, Libya: A Combined Chemical and Microbiological Assessment

Mansor S. Bofaris *
High Institute for Medical Sciences and Technology, Garabolli, Libya

التقييم المتكامل لسلامة وجودة مياه الشرب المعبأة في مدينة طرابلس – ليبيا: دراسة كيميائية وميكروبيولوجية

منصور سليمان بوفارس *
المعهد العالي للعلوم والتقنيات الطبية، القره بوللى، ليبيا

*Corresponding author: mansor.bofars@gmail.com

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Abstract
Bottled drinking water has become an increasingly important source of potable water worldwide, particularly in regions where concerns regarding the safety of tap water and the reliability of public water supply systems persist. This study aimed to evaluate the physicochemical and microbiological quality of selected bottled drinking water brands and to assess their compliance with Libyan drinking water standards and the World Health Organization (WHO) guidelines.
A total of ten commercially available bottled water brands (Bs1–Bs10) were analyzed. Physicochemical parameters including pH, total dissolved solids (TDS), total hardness, bicarbonate (HCO_3^-), chloride (Cl^-), sulphate (SO_4^{2-}), sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^+) were determined using standard analytical methods such as pH meter measurement, conductivity-based TDS determination, EDTA titration for hardness, acid–base titration for bicarbonate, argentometric titration for chloride, turbidimetric determination for sulphate, and flame photometry or atomic absorption spectrophotometry for major cations.
Microbiological quality was assessed by determining the total viable count (TVC) at 22°C for 72 h and at 37°C for 48 h, as well as the presence of total coliforms and *Escherichia coli*. The results showed that TVC values ranged from 0 to 2 CFU/ml at 22°C and from 0 to 1 CFU/ml at 37°C. Total coliforms and *E. coli* were not detected in any of the analyzed samples.
Overall, the results indicated that all bottled water brands complied with both Libyan standards and WHO guidelines for drinking water quality. The physicochemical parameters were within acceptable limits, while the absence of indicator bacteria confirmed the microbiological safety of the examined samples. Continuous monitoring of bottled water quality is recommended to ensure consumer protection and maintain public health standards.

Keywords: Bottled drinking water; Physicochemical analysis; Microbiological quality; Total viable count; *Escherichia coli*; Drinking water standards; Water quality assessment.

الملخص
أصبحت المياه المعبأة مصدرا متزايد الاهمية لمياه الشرب في مختلف انحاء العالم، ولا سيما في المناطق التي تتزايد فيها المخاوف المتعلقة بسلامة مياه الشبكات العامة وموثوقية نظم امداد المياه. هدفت هذه الدراسة الى تقييم الجودة الفيزيائية والكيميائية والميكروبيولوجية لعدد من العلامات التجارية للمياه المعبأة، والتحقق من مدى مطابقتها للمواصفات القياسية الليبية وارشادات منظمة الصحة العالمية الخاصة بجودة مياه الشرب.
شملت الدراسة تحليل عشر علامات تجارية من المياه المعبأة. (Bs1–Bs10) وتم تحديد مجموعة من المؤشرات الفيزيائية والكيميائية الرئيسة، من بينها الاس الهيدروجيني(pH) ، واجمالي المواد الصلبة الذائبة(TDS) ، والعسر الكلي، وايونات البيكربونات(-HCO3) ، والكلوريد(-Cl) ، والكبريتات(-SO4 2) ، والصوديوم(+Na) ، والكالسيوم(+Ca2) ،

