



## Evaluation of Physicochemical and Microbiological Characteristics of Drinking Water in Educational Institutions of Al-Qarabully, Libya

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تقييم الخصائص الفيزيائية والكيميائية والميكروبيولوجية لمياه الشرب في المؤسسات التعليمية بمنطقة القره بوللي، ليبيا

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### Abstract:

Ensuring the safety and quality of drinking water is a fundamental requirement for protecting public health, particularly within educational institutions where students depend on reliable water sources for daily consumption. This study aimed to evaluate the physicochemical and microbiological quality of drinking water supplied to selected educational institutions in Garabolli, Libya, and to assess its compliance with Libyan and international drinking water standards. Six water samples were collected from different educational facilities and analyzed using standard laboratory methods. Physicochemical parameters included pH, total dissolved solids (TDS), electrical conductivity (EC), sodium, potassium, calcium, magnesium, bicarbonate, and total hardness. Microbiological analyses were also conducted to detect total coliform bacteria and *Escherichia coli* as indicators of potential fecal contamination. The results indicated that pH values ranged from 7.38 to 7.94, while electrical conductivity varied between 1223 and 1983  $\mu\text{S}/\text{cm}$ . Bicarbonate concentrations ranged from 0.96 to 2.72 mg/L, all of which were within the permissible limits specified by Libyan drinking water standards. However, TDS values (795–1288 mg/L) and total hardness (320–448 mg/L) exceeded the recommended limits of 500 mg/L and 200 mg/L, respectively. Microbiological examination showed no detectable presence of total coliforms or *E. coli* in any of the analyzed samples. Overall, the findings indicate that although the examined water samples were microbiologically safe, the elevated TDS and hardness levels suggest increased mineralization that may affect overall water quality. Continuous monitoring, improved treatment processes, and stricter regulatory control are recommended to ensure compliance with drinking water standards and to safeguard public health.

**Keywords:** physicochemical characteristics, total dissolved solids (TDS), total hardness, microbiological contamination, *Escherichia coli*, educational institutions in Libya.

### المخلص:

يُعد ضمان سلامة وجودة مياه الشرب من المتطلبات الأساسية لحماية الصحة العامة، ولا سيما في المؤسسات التعليمية التي يعتمد فيها الطلبة على مصادر مياه آمنة للاستهلاك اليومي. هدفت هذه الدراسة إلى تقييم الخصائص الفيزيائية والكيميائية والميكروبيولوجية لمياه الشرب المتوفرة في بعض المؤسسات التعليمية بمنطقة الخروبة في ليبيا، وذلك بهدف تحديد مدى

مطابقتها للمواصفات القياسية الليبية والمعايير الدولية لمياه الشرب. تم جمع ست عينات من المياه من مؤسسات تعليمية مختلفة، وتحليلها باستخدام الطرق المخبرية القياسية. شملت التحاليل الفيزيائية والكيميائية قياس الرقم الهيدروجيني (pH)، والمواد الصلبة الذائبة الكلية (TDS)، والتوصيلية الكهربائية (EC)، إضافة إلى تركيزات الصوديوم والبوتاسيوم والكالسيوم والمغنيسيوم والبيكربونات، وكذلك العسر الكلي. كما أجريت التحاليل الميكروبيولوجية للكشف عن بكتيريا القولونيات الكلية وبكتيريا الإشريكية القولونية (*Escherichia coli*) بوصفهما مؤشرين محتملين للتلوث البرازي. أظهرت النتائج أن قيم الرقم الهيدروجيني تراوحت بين 7.38 و7.94، في حين تراوحت التوصيلية الكهربائية بين 1223 و1983 ميكروسيمنز/سم. كما تراوحت تراكيز البيكربونات بين 0.96 و2.72 ملغم/لتر، وجميعها ضمن الحدود المسموح بها وفق المواصفات القياسية الليبية لمياه الشرب. في المقابل، تراوحت قيم المواد الصلبة الذائبة الكلية بين 795 و1288 ملغم/لتر، بينما تراوح العسر الكلي بين 320 و448 ملغم/لتر، وهي قيم تجاوزت الحدود المسموح بها البالغة 500 ملغم/لتر و200 ملغم/لتر على التوالي. كما أظهرت الفحوصات الميكروبيولوجية عدم وجود بكتيريا القولونيات الكلية أو بكتيريا الإشريكية القولونية في جميع العينات محل الدراسة. تشير هذه النتائج إلى أن عينات المياه المدروسة كانت آمنة من الناحية الميكروبيولوجية، إلا أن الارتفاع الملحوظ في قيم المواد الصلبة الذائبة الكلية والعسر الكلي يعكس زيادة في التمدن قد تؤثر في جودة المياه. وعليه توصي الدراسة بضرورة الاستمرار في المراقبة الدورية لجودة المياه، وتحسين عمليات المعالجة، وتعزيز الرقابة التنظيمية لضمان مطابقة المياه لمعايير السلامة وحماية الصحة العامة.

