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# Evaluation of the Quality of Bottled Water Available in Benghazi, Libya

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**A B S T R A C T**

Water quality indices serve as effective tool for evaluating overall water quality. They are beneficial for decision- makers, stakeholders, and individuals lacking extensive expertise in the numerous parameters that define water quality. This study evaluates the quality of drinking water by employing the weighted arithmetic Water Quality Index (WQI) method, utilizing various physicochemical parameters from five different brands of bottled water available in Benghazi City, Libya. The WQI was calculated for the 14 physicochemical parameters (EC, TDS, pH, total hardness, fluoride, chloride, nitrate, Bicarbonate $HCO^{3-}$, sulphate, NTU, $Ca^{+2}$, $Mg^{+2}$, $K^{+}$, and $Na^{+}$). All brands demonstrated excellent quality of drinking water as indicated by their Water Quality Index (WQI) values.

## 1 INTRODUCTION

Clean and safe water is critical for preventing the spread of waterborne diseases [1]. The quality of drinking water serves as a vital measure of its safety for human consumption. As a result, drinking high-quality water is essential for supporting and improving overall health [2]. The quality of water is affected by a combination of natural processes and anthropogenic activities that change its chemical composition. To assess water quality, various parameters are taken into account, including physical, chemical, and microbiological factors [3- 6]. These parameters must remain within the established safe limits to prevent any potential risks to human health [7]. Drinking water quality is vital, emphasizing the necessity of monitoring and evaluating water for multiple applications, such as consumption, industrial processes, and agricultural needs [8]. In developing countries, drinking contaminated water leads to a considerable number of diseases. Many people in these areas face challenges in accessing safe drinking water, primarily due to environmental pollution [9]. Therefore, it is essential to identify the pollution sources and the specific contaminants in the area. This knowledge is critical for protecting water resources and ensuring their safe and efficient use [10]. Monitoring water quality is significant for assessing current conditions and recognizing long-term trends, both of which are vital for effective management. Thus, closely regulating drinking water is essential to ensure a steady supply of clean water for various purposes [11].

Several factors can negatively impact water quality, making it vital to assess both physicochemical and microbiological parameters, such as pH, total dissolved solids (TDS), turbidity, hardness, nitrate levels, electrical conductivity (EC), chloride, and phosphate concentrations. If the values of these parameters surpass the thresholds set by the World Health Organization (WHO), the drinking water is classified as unsafe [12, 13]. Drinkable water must be devoid of pathogenic microorganisms, harmful contaminants, and excessive concentrations of minerals and organic materials. It should also have desirable qualities, such as being clear (free from colour and turbidity), odourless, and tasteless [4, 14]. Consequently, the continuous assessment of water quality is essential for formulating effective protective measures.

The decline in drinking water quality is principally attributed to the introduction of a range of chemicals into freshwater sources and their distribution systems. This contamination results from both natural events and human activities [15-17]. Naturally occurring substances that affect water quality are typically linked to the geological features of a region. On the other hand, human-driven contamination mainly arises from agricultural practices, including the use of pesticides and herbicides. Additionally, factors such as the leaching of toxic substances, septic system failures, waste disposal methods, coal mining, and petroleum refining play a significant role in the deterioration of water quality [18]. In the coming decades, we are likely to encounter numerous challenges in ensuring that everyone has access to an adequate supply of water that meets established quality standards [19]. Furthermore, numerous developing nations face significant difficulties in preserving water quality as they strive to enhance their water supply and sanitation infrastructure systems [20, 21].

In recent times, humans obtain water from a variety of sources and in different forms, one of which is bottled water [22]. Bottled waters are often regarded as pure, safe, and of superior taste, leading to a rise in their consumption, even though they are significantly more expensive than tap water [23]. In order to save their health, many consumers believe that bottled water offers higher quality and taste compared to its tap counterpart [24]. However, scientific research indicates that this belief may not be accurate [25, 26]. They stated that bottled water may not always meet high-quality standards and may pose safety concerns due to detectable levels of viruses, bacteria, and fungi that exceed acceptable limits. This can potentially result in serious gastrointestinal illnesses [27-30]. Consumers use bottled drinking water for several purposes beyond just drinking, such as making infant formula, cooking, skincare, cleaning contact lenses, and refilling humidifiers [31]. In addition, the consumption of bottled water worldwide is rising at an annual rate of ten percent, with the most rapid expansion occurring in developing nations [32]. The United States ranks as the largest consumer market for bottled water in the world [33]. Research conducted across diverse geographical regions has provided significant insights into bottled water quality. These studies encompass a variety of assessments, including the analysis of heavy metals as well as physical, chemical, and microbial examinations of bottled drinking water [34 - 40].