والمغنيسيوم(+Mg2) ، والبوتاسيوم .(+K) وقد استخدمت في التحليل طرق كيميائية قياسية شملت القياس بجهاز الاس الهيدروجيني، وتحديد المواد الصلبة الذائبة اعتمادا على التوصيلية الكهربائية، ومعايرة EDTA لتحديد العسر الكلي، والمعايرة الحمضية القاعدية لتحديد البيكربونات، والمعايرة الارجنومترية لتحديد الكلوريد، والطريقة العكارية لتحديد الكبريتات، اضافة الى استخدام الفوتومتر اللهبي او مطيافية الامتصاص الذري لتحديد الايونات الموجبة الرئيسة.
كما تم تقييم الجودة الميكروبيولوجية من خلال تحديد العدد الكلي للبكتيريا الحية (TVC) عند درجتي حرارة 22 درجة مئوية لمدة 72 ساعة و37 درجة مئوية لمدة 48 ساعة، اضافة الى الكشف عن بكتيريا القولونيات الكلية وبكتيريا الاشريكية القولونية .(E. coli) واظهرت النتائج ان قيم العدد الكلي للبكتيريا تراوحت بين 0 و2 وحدة تكوين مستعمرة لكل مل عند 22 درجة مئوية، وبين 0 و1 وحدة تكوين مستعمرة لكل مل عند 37 درجة مئوية، في حين لم يتم الكشف عن القولونيات الكلية او بكتيريا E. coli في اي من العينات المدروسة.
وبشكل عام اظهرت النتائج ان جميع العلامات التجارية للمياه المعبأة محل الدراسة تتوافق مع المواصفات القياسية الليبية وارشادات منظمة الصحة العالمية لجودة مياه الشرب، حيث كانت الخصائص الفيزيائية والكيميائية ضمن الحدود المقبولة، كما أكد غياب البكتيريا الدالة على التلوث البرازي سلامة هذه المياه من الناحية الميكروبيولوجية. وتؤكد هذه النتائج اهمية الاستمرار في مراقبة جودة المياه المعبأة لضمان حماية المستهلك والحفاظ على معايير الصحة العامة.

الكلمات المفتاحية: المياه المعبأة، الخصائص الفيزيائية والكيميائية، الجودة الميكروبيولوجية، العدد الكلي للبكتيريا، الاشريكية القولونية، معايير مياه الشرب، تقييم جودة المياه.

1-Introduction

Water is a fundamental requirement for human survival, and the quality of drinking water is closely associated with public health and overall well-being. In recent years, growing public awareness of potential issues related to tap water quality, combined with increasing concern about the safety and storage conditions of household water supplies, has contributed to a noticeable rise in the consumption of bottled drinking water. At the same time, environmental concerns regarding plastic bottle use have stimulated broader discussions about the sustainability of bottled water production. Despite its popularity, the quality of bottled water may vary among brands depending on several production and quality-control factors [1].

The safety and overall quality of bottled drinking water are influenced by multiple variables, most notably the origin of the water, the purification technologies employed during processing, and the materials used for packaging and storage. Careful evaluation of these factors enables consumers to identify products that meet acceptable safety standards and suit their individual preferences. Consequently, when selecting bottled water, attention should be directed toward the reliability of the water source, the effectiveness of treatment processes, and the quality assurance measures implemented by manufacturers [2].

In addition to meeting consumer demand for safe hydration, the bottled water industry has increasingly incorporated principles of sustainable resource management into its operations. Many companies are investing in advanced purification technologies and improved production practices aimed at enhancing water quality while minimizing environmental impact and conserving freshwater resources. Comparative assessments of packaged beverages have suggested that bottled water generally has a relatively lower environmental footprint when contrasted with other commercially packaged drinks, particularly those requiring additional ingredients, energy-intensive processing, or refrigeration [3].

Furthermore, industry initiatives increasingly emphasize reducing environmental burdens associated with packaging materials. Manufacturers have introduced recycling programs and alternative packaging strategies designed to decrease plastic waste and encourage circular resource use. Collaboration with environmental organizations and local communities also plays a role in protecting natural water sources and ensuring their long-term sustainability.

From a public health perspective, selecting water as a primary beverage represents a simple but effective lifestyle adjustment. Substituting water for sugar-sweetened beverages can significantly reduce the intake of calories, sugars, caffeine, and artificial additives that are commonly present in many commercial drinks. In modern societies where convenience often shapes consumer choices, bottled water offers a readily available option that supports healthier hydration habits.

Bottled water also plays a critical role during emergency situations. Natural disasters, infrastructure failures, or other catastrophic events can disrupt public water supply systems, leaving communities without immediate access to safe drinking water. Under such circumstances, bottled water provides a rapid and practical means of delivering potable water to affected populations and emergency responders, thereby supporting relief operations and protecting public health [4].

Consumers frequently perceive bottled water as a dependable and convenient source of safe hydration. Whether the water originates from protected underground aquifers or is derived from treated municipal supplies, bottled water products are typically processed under strict regulatory and quality-control standards. These standards are designed to ensure that the final product meets established safety requirements for drinking water [5].