**الكلمات الافتتاحية:** الخصائص الفيزيائية والكيميائية، المواد الصلبة الذائبة الكلية، العسر الكلي، التلوث الميكروبيولوجي، بكتيريا الإشريكية القولونية، المؤسسات التعليمية في ليبيا.

## Introduction:

Access to safe and reliable drinking water represents a fundamental component of public health protection and sustainable development. Water quality directly influences the well-being of communities and plays a crucial role in preventing waterborne diseases. In environments such as schools and higher education institutions, where large populations depend on shared water resources throughout the day, ensuring the safety of drinking water is particularly important [1].

In this direction, the global demand for bottled drinking water has increased substantially. This growth is largely driven by concerns regarding the safety and taste of municipal water supplies, as well as the perception that bottled water undergoes stricter treatment and quality control procedures. Despite this perception, numerous investigations have demonstrated that the chemical and microbiological characteristics of bottled water can vary depending on source water composition, treatment technologies, packaging conditions, and regulatory oversight [1].

Physicochemical parameters provide essential information regarding the chemical composition and suitability of drinking water. Indicators such as pH, electrical conductivity, total dissolved solids, and major mineral ions are widely used to evaluate water chemistry and identify potential sources of contamination. Elevated mineral concentrations may originate from natural geological formations, seawater intrusion in coastal aquifers, agricultural activities, or limitations in treatment processes [2]. Among these parameters, total dissolved solids and water hardness are particularly important indicators of groundwater mineralization. Hardness results primarily from calcium and magnesium ions dissolved from carbonate-rich geological formations. Although moderate hardness is not considered harmful to human health and may even contribute beneficial minerals, excessive concentrations may affect water palatability and consumer acceptance [3].

Microbiological quality is another critical factor in drinking water safety. The presence of indicator organisms such as Total Coliforms and *Escherichia coli* is commonly used to assess fecal contamination and evaluate the effectiveness of disinfection processes. Contaminated water remains one of the primary pathways for the transmission of infectious diseases in many parts of the world [1]. In Libya, bottled drinking water has become increasingly popular due to concerns related to groundwater salinity and the reliability of municipal water distribution systems. Coastal regions such as Al-Qarabully are particularly vulnerable to seawater intrusion and natural mineralization processes that may influence groundwater chemistry. Despite the widespread consumption of bottled water in the country, scientific studies examining its quality remain limited. Therefore, this research aims to evaluate the physicochemical composition and microbiological safety of bottled drinking water supplied to selected educational institutions in Al-Qarabully, Libya, and to compare the obtained results with Libyan national standards and international drinking water quality guidelines.

## Materials and Methods:

### Study Area:

Al-Qarabully is a coastal municipality located in northwestern Libya along the Mediterranean Sea, approximately 65 km east of Tripoli and 58 km west of Al-Khoms. The region is bordered by Tajoura to the west, Qasr Al-Akhiyar to the east, Tarhuna to the south, and the Mediterranean Sea to the north. The population of the municipality is estimated at approximately 170,000 inhabitants. Due to its

geographic position along the Mediterranean coast, groundwater resources in this region are influenced by marine intrusion and geological mineralization processes that may affect water chemistry.

#### Sample Collection:

A total of six drinking water samples were collected from several educational institutions located in the Al-Qarabully region, Libya. The sampling sites included both primary and secondary schools as well as higher education institutions in order to obtain a representative overview of drinking water quality within educational environments in the study area.

Six samples were collected, namely: Al-Kifah School (sample 1), Abu Al-Tayeb Al-Mutanabbi School (sample 2), the Higher Institute of Medical Sciences and Technologies, Al-Qarahbulli (sample 3), Shabab Al-Ghad School (sample 4), Qasr Al-Akhyar College (sample 5), and Khadija Al-Kubra (sample6).

Water samples were collected in sterile sampling bottles to minimize the risk of contamination during the sampling procedure. Immediately after collection, each bottle was clearly labeled with the sampling site name and sample identification code. The samples were then transported to the laboratory under controlled conditions to preserve their physicochemical and microbiological integrity prior to analysis. Care was taken to ensure that the time between sample collection and laboratory analysis was minimized in order to maintain the reliability and accuracy of the results.