The chemical composition of bottled drinking water can vary greatly between different brands, which could raise concerns about its potential effects on health. In 2023, a study was conducted to evaluate bottled water for chemical contaminants and microbial presence. The results showed that while most brands met regulatory standards, some bottled water products contained trace amounts of contaminants that could pose potential health risks with long-term consumption [41]. These results highlight the need for strict quality control measures to protect the safety of bottled water. Another study found that the most common inorganic elements detected in the samples were calcium (Ca), chloride (Cl-), potassium (K), magnesium (Mg), sodium (Na), sulfur (S), and silicon (Si) [42]. A separate study recommended that ideal bottled water should have a high concentration of calcium (Ca) and magnesium (Mg), while keeping sodium (Na) levels low [43]. Despite significant efforts by national and international authorities, there is evidence that ensuring safe drinking water quality continues to be a challenging task. This has led to extensive research aimed at developing tools to assess water quality, including models like the Water Quality Index (WQI) [44, 45]. The WQI is a highly effective means of conveying the quality of water [46]. It plays a crucial role in the evaluation and management of water resources [47]. In addition, it provides valuable insights into the trends of water quality changes over time [48]. Such a model is a valuable resource that aids in simplifying the evaluation process [21, 49, 50]. Precise prediction of this index is essential for effective management of water quality, protecting public health, and ensuring the availability of safe water for drinking and everyday use. This index utilizes measurable properties of water as quality metrics to evaluate the overall water quality index [51, 52].

Turning to Libya, the demand for fresh water in Libya has significantly increased due to population growth, leading to a marked rise in public water supply for both urban and rural communities. As mentioned above, the lack of access to safe drinking water still significant challenges in many regions across the globe including Libya. Libya is semi- arid, distinguished by scarce rainfall and restricted groundwater supplies. In this country, the nation's water resources are primarily divided into two key categories: conventional water resources, encompassing both surface water and groundwater, which represent about 97.3% of the total, and non-conventional water resources, including seawater desalination and treated wastewater, which account for roughly 2.7% [53]. Research has shown that the quality of drinking water in these areas does not have any harmful effects on human health. However, it is crucial to perform a comprehensive analysis of water quality parameters to confirm that they align with established national and international standards, particularly the maximum permissible limits set by the Libyan regulations and World Health Organization (WHO) [54, 55]. A research study was conducted to assess the quality of drinking water in particular regions of Libya [56]. Physical and chemical assessments were conducted and compared to Libyan standards. The results indicate that all water sources sampled are safe for consumption. However, the detection of individual metals and heavy metal ions in both groundwater and surface water may be linked to pollution from industrial or mining activities, as well as natural geological sources [57]. The demand for bottled drinking water in our region is significant due to the limited availability of fresh water sources [58]. A study analysed the chemical properties of bottled drinking water sourced from the western region of Libya. The objective of this study was to assess the quality of the most widely consumed bottled water in that area, and subsequently, to compare the findings with the standards established by Libyan regulations as well as the (WHO). The study indicated that all bottled water brands exhibited pH levels that were within the acceptable range according to the standards set by both the (WHO) and Libyan regulations [59]. However, the total dissolved solids, hardness, sodium, chloride, and nitrate levels in the samples were significantly lower than the acceptable limits, potentially leading to various health issues. In 2013, a study was conducted in Misurata City, where twelve samples of bottled drinking water were collected from various factories within the city. The analysis focused on several parameters, including total hardness, pH, soluble salts, and the levels of sodium, potassium, calcium, magnesium, chlorides, and bicarbonates. The findings revealed that the pH values of eight samples fell below the acceptable limits set by Libyan standards. Additionally, one sample exceeded the allowable thresholds for dissolved salts and total hardness, while another sample registered chlorides above the maximum permissible level. However, the concentrations of sodium, calcium, magnesium, potassium, copper, lead, and zinc were within the acceptable ranges according to Libyan standards. In contrast, cadmium and mercury levels were found to be higher than both Libyan and international safety limits [60]. Another study was performed to assess the physical and chemical properties of five different brands of locally bottled drinking water available in the Libyan market. The results indicated that the majority of the evaluated properties for these five bottled water types fell within the acceptable limits set by Libyan standards for drinking water. However, it was noted that the total dissolved solids (TDS) in three samples were below the minimum permissible levels [61]. Recent research has pointed out cases of non-compliance and inconsistencies in the chemical makeup of drinking water. For example, a study in Libya found variations in the chemical composition of bottled drinking water [62]. Yet, achieving safe drinking water quality remains a challenging task. Therefore, there remains a need for techniques to develop strategies for controlling drinking water via governing several parameters, including physical, chemical, and microbiological using less critical conditions.