The production of bottled water commonly relies on a multi-barrier safety approach intended to prevent contamination by microorganisms or other harmful substances. This approach generally includes protection of the water source, continuous monitoring of water quality, and the application of purification technologies such as reverse osmosis, filtration, ozonation, or ultraviolet (UV) disinfection. Through these combined measures, bottled water manufacturers aim to maintain consistent product safety and quality, reinforcing consumer confidence in bottled water as a reliable hydration option in everyday life and during emergency conditions [6].

2- Materials and Methods

2.1 .Water Samples

Ten different bottled water samples (0.50 L each) were collected from local markets in Tripoli, Libya (designated as Bs1 through Bs10). The samples were stored in a cool, dry place prior to analysis. The study was conducted over one week in May 2024. All samples were transported to the analytical laboratory in Tripoli, Libya, for comprehensive analysis.

The study employed qualitative analysis of bottled water, examining key chemical and physical properties including pH, electrical conductivity (EC), total dissolved solids (TDS), calcium, sodium, total hardness, bicarbonate, sulfate, and potassium. The findings were compared against Libyan national specifications and standards, as well as World Health Organization guidelines.

2.2 Laboratory Analysis

Various physical parameters including pH (measured using HANNA HI 8314 pH meter), TDS, and EC were determined using a digital multiparameter device (HACH HQ 40D). Calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), bicarbonate (HCO_3^-), and sulfate (SO_4^{2-}) concentrations were determined by volumetric titration methods, while sodium (Na^+) and potassium (K^+) were quantified using flame photometry. All analyses followed standard protocols and procedures established by the American Public Health Association [7].

All experiments were performed in triplicate, with means and standard deviations calculated using standard statistical procedures. Statistical analysis was performed on the data, and the coefficient of determination (R^2) was calculated using Microsoft Excel.

2.3. Microbiological Analysis

Water samples were analyzed for microbial contamination following standard methods:

1. Total Viable Count (TVC): Using the pour plate method with Plate Count Agar (PCA), incubated at 37°C for 48 hours for mesophilic bacteria, and at 22°C for 72 hours for psychrophilic bacteria.
2. Total Coliforms: Determined by membrane filtration technique (0.45 µm pore size) using m-Endo Agar LES, incubated at 37°C for 24 hours. Results expressed as colony-forming units per 100 ml (CFU/100ml).
3. Escherichia coli: Confirmed from coliform colonies using Chromocult Coliform Agar and biochemical tests (IMViC: Indole, Methyl Red, Voges-Proskauer, Citrate). Results expressed as CFU/100ml.
4. Quality Control: Sterility controls (negative controls using sterile distilled water) and positive controls (using reference strains: *E. coli* ATCC 25922) were included in each batch of analysis.

Incubation conditions and media were prepared according to APHA standards [7]. All analyses were performed in triplicate under aseptic conditions in a laminar flow cabinet.

3. Results and Discussion

3.1. Physical Parameters

3.1.1 pH Levels

The permissible pH range for drinking water is between 6.5 and 8.5. Data presented in Table 1 and Figure 1 show that pH levels in the samples ranged from 6.5 to 7.4. These results demonstrate good compliance with internationally accepted drinking water standards (The Libyan National Centre for Standardization and Metrology [8] and World Health Organization guidelines (6.5-8.5) [9].

Water acidity can potentially cause dental enamel erosion, hinder calcium absorption, and contribute to bone demineralization and heavy metal accumulation. Conversely, alkalinity in water, typically caused by carbonates and minerals, can affect taste, color, and promote metal corrosion. Water is considered alkaline if its pH consistently reaches 9.0, which may harm aquatic biodiversity and human organ systems. The pH values observed in this study (6.5-7.4) fall within the optimal range for human consumption and are consistent with previous local studies conducted on bottled water in Libya, which reported pH values ranging between 6.01 and 7.45.(Table 4).