#### Laboratory Analysis:

All laboratory analyses were performed at the Libyan Advanced Center for Chemical Analysis (Tripoli, Libya) using calibrated instruments and standardized analytical procedures. Physicochemical and microbiological analyses were conducted following internationally recognized protocols for water quality assessment [4].

#### Physicochemical Measurements:

The following parameters were determined:

- pH using a calibrated digital pH meter.
- Total Dissolved Solids (TDS) using a TDS meter.
- Electrical Conductivity (EC) using a conductivity meter.
- Sodium and Potassium measured through flame photometry.
- Calcium and Magnesium determined using titration methods.
- Bicarbonate concentration measured by acid titration.
- Total hardness calculated as mg/L CaCO<sub>3</sub>.

#### Microbiological Examination:

Microbiological analysis was performed to detect indicator bacteria associated with fecal contamination. Total Coliforms and *Escherichia coli* were determined using standard microbiological techniques for drinking water analysis in accordance with internationally accepted protocols [4].

- Detection of Total Coliform bacteria.
- Identification of *Escherichia coli* as a fecal contamination indicator.

#### Data Evaluation:

The measured values were compared with the Libyan Standard Specifications for Drinking Water [5] as well as relevant international drinking water quality guidelines published by the World Health Organization.

#### Results and Discussion:

##### Chemical Characteristics of Drinking Water:

The physicochemical characteristics of the drinking water samples collected from educational institutions in Al-Qarabully are presented in Table 1. The measured parameters were compared with the Libyan drinking water standards to evaluate their compliance and overall water quality.

**Table (1):** Physicochemical Analysis Results of Bottled Water Samples from Al-Qarabully Educational schools

Samples	TDS (mg/L)	pH	EC (µS/cm)	Na <sup>+</sup> (mg/L)	K <sup>+</sup> (mg/L)	Ca <sup>2+</sup> (mg/L)	Mg <sup>2+</sup> (mg/L)	HCO <sub>3</sub> <sup>-</sup> (mg/L)	T.H (mg/L as CaCO <sub>3</sub> )
Sample 1	1045	7.38	1608	94.90	4.30	240	96.10	0.96	339
Sample 2	1288	7.76	1983	124.00	6.09	176	70.47	2.72	448
Sample 3	891	7.77	1372	62.74	2.50	176	70.47	2.32	408
Sample 4	795	7.72	1223	86.58	3.99	128	51.25	1.92	320
Sample 5	1216	7.81	1815	131.70	6.02	192	76.80	2.40	432
Sample 6	1049	7.94	1615	128.30	9.38	192	76.80	1.68	360
Libyan Standard	≤ 500	6.5–8.5	—	≤ 200	—	—	—	≤ 250	≤ 200

The chemical analysis of the investigated drinking water samples revealed moderate variation among the measured parameters, reflecting the hydrochemical characteristics of the water source. The pH values ranged from 7.38 to 7.94, indicating slightly alkaline water conditions. These values fall within the recommended limits for drinking water quality established by international and national standards, which typically range from 6.5 to 8.5 [6]. Slightly alkaline pH values are common in groundwater systems and are generally associated with the dissolution of carbonate minerals such as limestone and dolomite within aquifer formations [7].

In contrast, the total dissolved solids (TDS) concentrations recorded in the analyzed samples ranged from 795 to 1288 mg/L, exceeding the maximum permissible limit of 500 mg/L specified in the Libyan drinking water standards. Elevated TDS values often indicate a high degree of mineralization in groundwater resources and are commonly associated with prolonged water–rock interactions within aquifer systems [2]. The relatively high TDS concentrations observed in this study may therefore reflect natural geochemical processes occurring in the aquifer matrix.

Similarly, the electrical conductivity (EC) values ranged from 1223 to 1983  $\mu\text{S}/\text{cm}$ , which corresponds closely with the elevated TDS concentrations. Electrical conductivity is widely used as an indicator of ionic content in water, and increased EC values typically reflect higher concentrations of dissolved salts and minerals [8]. Comparable conductivity levels have been reported in groundwater resources in several arid and semi-arid regions where mineral dissolution significantly influences water chemistry [3].

The concentrations of sodium ( $\text{Na}^+$ ) in the analyzed samples ranged from 62.74 to 131.70 mg/L, remaining within the recommended limits for potable water. Sodium in groundwater commonly originates from natural geological sources, particularly through weathering processes affecting feldspar minerals and ion exchange reactions occurring within aquifer materials [8]. Likewise, the measured potassium ( $\text{K}^+$ ) concentrations ranged between 2.50 and 9.38 mg/L, which are relatively low compared with other dissolved ions and are typical for groundwater systems.