This study aims to measure drinking water quality with the application of weighted arithmetic WQI method based on some the physicochemical quality parameters of five brands of bottled drinking water available in Benghazi City, Libya.

## 2 Materials and Methods

### 2.1 Study Area

The current study was conducted in Benghazi City, Libya, where the population was estimated to be 632,937 in 2019. It is located in the geographical coordinate 32° 7' 0.0084" N and 20° 4' 0.0048" E.with an estimated area of 1,104,300 sq km.

Besides, Benghazi holds considerable political and economic importance. The residents obtain their drinking water from the great man-made river that employs a network of pipelines to transport water from the Nubian Sandstone Aquifer System in southern Libya to the densely populated cities along the northern Mediterranean coast, including Tripoli and Benghazi. In addition to the tap water supply, this city enjoys convenient access to various brands of bottled water, primarily utilized for drinking.


Figure 1. Study Area-Benghazi

## 2.2 Sampling

For this study, five brands of bottled drinking water—referred to as Bw1, Bw2, Bw3, Bw4, and Bw5—were selected. Each brand was acquired through random purchases from various shops and supermarkets located throughout Benghazi, Libya, during the months of July and August 2024. Upon arrival at the laboratory, all samples were stored in their original packaging at a temperature of 4 °C in the refrigerator until they were analyzed. The capacities of bottled water containers analyzed were 0.5, 1, 2, and 5 liters. For each brand of bottled water, three identical samples were combined to create a composite sample. Additionally, the water sampled was categorized as purified water, which is produced by water purification facilities employing methods such as ion exchange, reverse osmosis (RO), or distillation. The origin of the bottled water is primarily groundwater.

## 2.3 Analytical Measurements and Statistical Techniques

The Equipment and Analytical Methods used for Physico-chemical Analysis namely ph,Ec,Tds ,TH,Cl,NO3,NTU, Calcium, Magnesium, Potassium,,Fluoride,,sulfate,sodium, ,and Bicarbonate, were carried out – as shown in Table 1.

This study utilized the average results from triplicate measurements across all 14 parameters for each of the 20 samples (n = 20) to assess the precision of the method.

Table 1: Analytical Equipment and Methods Employed for Physico-Chemical Analysis.

| Parameter | Type of test | Equipment/Analytical Method |
|---|---|---|
| pH | In-situ | Digital pH meter |
| NTU | Laboratory | Nephelometric Turbidity Meter |
| Conductivity | In-situ | Digital conductivity meter |
| Calcium, Magnesium, Potassium | Laboratory | Direct atomic absorption |
| Sodium | Laboratory | Titration method |
| Total Dissolved Solids | Laboratory | Filtration and evaporation |
| Sulphate | Laboratory | Turbidimetric method |
| Chloride | Laboratory | Silver nitrate titration |
| Nitrate | Laboratory | Brucine method |
| Bicarbonate $HCO^{3-}$ | Laboratory | Colorimetric method |
| Fluoride | Laboratory | thermos Scientific Orion Star A214 Benchtop pH/ISE meter |
| Total hardness (TH ) | Laboratory | Titre Hydrotimétrique, |

## 2.4. CALCULATION OF WATER QUALITY INDEX (WQI)

### 2.4.1. Assessment of water quality index (WQI)

The water quality index was determined through the weighted arithmetic method, utilizing a range of physicochemical parameters from various bottled water samples [63]. The bottled drinking water can be categorized into five distinct quality levels—excellent, good, poor, very poor, and unstable—based on the water quality index [44, 64 - 67].

Calculation of quality rating for all parameters using equation 1:

$Qn = 100\ (vn - vi)\ /\ (si - vi)$……. …………...(1 )

Where, si : standard value; Vi : ideal value.

Vn: is the measured value of the parameter at a given sampling point

In most cases Vi = 0 except in certain parameters like pH, the calculation of quality rating for pH (Vi was not zero) using equation 2.