3.1.2 Total Dissolved Solids (TDS)

Total Dissolved Solids in bottled water represents the combined content of all inorganic and organic substances present in molecular, ionized, or micro-granular suspended forms, typically measured in mg/L or ppm. TDS

primarily consists of inorganic salts including calcium, potassium, magnesium, sodium, bicarbonates, sulfates, and chlorides, with minor amounts of dissolved organic matter.
Higher TDS concentrations generally correspond to increased free ion concentrations, thereby increasing the electrical conductivity (μS/cm) of water. However, this relationship is approximate and depends on the specific ion composition. An approximate conversion formula exists: $TDS = k \times EC$, where k typically ranges from 0.55 to 0.75, with 0.64 being most commonly used.
The results presented in Table 1 and Figure 2 indicate TDS readings between 80 and 110 mg/L. All values are well below the standard limit of 500 mg/L established by both Libyan standards and WHO guidelines. The low variability and minimal TDS values indicate low-salinity water of excellent quality. These findings align with previously documented TDS ranges (28-303 mg/L) from local studies on various Libyan water sources (Table 4).

Table 1: Physical Composition of Bottled Water Samples (Mean ± SD)

Bottled water brands	pH	TDS
1	6.9±0.50	80±0.61
2	7.0±0.38	100±0.70
3	6.8±0.48	85±0.58
4	6.9±0.52	90±0.60
5	7.0±0.30	100±0.75
6	6.5±0.47	90±0.69
7	7.0±0.40	105±0.50
8	6.9±0.33	100±0.53
9	7.1±0.29	95±0.68
10	7.4±0.38	110±0.61
Libyan Standards	8.5-6.5	≤ 500
WHO 2018	8.5-6.5	500

3.2Major Cations Composition

3.2.1Sodium (Na^+)

Sodium is essential for maintaining fluid balance, blood pressure regulation, and nerve signal transmission. Its concentration in water also serves as a water quality indicator. While moderate levels are generally safe for most individuals, elevated sodium concentrations may pose health risks, particularly for people with hypertension or cardiovascular conditions, and can affect water taste.
The mean sodium concentrations across all samples ranged from 15 to 30 mg/L (Figure 3, Table 2). All measured parameters comply with permissible drinking water limits established by both Libyan standards (≤100 mg/L) and WHO guidelines (≤200 mg/L). These sodium values are consistent with findings from previous local investigations on Libyan water sources, which documented sodium concentrations ranging from 0.01 to 62 mg/L (Table 4), reflecting considerable geographical variability.

3.2.2Calcium (Ca^{2+})

Calcium is crucial for bone health, muscle function, and nerve transmission. The mean calcium concentration ranged from 4 to 10 mg/L (Figure 3). None of the samples exceeded the WHO permissible limit for bottled water (200 mg/L), confirming their safety for consumption. However, the calcium content of all bottled water samples was below the Libyan standard value of 100 mg/L.
The mean calcium values (Table 2) fall within ranges reported by other local studies on Libyan water sources (0.4 to 35 mg/L). The overall calcium content across all samples is consistent with literature values (Table 4).

3.2.3 Magnesium (Mg^{2+})

Magnesium is essential for DNA synthesis and stability, bone mineralization, and numerous enzymatic reactions. All samples in this investigation had magnesium concentrations ranging from 2 to 7 mg/L (Table 2, Figure 4). These magnesium values are similar to those reported in other local studies on Libya's water resources, which documented magnesium levels between 0.14 and 19 mg/L (Table 4).

3.2.4 Potassium (K^+)

Potassium is vital for intracellular fluid balance, nerve signal transmission, and cardiovascular function. Potassium concentrations ranged from 0.9 to 3.0 mg/L (Table 2, Figure 3). The mean potassium concentration is consistent with literature values reported for similar water sources (0.3-14 mg/L, Table 4).

Table 2: Major Cations Composition of Bottled Water Samples (Mean ± SD)

Bottled water brands	**Sodium** (mg/l)	**Calcium** (mg/l)	**Magnesium** (mg/l)	**Potassium** (mg/l)
1	19± 0.7	10±0.5	4±0.2	2.4±0.2
2	15± 0.9	8±0.3	2±0.4	1.9±0.8
3	20± 0.8	6±0.5	3±0.3	1.3±0.5
4	18± 0.7	5±0.4	4±0.3	0.8±0.6
5	23±0.4	6±0.3	7±0.2	3.0±0.5
6	25±0.6	4±0.7	4±0.4	2.0±0.3
7	30±0.9	7±0.4	5±0.3	1.7±0.1
8	28±0.3	8±0.4	4±0.4	2.4±0.3
9	26±0.1	6±0.6	6±0.3	1.7±0.4
10	28±0.3	5±0.7	5±0.5	0.9±0.6
Libyan Standards (mg/l)	100	100	150	12
WHO	≤ 200	300	150	-

3.3 Major Anions and Hardness

3.3.1Total Hardness

Total hardness values in bottled water samples ranged from 35 to 84 mg/L (Table 3, Figure 4). All values fall within permissible drinking water limits set by WHO (<500 mg/L) and Libyan standards (<200 mg/L). Based on the classification of water hardness (<75 mg/L = soft; 75-150 mg/L = moderately hard; >150 mg/L = hard), all samples in this study are classified as "soft" water. The mean total hardness values are consistent with literature reports (7.25-80.95 mg/L, Table 4).