The results also revealed relatively elevated levels of calcium ( $\text{Ca}^{2+}$ ) and magnesium ( $\text{Mg}^{2+}$ ), which contributed to the observed total hardness values ranging from 320 to 448 mg/L as  $\text{CaCO}_3$ . These values exceed the recommended limit of 200 mg/L, indicating that the studied water samples can be classified as hard to very hard water. Water hardness is primarily associated with the dissolution of carbonate minerals, particularly limestone and dolomite, within geological formations [7]. Although hard water is not typically associated with direct health risks, it may affect water taste and contribute to scaling in water distribution systems.

When compared with previous investigations conducted in Libya, the chemical characteristics observed in the present study are consistent with findings reported in several regions. For example, studies carried out in Tripoli and Benghazi have reported relatively high levels of dissolved minerals and water hardness in groundwater used for drinking purposes [9]. Similarly, hydrochemical investigations in Misurata and Zliten have indicated that groundwater in these regions often exhibits elevated mineralization due to the interaction between water and carbonate geological formations [10]. These similarities suggest that the chemical composition observed in this study reflects the typical hydrogeochemical conditions of groundwater resources in Libya

#### Microbiological Quality of Drinking Water:

The microbiological results of the analyzed drinking water samples are presented in Table 2. The analysis showed that Total Coliform bacteria and *Escherichia coli* were not detected in any of the examined samples, indicating full compliance with microbiological drinking water standards.

**Table (2):** Microbiological quality of drinking water samples collected from educational institutions in Al-Qarabully

Sample Code / ID	Total Coliforms	Escherichia coli (E. coli)	Microbiological Compliance
Sample 1	Negative	Negative	Compliant
Sample 2	Negative	Negative	Compliant
Sample 3	Negative	Negative	Compliant
Sample 4	Negative	Negative	Compliant
Sample 5	Negative	Negative	Compliant
Sample 6	Negative	Negative	Compliant
Overall Result	All Negative	All Negative	All Samples Compliant

The microbiological analysis showed that all water samples were negative for Total Coliforms and *Escherichia coli*, indicating full compliance with microbiological drinking water standards. The absence

of these bacterial indicators suggests that the analyzed water samples were not affected by fecal contamination and therefore present minimal microbiological risk for human consumption.

*Escherichia coli* is widely used as a primary indicator organism for detecting fecal pollution in drinking water systems. The presence of this bacterium typically indicates contamination from human or animal waste and may imply the possible presence of pathogenic microorganisms capable of causing waterborne diseases [6]. Consequently, international drinking water guidelines recommend that *E. coli* should not be detectable in any 100 mL sample of drinking water.

The absence of coliform bacteria in the present study may indicate that the water source is well protected from contamination or that effective treatment and sanitation measures are in place. Similar findings have been reported in several studies conducted on treated or bottled drinking water in Libya. For instance, an investigation conducted in Tripoli reported that most bottled drinking water samples were microbiologically safe and free from coliform bacteria due to adequate treatment processes and quality control measures [8]. Likewise, research conducted in Benghazi found that many commercially available drinking water brands met microbiological safety standards and showed no detectable levels of fecal indicator bacteria [11].

However, other studies focusing on water quality in Libyan schools have reported contrasting results. Some investigations have detected coliform contamination in school water storage tanks, which was attributed to inadequate sanitation practices, poor maintenance of storage facilities, or contamination during water distribution [12]. These differences highlight the importance of proper water storage management and routine monitoring to prevent microbial contamination.

Internationally, studies conducted in educational institutions have also demonstrated that microbiological contamination in drinking water systems is often linked to infrastructure deficiencies, aging distribution networks, or insufficient disinfection practices [13]. Therefore, maintaining proper water treatment and monitoring systems remains essential to ensure the microbiological safety of drinking water supplies [14-18].

#### **Conclusion:**

Overall, the integrated chemical and microbiological assessment indicates that the analyzed water samples demonstrate acceptable microbiological quality but elevated mineralization levels, particularly with respect to total dissolved solids and water hardness. The absence of microbial contamination suggests that the water source or treatment process effectively protects against fecal pollution. Nevertheless, the relatively high mineral content observed in the chemical analysis reflects the hydrogeological characteristics of groundwater systems in the region. The analysis revealed that all examined samples were microbiologically safe, as no Total Coliform bacteria or *Escherichia coli* were detected. These findings indicate that the water treatment and handling processes were effective in preventing fecal contamination and ensuring microbiological safety at the time of sampling.

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