$QpH = 100\ (V\ pH - 7.0)\ /\ (8.5 - 7.0)$……... (2 )

The unit weight (Wi) of various water quality parameters is inversely proportional to the recommended standards for the corresponding parameters.

The Unit weight (Wn) to various water Quality parameters are inversely proportional to the recommended standards for the corresponding parameters. unit weight is calculated using equation 3:

$Wn = K/Sn$……………………………………..(3 )

Where, Wi : unit weight for the $n^{th}$ parameter a, Si = standards permissible value of $n^{th}$ parameter , and k : proportionality constant. Calculation of proportionality constant using equation 4:

$K = 1/\sum 1/sn$…………………………………..( 4 )

Water quality index (WQI) is calculated using equation 5:

$WQI = \sum Wn\ qn/\sum Wn$……………...………..( 5 )

Based on the value obtained for the Weighted Arithmetic WQI method, the water ecological status may be determined, as illustrated by Table 2.

Table 2: Water Quality Rating as per Weight Arithmetic Water Quality Index Method

| Water quality index level | Water quality status | Grading quality |
|---|---|---|
| 0-25 | Excellent water quality | A |
| 26-50 | Good water quality | B |
| 51-75 | Poor water quality | C |
| 76-100 | Very poor water quality | D |
| >100 | Unsuitable for drinking | E |

## 3. RESULTS AND DISCUSSION

The result from our analytical measurements indicate that all physicochemical parameters across the various brands of bottled drinking water are within the limits established by WHO standards for drinking water quality, as detailed in Table 3.

The water quality index results obtained in this study ranged from 9.630581 to 21.13755. Consequently, all bottled water samples examined were classified as possessing an excellent level of water quality. Detailed calculations of the water quality index can be found in Tables 4 to 8. Additionally, Figure 2 illustrates the water quality index for the analysed bottled water.

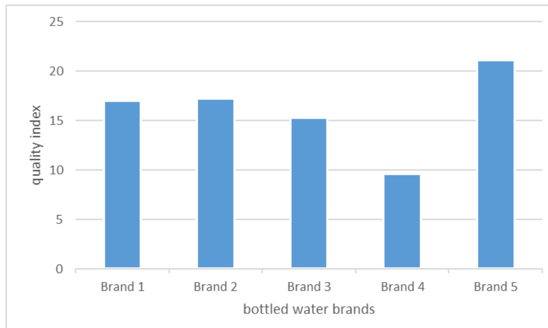


Figure 2. Illustrate the WQI for five brands of bottled water samples.

The physicochemical characteristics of the bottled water samples were assessed and subsequently compared to the values specified on their labels (Table 9). This comparison indicates that there are only minor differences between the measured parameters and those reported on the labels for the bottled water samples.

**Table 3:** The comparison of Arithmetic mean of the physicochemical parameters of bottled drinking water with values of (WHO) [68] and Libyan standards [69]

**Table 4.** The water quality index calculation of bottled water- Brand 1

| par | Sn | 1/Sn | &1/Sn | k | w | Vi | vn | vn/sn | Qn | WQI |
|---|---|---|---|---|---|---|---|---|---|---|
| **PH** | 8.5 | 0.1176 | 1.1626 | 0.8601 | 0.1012 | 7 | 7.2 | 0.133 | 13.3 | 1.3458 |
| **EC** | 1000 | 0.001 | 1.1626 | 0.8601 | 0.0009 | 0 | 173 | 0.173 | 17.3 | 0.0149 |
| **TDS** | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 110 | 0.22 | 22 | 0.0378 |
| **TH** | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 15 | 0.03 | 3 | 0.0052 |
| **CL** | 250 | 0.004 | 1.1626 | 0.8601 | 0.0034 | 0 | 27 | 0.108 | 10.8 | 0.0372 |
| **NO3** | 50 | 0.02 | 1.1626 | 0.8601 | 0.0172 | 0 | 3 | 0.06 | 6 | 0.1032 |
| **NTU** | 5 | 0.2 | 1.1626 | 0.8601 | 0.1720 | 0 | 1.5 | 0.3 | 30 | 5.1606 |
| **CACSIUM** | 200 | 0.005 | 1.1626 | 0.8601 | 0.0043 | 0 | 6 | 0.03 | 3 | 0.0129 |
| **MG** | 30 | 0.0333 | 1.1626 | 0.8601 | 0.0287 | 0 | 9 | 0.3 | 30 | 0.8601 |
| **FLOURID** | 1.5 | 0.6667 | 1.1626 | 0.8601 | 0.5734 | 0 | 0.2 | 0.1333 | 13.333 | 7.6454 |
| **SULFATE** | 250 | 0.004 | 1.1626 | 0.8601 | 0.0034 | 0 | 11 | 0.044 | 4.4 | 0.0151 |
| **SODIUM** | 200 | 0.005 | 1.1626 | 0.8601 | 0.0043 | 0 | 28 | 0.14 | 14 | 0.0602 |
| **POTASSIUM** | 10 | 0.1 | 1.1626 | 0.8601 | 0.0860 | 0 | 2 | 0.2 | 20 | 1.7202 |
| **BIO** | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 34 | 0.068 | 6.8 | 0.0117 |
| | | 1.1626 | 16.277 | 12.042 | 1 | | | | | 17.030 |