3.3.2Bicarbonate (HCO_3^-)

The mean bicarbonate concentration ranged from 15 to 35 mg/L (Table 3, Figure 4). All bottled water samples have bicarbonate levels well below the Libyan standard value of 150 mg/L and WHO guideline. The bicarbonate content found in this study is suitable for consumption and falls within ranges reported in previous local studies (0.01-42.7 mg/L, Table 4).

3.3.3 Sulfate (SO_4^{2-})

Sulfate is a naturally occurring substance in drinking water. There have been reports of potential associations between elevated sulfate levels in drinking water and gastrointestinal issues, particularly diarrhea. The mean sulfate concentration ranged from 9 to 20 mg/L (Table 3, Figure 4). All samples contained sulfate concentrations below limits established by both Libyan and WHO standards. High sulfate levels in drinking water can potentially impact gastrointestinal health and increase kidney stone risk. The sulfate concentrations measured in this study (9-20 mg/L) are lower than values reported in similar studies on bottled water brands (2-73 mg/L, Table 4).

3.3.4 Chloride (Cl^-)

Chloride concentrations ranged from 15 to 36 mg/L (Table 3), all well below the permissible limits of 150 mg/L (Libyan standard) and 250 mg/L (WHO guideline). Chloride levels contribute to water taste and are generally not a health concern at these concentrations.

Table 3: Major Anions Composition and Hardness of Bottled Water Samples (Mean ± SD)

Bottled water brands	Total hardnes	Bicarbonate	Chloride	Sulphate
1	40±0.3	27±0.1	20±0.3	12±0.2
2	80±0.5	25±0.2	28±0.8	14±0.3
3	40±0.2	15±0.3	15±0.9	15±0.1
4	55±0.6	35±0.4	18±0.3	13±0.8
5	35±0.1	24±0.5	20±0.1	10±0.3
6	84±0.9	20±0.6	36±0.4	13±0.1
7	40±0.5	15±0.7	18±0.6	9±0.6
8	70±.4	25±0.9	28±0.3	20±0.4
9	55±0.6	25±0.5	20±0.2	14±0.9
10	60±0.8	20±0.3	15±0.5	15±0.5
Libyan Standards (mg/l)	200	150	150	150
WHO Guideline	≤ 500	≤ 150	≤ 250	≤ 250

