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## Assessment of Water Quality of Selected Natural Springs in Al-Jabal Al-Akhdar, Libya Using Water Quality Index (WQI)

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### ABSTRACT

Natural springs are among the most important traditional water resources in the Al-Jabal Al-Akhdar region in eastern Libya, as the local population relies on them for agricultural and domestic uses. Therefore, assessing their water quality is essential to ensure their safety and sustainability. This study aimed to evaluate the quality of water from selected natural springs using the Water Quality Index (WQI) and to compare the results with Libyan and international standard guidelines to determine their suitability for various uses. A total of ten water samples were collected, with three replicates per sample, from springs distributed across several locations within the study area. The main physicochemical parameters were analyzed, including pH, total dissolved solids (TDS), electrical conductivity (EC), total hardness (TH), nitrate ( $\text{NO}_3^-$ ), chloride ( $\text{Cl}^-$ ), and sulfate ( $\text{SO}_4^{2-}$ ). The Water Quality Index was calculated using the weighted arithmetic method to classify water quality. The results showed that most of the studied parameters were within the permissible limits according to standard guidelines, indicating acceptable water quality in the majority of the springs. However, Ain Al-Ajal spring recorded an elevated nitrate concentration (57.8 mg/L), likely due to agricultural activities and geological influences, which affected its WQI value. The WQI values ranged from 75.91 to 101.2, with most springs classified as having good water quality suitable for domestic and agricultural uses, while Ain Al-Ajal spring was classified as poor water quality. These findings confirm the effectiveness of the Water Quality Index as a reliable tool for evaluating natural water resources and highlight the importance of continuous monitoring and sustainable management to protect these resources from contamination and ensure their safe future use.

### تقييم جودة مياه بعض العينات الطبيعية في منطقة الجبل الأخضر، ليبيا باستخدام مؤشر جودة المياه (WQI)

توفيق الباقرمي عبد السلام أمحارب عيسى الهين محمد الهين

تعد العينات الطبيعية من أهم مصادر المياه التقليدية في منطقة الجبل الأخضر شرق ليبيا، نظرًا لاعتماد السكان عليها في الزراعة والاستخدامات المنزلية، مما يجعل تقييم جودتها أمرًا ضروريًا لضمان سلامتها واستدامتها. هدفت هذه الدراسة إلى تقييم جودة مياه بعض العينات الطبيعية باستخدام مؤشر جودة المياه (WQI) ومقارنتها بالمواصفات القياسية الليبية والعالمية لتحديد مدى صلاحيتها للاستخدامات المختلفة. تم جمع عشر عينات بواقع ثلاثة مكررات للعينات من عينات موزعة في عدة مواقع داخل منطقة الدراسة، ثم تحليل الخصائص الفيزيائية والكيميائية الرئيسية، والتي شملت الأس الهيدروجيني pH، الأملاح الذائبة الكلية TDS، الإصلية الكهربائية Ec، العسرة الكلية TH، النترات  $\text{NO}_3^-$ ، الكلوريد  $\text{Cl}^-$ ، والكبريتات  $\text{SO}_4^{2-}$ ، كما تم حساب مؤشر جودة المياه باستخدام الطريقة الرياضية الموزونة لتصنيف جودة المياه. أظهرت النتائج أن معظم الخصائص المدروسة كانت ضمن الحدود المسموح بها وفق المعايير القياسية، مما يشير إلى جودة مقبولة للمياه في غالبية العينات. ومع ذلك، سجلت عين العجل ارتفاعًا في تركيز النترات  $\text{mg/l}$  7.85 نتيجة تأثير الأنشطة الزراعية والعوامل الجيولوجية، مما انعكس على قيم مؤشر جودة المياه. تراوحت قيم مؤشر جودة المياه بين 75.91 و101.2، حيث صنفت معظم العينات ضمن فئة المياه الجيدة المناسبة للاستخدامات المنزلية والزراعية، بينما صنفت عين العجل ضمن فئة المياه الفقيرة. تؤكد هذه النتائج أهمية استخدام مؤشر جودة المياه كأداة فعالة لتقييم الموارد المائية الطبيعية، كما تبرز ضرورة المراقبة المستمرة والإدارة المستدامة لحماية هذه الموارد من التلوث وضمان استخدامها الآمن في المستقبل.