| par | Brand 1 | Brand 2 | Brand 3 | Brand 4 | Brand 5 | Who stundards (WHO) (2011) | Libya standards |
|---|---|---|---|---|---|---|---|
| **PH** | 7.2 | 6.6 | 6.2 | 7 | 6.5 | 6.5-8. | 6.5-8.5 |
| **EC** | 173 | 180 | 214 | 169 | 150 | 1000 | 30-1500 |
| **TDS** | 110 | 115 | 136 | 118 | 105 | 500 | (500-1000 mg/L |
| **TH** | 15 | 25 | 8 | 11 | 11 | 500 | 200 |
| **CL** | 27 | 2 | 47 | 16 | 28 | 250 | 150 |
| **NO3** | 3 | 6 | 12 | 8 | 11 | 50 | 10> mg/L |
| **NTU** | 1.5 | 3 | 2 | 2 | 2 | 5 | 5 |
| **CACSIUM** | 6 | 2 | 2 | 4 | 4 | 200 | 100 |
| **MG** | 9 | 23 | 6 | 7 | 7 | 30 | 75-150 |
| **FLOURID** | 0.2 | 0.02 | 0.1 | 0.02 | 0.2 | 1.5 | 1.5 |
| **SULFATE** | 11 | 90 | 2 | 17 | 10 | 250 | >150 mg/L |
| **SODIUM** | 28 | 3 | 68 | 22 | 5 | 200 | > 100 mg/L |
| **POTASSIUM** | 2 | 1 | 3 | 1 | 2 | 10 | r (>12 mg/L) |
| **BIO** | 34 | 3 | 24 | 60 | 28 | 125-500 | - |

| | | | | |
|---|---|---|---|---|
| 0.0151 | 0.0602 | 1.7202 | 0.0117 | 17.030 |
| 4.4 | 14 | 20 | 6.8 | |
| 0.044 | 0.14 | 0.2 | 0.068 | |
| 11 | 28 | 2 | 34 | |
| 0 | 0 | 0 | 0 | |
| 0.0034 | 0.0043 | 0.0860 | 0.0017 | 1 |
| 0.8601 | 0.8601 | 0.8601 | 0.8601 | 12.042 |
| 1.1626 | 1.1626 | 1.1626 | 1.1626 | 16.277 |
| 0.004 | 0.005 | 0.1 | 0.002 | 1.1626 |
| 250 | 200 | 10 | 500 | |
| **SULFATE** | **SODIUM** | **POTASSIUM** | **BIO** | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **WQI** | 1.3458 | 0.0149 | 0.0378 | 0.0052 | 0.0372 | 0.1032 | 5.1606 | 0.0129 | 0.8601 | 7.6454 |
| **Qn** | 13.3 | 17.3 | 22 | 3 | 10.8 | 6 | 30 | 3 | 30 | 13.333 |
| **vn/sn** | 0.133 | 0.173 | 0.22 | 0.03 | 0.108 | 0.06 | 0.3 | 0.03 | 0.3 | 0.1333 |
| **vn** | 7.2 | 173 | 110 | 15 | 27 | 3 | 1.5 | 6 | 9 | 0.2 |
| **Vi** | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **w** | 0.1012 | 0.0009 | 0.0017 | 0.0017 | 0.0034 | 0.0172 | 0.1720 | 0.0043 | 0.0287 | 0.5734 |
| **k** | 0.8601 | 0.8601 | 0.8601 | 0.8601 | 0.8601 | 0.8601 | 0.8601 | 0.8601 | 0.8601 | 0.8601 |
| **&1/Sn** | 1.1626 | 1.1626 | 1.1626 | 1.1626 | 1.1626 | 1.1626 | 1.1626 | 1.1626 | 1.1626 | 1.1626 |
| **1/Sn** | 0.1176 | 0.001 | 0.002 | 0.002 | 0.004 | 0.02 | 0.2 | 0.005 | 0.0333 | 0.6667 |
| **Sn** | 8.5 | 1000 | 500 | 500 | 250 | 50 | 5 | 200 | 30 | 1.5 |
| **par** | **PH** | **EC** | **TDS** | **TH** | **CL** | **NO3** | **NTU** | **CACSIUM** | **MG** | **FLOURID** |