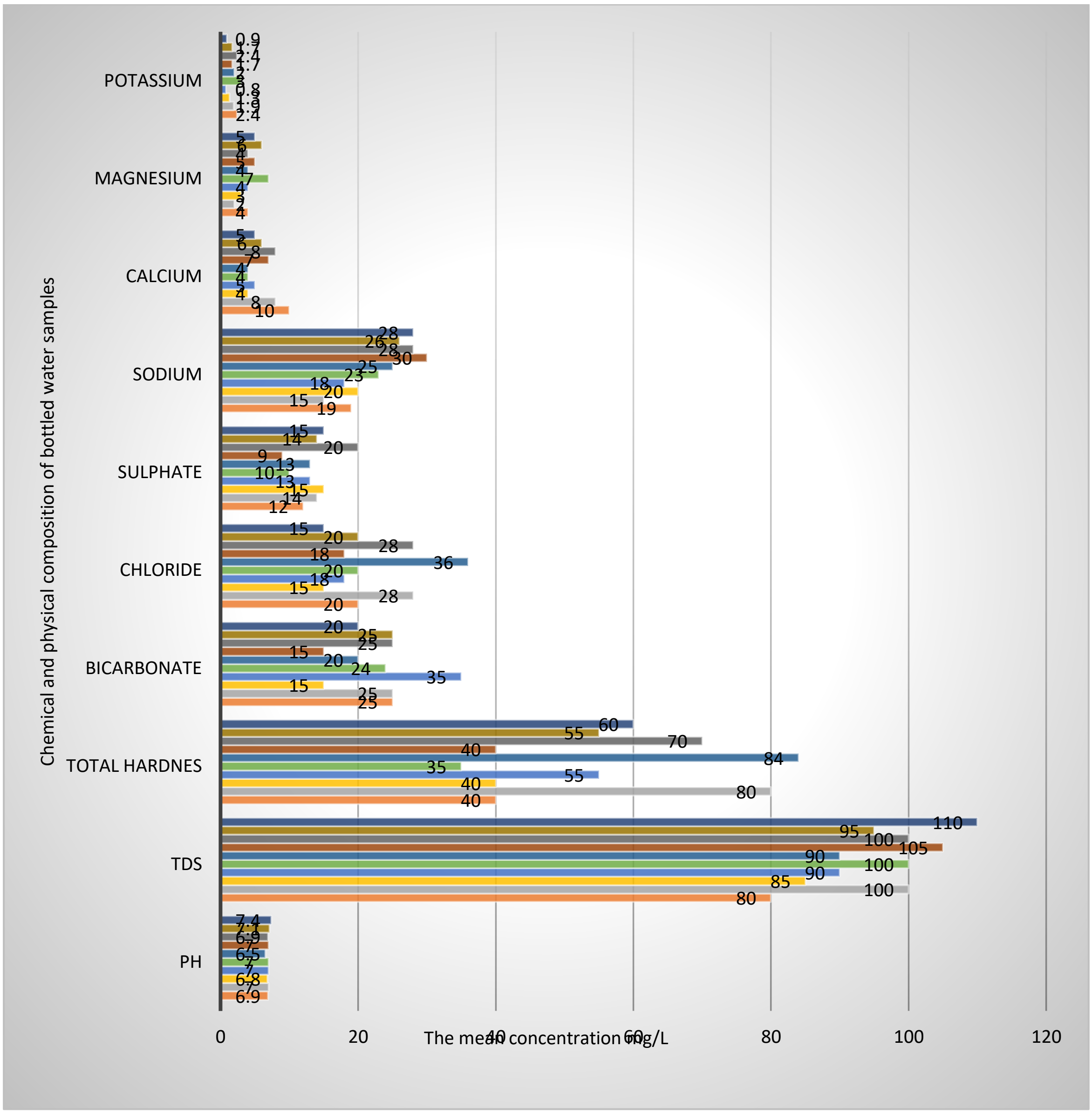

Figure 1 : Chemical Composition of Bottled Water Samples

Table 4: Comparison with Previous Local Studies in Libya (Concentration Ranges in mg/L

	Re [10]	Re [11]	Re [12]	Re [13]	Re [14]	Re [15]	Re [16]	Current Study
PH	6.5-6.68	6.11-7.45	6.92-7.45	6.95-7.25	6.5	5.8- 6.89	6.01 - 7.15	6.5 - 7.4
TDS	40-80	28-303	44.4- 75.3	78-114.5	45-80	21.78-115.44	75 - to 160	80 - 110
Total hardnes (CaCo3)	22-35	2-36		7.25-80.95	22-35		16 - 60	35 - 84
Bicarbonate	5.5-48	6-29			5.5-48	0.01- 42.7	17.02 –30.06	15 - 35
Chloride		0-45		18.2-35.35	17-70	0.6- 27.8		15 - 36
Sulphates	11-76	2-73		10-34	11-76		5.1 - 10.2	9 - 20
Sodium	18.21-62.16	2-23	13.6-34.8	2.05-19.5		0.01-36.4	0.3618.21	15 - 30
Calcium		0.4-6	4.2-7	3.7-35		0.01- 5.6	8.0 - 24.02	4 - 10
Magnesium		0.24-4		1.45-19		0.01- 12.1 52	0.94- 3.89	2 - 7
Potassium	6-14	0.4-17	0-0.3	0.8-1.37		0.3- 2.01	0.7 - 1.4	0.8 - 3.0

3.4. Microbiological Quality Assessment

Microbiological assessment confirmed the absence of pathogenic indicators in all samples, with total bacterial counts well within acceptable limits

The satisfactory microbiological results complement the favorable physicochemical findings, collectively affirming product safety

The microbiological analysis (Table 5) revealed excellent microbial quality across all bottled water samples. Total Viable Counts were exceptionally low, ranging from 0-2 CFU/ml, which is significantly below the permissible limit of 100 CFU/ml established by both Libyan standards and WHO guidelines. This indicates effective disinfection processes and hygienic bottling conditions.