## INTRODUCTION

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Access to safe and clean water is a critical global necessity, including in Libya. In Al-Jabal Al-Akhdar, natural spring water represents an important freshwater resource due to the limited availability of alternative water resources. Consequently, natural springs have received considerable attention due to their relatively high water quality and suitability for human consumption. Springs are formed when groundwater naturally emerges at the Earth's surface, typically originating from aquifers. The geological characteristics of the surrounding area, such as rock formations and hydrological processes, play a crucial role in determining the unique composition and quality of spring water (Kresic & Stevanovic, 2009). These systems are characterized by complex interactions between groundwater and surface water, as well as between aquatic and terrestrial ecosystems, making them naturally unique and diverse environments. Springs develop through natural processes that allow groundwater to reach the surface through faults, fractures, or rock contacts (Ibeneme et al., 2013; von Fumetti et al., 2017). The quality of spring water significantly influences its suitability for human consumption and agricultural practices, as contaminants present in water may pose risks to human health and negatively affect crop productivity and quality.

Therefore, assessing spring water quality is essential to ensure its safe use for various purposes, including livestock watering, agriculture, domestic use, and drinking water. In a study conducted by Lamloom (2023), which evaluated groundwater and spring water quality in Al-Jabal Al-Akhdar, Libya, during the summer and winter of 2017, water samples were collected from 47 wells and 15 seasonal springs and assessed using the Water Quality Index (WQI). The results indicated that most samples fell within the freshwater category suitable for human consumption, with some exceptions due to the accumulation of untreated waste. Continuous monitoring of water quality over time is essential, particularly in regions such as Al-Jabal Al-Akhdar, where these springs represent an important traditional water resource. Comparing recent data with previous data using the same index (WQI) enables the identification of potential changes in water quality resulting from factors such as climate change, urbanization, agricultural expansion, and possible contamination affecting these natural resources.

Similarly, a study conducted by Abou Abbass et al. (2024) at Nabaa El-Tasseh Spring in Lebanon using the Water Quality Index (WQI) revealed that spring water in the region was unsuitable for human consumption without treatment, particularly during winter when WQI values reached 88.608, whereas water quality improved in other seasons, reaching a value of 31.51 in spring. In Nepal, Pantha et al. (2022) applied the same index (WQI) to evaluate spring water quality in the Tanahun region during pre-monsoon and monsoon seasons. The results showed that most spring water

ranged from good to excellent quality for drinking and irrigation purposes, although some springs exhibited elevated contaminant levels, rendering them unsuitable for drinking without treatment.

Libya relies heavily on groundwater to meet its water demands for various uses; however, it experiences significant water stress due to limited water resources, increasing demand, human activities, and inadequate water resource management. These factors have contributed to groundwater depletion and deterioration in water quality. Under such conditions, natural springs have become important traditional water sources that may help alleviate water shortages, particularly in areas lacking alternative water supplies. However, available information on the quality of these springs remains limited and outdated, and does not adequately reflect their suitability for different uses according to local and international standards.

Evaluating the quality of these natural springs is essential for providing updated scientific data to determine their suitability for domestic and agricultural uses, supporting sustainable water resource management, and contributing to the development of effective strategies for protecting these resources from pollution and unsustainable exploitation. Furthermore, such assessment helps establish a scientific database that can support future planning and management of traditional water resources in Libya, especially under increasing pressure on conventional water sources. Therefore, the present study aims to assess the water quality of selected natural springs in Al-Jabal Al-Akhdar, Libya, using the Water Quality Index (WQI), and to compare the results with Libyan and international standard guidelines.

## MATERIALS AND METHODS

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**Study Area** The study area is located in northeastern Libya and covers an area of approximately 2,000 km<sup>2</sup>. The population of the study region was approximately 163,506 according to the 2006 census. The area extends from the city of Derna in the east to the city of Shahat in the west, and from the Mediterranean coast in the north to Ain Mara, Al-Qubbah, Lamludah, and Al-Abyar in the south (Al-Rawashda, 2012). Geographically, the study area lies between latitudes 32°56' and 34°32' N and longitudes 21°50' and 22°38' E. Figure (1) illustrates the location of the study area and the sampling sites. The region includes several medium-sized towns, such as Al-Qubbah and Shahat.

**Sample Collection** The present study was conducted in October 2024 (autumn) on a group of springs in the Al-Jabal Al-Akhdar region in eastern Libya, located approximately 200 km east of Benghazi. Sampling sites were selected from several locations, including Al-Qubbah, Balkhna, Wadi Al-Ain, Shahat, and Susa. A total of ten water samples were collected from the springs using sterile 500-mL polyethylene sampling bottles. Samples were collected from

the center of each spring at depths ranging from 15 to 30 cm, with three replicates per sampling site. The samples were immediately transported to the laboratory for analysis and stored in a cooled container at 4°C to prevent microbial growth until further analysis. The geographic coordinates of the sampling sites were recorded using a Global Positioning System (GPS) device.



Figure (1). Location of the study area and sampling sites.

**Physicochemical Analysis**

**pH**

The pH of water samples was measured immediately after collection using a pH meter (Model AR-50-HACH).