**Table 5.** The water quality index calculation of bottled water- Brand 2

ف

| par | Sn | 1/Sn | &1/Sn | k | w | Vi | vn | vn/sn | Qn | WQI |
|---|---|---|---|---|---|---|---|---|---|---|
| PH | 8.5 | 0.1176 | 1.1626 | 0.8601 | 0.1012 | 7 | 6.6 | 0.2667 | 26.667 | 2.6984 |
| EC | 1000 | 0.001 | 1.1626 | 0.8601 | 0.0009 | 0 | 180 | 0.18 | 18 | 0.0155 |
| TDS | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 115 | 0.23 | 23 | 0.0396 |
| TH | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 25 | 0.05 | 5 | 0.0086 |
| CL | 250 | 0.004 | 1.1626 | 0.8601 | 0.0034 | 0 | 2 | 0.008 | 0.8 | 0.0028 |
| NO3 | 50 | 0.02 | 1.1626 | 0.8601 | 0.0172 | 0 | 6 | 0.12 | 12 | 0.2064 |
| NTU | 5 | 0.2 | 1.1626 | 0.8601 | 0.1720 | 0 | 3 | 0.6 | 60 | 10.321 |
| CACSIUM | 200 | 0.005 | 1.1626 | 0.8601 | 0.0043 | 0 | 2 | 0.01 | 1 | 0.0043 |
| MG | 30 | 0.0333 | 1.1626 | 0.8601 | 0.0287 | 0 | 23 | 0.7667 | 76.667 | 2.1980 |
| FLOURID | 1.5 | 0.6667 | 1.1626 | 0.8601 | 0.5734 | 0 | 0.02 | 0.0133 | 1.3333 | 0.7645 |
| SULFATE | 250 | 0.004 | 1.1626 | 0.8601 | 0.0034 | 0 | 90 | 0.36 | 36 | 0.1239 |
| SODIUM | 200 | 0.005 | 1.1626 | 0.8601 | 0.0043 | 0 | 3 | 0.015 | 1.5 | 0.0065 |
| POTASSIUM | 10 | 0.1 | 1.1626 | 0.8601 | 0.0860 | 0 | 1 | 0.1 | 10 | 0.8601 |
| BIO | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 3 | 0.006 | 0.6 | 0.0010 |
| | | 1.1626 | 16.277 | 12.041 | 1 | | | | | 17.250 |

**Table 6.** The water quality index calculation of bottled water- Brand 3

| par | Sn | 1/Sn | &1/Sn | k | w | Vi | vn | vn/sn | Qn | WQI |
|---|---|---|---|---|---|---|---|---|---|---|
| PH | 8.5 | 0.1176 | 1.1626 | 0.8601 | 0.1012 | 7 | 6.2 | 0.0695 | 6.95 | 0.7034 |
| EC | 1000 | 0.001 | 1.1626 | 0.8601 | 0.0009 | 0 | 214 | 0.214 | 21.4 | 0.0184 |
| TDS | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 136 | 0.272 | 27.2 | 0.0468 |
| TH | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 8 | 0.016 | 1.6 | 0.0028 |
| CL | 250 | 0.004 | 1.1626 | 0.8601 | 0.0034 | 0 | 47 | 0.188 | 18.8 | 0.0647 |
| NO3 | 50 | 0.02 | 1.1626 | 0.8601 | 0.0172 | 0 | 12 | 0.24 | 24 | 0.4129 |
| NTU | 5 | 0.2 | 1.1626 | 0.8601 | 0.1720 | 0 | 2 | 0.4 | 40 | 6.8809 |
| CACSIUM | 200 | 0.005 | 1.1626 | 0.8601 | 0.0043 | 0 | 2 | 0.01 | 1 | 0.0043 |
| MG | 30 | 0.0333 | 1.1626 | 0.8601 | 0.0287 | 0 | 6 | 0.2 | 20 | 0.5734 |
| FLOURID | 1.5 | 0.6667 | 1.1626 | 0.8601 | 0.5734 | 0 | 0.1 | 0.0667 | 6.6667 | 3.8227 |
| SULFATE | 250 | 0.004 | 1.1626 | 0.8601 | 0.0034 | 0 | 2 | 0.008 | 0.8 | 0.0028 |
| SODIUM | 200 | 0.005 | 1.1626 | 0.8601 | 0.0043 | 0 | 68 | 0.34 | 34 | 0.1462 |
| POTASSIUM | 10 | 0.1 | 1.1626 | 0.8601 | 0.0860 | 0 | 3 | 0.3 | 30 | 2.5803 |
| BIO | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 24 | 0.048 | 4.8 | 0.0083 |
| | | 1.1626 | 16.277 | 12.042 | 1 | | | | | 15.268 |