Total coliforms and Escherichia coli were not detected in any of the 100 ml samples tested, confirming the absence of fecal contamination. This is particularly important as *E. coli* serves as a key indicator of fecal pollution and potential presence of enteric pathogens.

Table 5: Microbiological Analysis Results of Bottled Water Samples

Brands	TVC (CFU/ml) 22°C/72h	TVC (CFU/ml) 37°C/48h	Total Coliforms (CFU/100ml)	E. coli (CFU/100ml)
Bs1	0	0	ND	ND
Bs2	1	0	ND	ND
Bs3	0	0	ND	ND
Bs4	0	0	ND	ND
Bs5	2	1	ND	ND
Bs6	0	0	ND	ND
Bs7	1	0	ND	ND
Bs8	0	0	ND	ND
Bs9	0	0	ND	ND
Bs10	0	0	ND	ND
Libyan standards	≤ 100 CFU/ml	≤ 20 CFU/ml	0/100ml	0/100ml
WHO	≤ 100 CFU/ml	≤ 20 CFU/ml	0/100ml	0/100ml

The low microbial counts can be attributed to:

1. Multi-barrier treatment processes including reverse osmosis, UV irradiation, and ozonation.
2. Aseptic bottling conditions in controlled manufacturing environments.
3. Proper sealing preventing post-production contamination.
4. Adequate residual disinfectant in some brands.

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3.5 Statistical Analysis

Pearson correlation coefficients (r) were calculated to examine relationships between water quality parameters. The coefficient ranges from -1 to +1, with values near +1 indicating strong positive linear relationships, values near -1 indicating strong negative linear relationships, and values near 0 suggesting weak or no linear relationships.

The analysis revealed a strong positive relationship between total hardness and chloride concentration ($r \approx 0.79$), suggesting that increased chloride levels are typically associated with higher water hardness. A moderate positive correlation was observed between total dissolved solids (TDS) and sodium ($r \approx 0.56$), indicating that sodium contributes significantly to the overall dissolved solids content. Other parameters exhibited weaker correlations, suggesting limited linear relationships within this dataset. The Pearson correlation analysis helped identify the most influential relationships among water quality variables and provided clearer understanding of how changes in one parameter may associate with changes in another.

These findings align with previous studies on bottled water quality in the region and confirm that commercially available bottled water in Tripoli markets meets stringent microbiological safety standards for drinking water.

4. Conclusions

1- All ten bottled water samples analyzed in this study comply with both Libyan national standards and World Health Organization guidelines for the physicochemical parameters examined.
2- pH values ranged from 6.5 to 7.4, indicating slightly acidic to neutral water suitable for human consumption.
3- Total Dissolved Solids levels (80-110 mg/L) were low, suggesting high-quality freshwater with minimal mineral content.
4- Concentrations of major cations (sodium, calcium, magnesium, potassium) and anions (bicarbonate, chloride, sulfate) were significantly below permissible limits, confirming the safety of these products.
5- All samples were classified as "soft" water based on total hardness values (35-84 mg/L).
6- Statistical analysis revealed strong positive correlations between total hardness and chloride, and moderate correlations between TDS and sodium.
7- The findings generally confirm the quality and safety of bottled drinking water available in Tripoli markets, Libya.

5 Recommendations

1- Implement periodic monitoring programs to regularly assess bottled water quality in Libyan markets.
2- Expand analytical parameters to include heavy metals, organic contaminants, and microbiological indicators for comprehensive safety assessment.
3- Conduct comparative studies between bottled water and local tap water sources to provide consumers with informed choices.
4- Enhance public awareness regarding drinking water quality standards and proper interpretation of product labeling.
5- Strengthen governmental regulatory oversight of water bottling facilities to ensure continuous compliance with national and international standards.
6- Encourage sustainable packaging initiatives within the bottled water industry to minimize environmental impact.

Compliance with ethical standards

Disclosure of conflict of interest

The author(s) declare that they have no conflict of interest.

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