**Table 7.** The water quality index calculation of bottled water- Brand 4

| par | Sn | 1/Sn | &1/Sn | k | w | Vi | vn | vn/sn | Qn | WQI |
|---|---|---|---|---|---|---|---|---|---|---|
| PH | 8.5 | 0.1176 | 1.1626 | 0.8601 | 0.1012 | 7 | 7 | 0 | 0 | 0 |
| EC | 1000 | 0.001 | 1.1626 | 0.8601 | 0.0009 | 0 | 169 | 0.169 | 16.9 | 0.0145 |
| TDS | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 118 | 0.236 | 23.6 | 0.0406 |
| TH | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 11 | 0.022 | 2.2 | 0.0037 |
| CL | 250 | 0.004 | 1.1626 | 0.8601 | 0.0034 | 0 | 16 | 0.064 | 6.4 | 0.0220 |
| NO3 | 50 | 0.02 | 1.1626 | 0.8601 | 0.0172 | 0 | 8 | 0.16 | 16 | 0.2752 |
| NTU | 5 | 0.2 | 1.1626 | 0.8601 | 0.1720 | 0 | 2 | 0.4 | 40 | 6.8809 |
| CACSIUM | 200 | 0.005 | 1.1626 | 0.8601 | 0.0043 | 0 | 4 | 0.02 | 2 | 0.0086 |
| MG | 30 | 0.0333 | 1.1626 | 0.8601 | 0.0287 | 0 | 7 | 0.2333 | 23.333 | 0.6689 |
| FLOURID | 1.5 | 0.6667 | 1.1626 | 0.8601 | 0.5734 | 0 | 0.02 | 0.0133 | 1.3333 | 0.7645 |
| SULFATE | 250 | 0.004 | 1.1626 | 0.8601 | 0.0034 | 0 | 17 | 0.068 | 6.8 | 0.0234 |
| SODIUM | 200 | 0.005 | 1.1626 | 0.8601 | 0.0043 | 0 | 22 | 0.11 | 11 | 0.0473 |
| POTASSIUM | 10 | 0.1 | 1.1626 | 0.8601 | 0.086 | 0 | 1 | 0.1 | 10 | 0.8601 |
| BIO | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 60 | 0.12 | 12 | 0.0206 |
| | | 1.1626 | 16.277 | 12.041 | 1 | | | | | 9.6306 |

**Table 8**. The water quality index calculation of bottled water- Brand 5

| par | Sn | 1/Sn | &1/Sn | k | w | Vi | vn | vn/sn | Qn | WQI |
|---|---|---|---|---|---|---|---|---|---|---|
| PH | 8.5 | 0.1176 | 1.1626 | 0.8601 | 0.1012 | 7 | 6.5 | 0.3666 | 36.66 | 3.7096 |
| EC | 1000 | 0.001 | 1.1626 | 0.8601 | 0.0009 | 0 | 150 | 0.15 | 15 | 0.0129 |
| TDS | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 105 | 0.21 | 21 | 0.0361 |
| TH | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 11 | 0.022 | 2.2 | 0.0038 |
| CL | 250 | 0.004 | 1.1626 | 0.8601 | 0.0034 | 0 | 28 | 0.112 | 11.2 | 0.0385 |
| NO3 | 50 | 0.02 | 1.1626 | 0.8601 | 0.0172 | 0 | 11 | 0.22 | 22 | 0.3784 |
| NTU | 5 | 0.2 | 1.1626 | 0.8601 | 0.1720 | 0 | 2 | 0.4 | 40 | 6.8808 |
| CACSIUM | 200 | 0.005 | 1.1626 | 0.8601 | 0.0043 | 0 | 4 | 0.02 | 2 | 0.0086 |
| MG | 30 | 0.0333 | 1.1626 | 0.8601 | 0.0287 | 0 | 7 | 0.2333 | 23.333 | 0.6689 |
| FLOURID | 1.5 | 0.6667 | 1.1626 | 0.8601 | 0.5734 | 0 | 0.2 | 0.1333 | 13.333 | 7.6454 |
| SULFATE | 250 | 0.004 | 1.1626 | 0.8601 | 0.0034 | 0 | 10 | 0.04 | 4 | 0.0137 |
| SODIUM | 200 | 0.005 | 1.1626 | 0.8601 | 0.0043 | 0 | 5 | 0.025 | 2.5 | 0.0107 |
| POTASSIUM | 10 | 0.1 | 1.1626 | 0.8601 | 0.0860 | 0 | 2 | 0.2 | 20 | 1.7202 |
| BIO | 500 | 0.002 | 1.1626 | 0.8601 | 0.0017 | 0 | 28 | 0.056 | 5.6 | 0.0096 |
| | | 1.1626 | 16.277 | 12.041 | 1 | | | | | 21.138 |

**Table 9.** Comparative analysis of physicochemical parameters (mg/L) identified in this study versus the labeled values of bottled water samples (EC in µs/cm).

| par | Brand 1 | | Brand 2 | | Brand 3 | | Brand 4 | | Brand 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | M | L | M | L | M | L | M | L | M | L |
| PH | **7.2** | 7 | 6.6 | 7 | 6.2 | 6.5 | 7 | 7.2 | 6.5 | 7 |
| EC | **173** | 172 | 180 | 172 | 214 | 212 | 169 | 167 | 150 | 145 |
| TDS | **110** | 108 | 115 | 108 | 136 | 137 | 118 | 116 | 105 | 103 |
| TH | **15** | 14 | 25 | 14 | 8 | 9 | 11 | 10 | 11 | 10 |
| CL | **27** | 28 | 2 | 28 | 47 | 50 | 16 | 18 | 28 | 26 |
| NO3 | **3** | 3.4 | 6 | 3.4 | 12 | 10 | 8 | 7 | 11 | 10 |
| NTU | **1.5** | 1.6 | 3 | 1.6 | 2 | 1.7 | 2 | 2 | 2 | 2 |
| CACSIUM | **6** | 5.6 | 2 | 5.6 | 2 | 2.5 | 4 | 5 | 4 | 5 |
| MG | **9** | 9.3 | 23 | 9.3 | 6 | 7 | 7 | 8 | 7 | 6 |
| FLOURID | **0.2** | 0.15 | 0.02 | 0.15 | 0.1 | 0.13 | 0.02 | 0.016 | 0.2 | 0.17 |
| SULFATE | **11** | 12 | 90 | 12 | 2 | 3 | 17 | 15 | 10 | 9 |
| SODIUM | **28** | 28.9 | 3 | 28.9 | 68 | 65 | 22 | 20 | 5 | 4 |
| POTASSIUM | **2** | 3 | 1 | 3 | 3 | 3 | 1 | 2 | 2 | 2 |
| BIO | **34** | 33 | 3 | 33 | 24 | 23 | 60 | 58 | 28 | 26 |

M and L indicate measured in this study and labelled at bottled water, respectively

## 4 Conclusions

This study evaluated the physicochemical quality parameters of five different brands of bottled water currently available in the shops and supermarkets in Benghazi City, Libya. The concentrations of certain physicochemical parameters identified in this investigation were found to be similar to those indicated on the bottled water labels. However, the number and type of parameters reported on the labels of bottled water showed a lack of uniformity. The analysis of the bottled water samples revealed that they are safe for human consumption, in accordance with the permissible limits established by the World Health Organization (WHO) and Libyan standards. The water quality index, assessed based on 14 critical parameters, demonstrated a minimum value of 9.63 and a maximum value of 21.13 for the bottled water samples, categorizing them as having excellent water quality. This study demonstrated that the quality parameters of bottled water brands in Benghazi were either within or below the acceptable limits set by the (WHO) [68] and Libyan standards [69]. In essence, the licensed water brands in Benghazi exhibited a high level of water quality that met the criteria established by WHO.

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