**Total Dissolved Solids (TDS)**

Total dissolved solids were measured using a TDS meter (Model AR-50-HACH), and values were expressed in mg/L.

**Electrical Conductivity (EC)**

Electrical conductivity was measured using a conductivity meter following the method described by Richards (1954).

**Nitrate (NO<sub>3</sub><sup>-</sup>)**

Nitrate concentrations were determined according to the standard methods described by APHA (1995) using a UV–Visible spectrophotometer (PHILIPS PU8625 Series) at a wavelength of 220 nm.

**Total Hardness (TH)**

Total hardness was determined as calcium carbonate (CaCO<sub>3</sub>) using the EDTA titration method with Eriochrome Black T indicator, following the procedures described by APHA (1992).

**Sulfate (SO<sub>4</sub><sup>2-</sup>)**

Sulfate concentration was determined using the turbidity method according to APHA (1995), using a UV–Visible spectrophotometer at a wavelength of 540 nm.

**Chloride (Cl<sup>-</sup>)**

Chloride concentration was determined using the Mohr titration method with silver nitrate solution and potassium

chromate indicator, following the procedure described by Black (1965).

**Water Quality Index (WQI)**

To evaluate the overall water quality, the Water Quality Index (WQI) was calculated for each sample using the weighted arithmetic index method. In this method, relative weights and quality rating scales were assigned based on international standard guidelines, and the index was calculated using the equations described by Khudair (2013)

$$qi = \frac{ci}{si} \times 100 \dots\dots\dots(1)$$

$$Wi = \frac{1}{si} \dots\dots\dots(2)$$

$$WQI = \sum_{i=1}^{i=n} wi \times qi \dots\dots\dots(3)$$

$$overall\ WQI = \frac{\sum_{i=1}^{i=n} wi \times qi}{\sum wi} \dots\dots\dots(4)$$

where:

- Wi**; is the relative weight of each parameter.
- qi**; is the quality rating scale.
- Ci**; is the measured concentration.
- Si**; is the permissible standard limit according to international standards.
- n**; is the total number of parameters analyzed.

**RESULTS AND DISCUSSION**

**pH**

The results presented in Table (1) indicate that the highest pH value was recorded at Ain Al-Ajal (8.4), while the lowest value was observed at Ain Al-Hafra (6.8). The increase in pH toward alkalinity may be attributed to lower temperatures, which reduce decomposition rates. Conversely, higher temperatures may decrease pH due to increased microbial and bacterial activity, which enhances decomposition processes and gradually shifts water toward neutral or slightly acidic conditions (Al-Nasih, 1993; Venkatesharaju et al., 2010). Based on the obtained results, all studied springs fall within the permissible range for drinking water according to the Libyan standard (2015) and the World Health Organization (WHO, 2017) guidelines (6.5–8.5). These findings are consistent with previous studies conducted in the Al-Jabal Al-Akhdar region (Al-Rawashda, 2012; Kaalouh, 2012), which also reported that pH values of spring water were within acceptable limits.

**Table (1): Physicochemical parameters of the studied water samples**

Spring Name	pH	TH mg/l	Ec μs/cm	TDS mg/l	NO3 mg/l	Cl mg/l	SO4 mg/l
Al-Ajal	8.4	115.7	1610	644	57.8	210.7	104.3
Abulo	7.5	89.1	1380	553	36.2	161.2	96.1

Al-Haddadiya	7	89.2	1171	470	26.8	123.8	91.1
Al-Ikhwan	7	101.3	1385	554	32.1	240.2	97.5
Al-Hashan	7.2	99.3	1410	564	32.8	170.6	98.3
Tari	7.9	82.7	1165	466	26.6	121.8	90.8
Ono	7.4	82.7	1190	476	27.2	126.8	90.6
Al-Hafra	6.8	70.5	920	369	20.3	173.6	79.6
Dawi	7.5	95	1347	539	30.2	148.6	93.1
Balkhna	7	94.4	1410	564	31.7	270.6	97.8

**Electrical Conductivity (EC)**

The results in Table (1) show that the highest electrical conductivity value was recorded at Ain Al-Ajal (1610  $\mu\text{S/cm}$ ), while the lowest value was observed at Ain Al-Hafra (920  $\mu\text{S/cm}$ ). According to the Libyan standard (2015) and WHO guidelines (2017), the maximum permissible limit for drinking water is 2300  $\mu\text{S/cm}$ . Electrical conductivity reflects the total concentration of dissolved salts in water; therefore, higher EC values indicate higher salinity levels. Increased salinity may result from natural factors, such as the geological composition of aquifer rocks, or from anthropogenic sources, such as domestic or industrial wastewater contamination (Al-Bahar, 2021). The results of the present study are consistent with those reported by Alkadi et al (2019) who investigated the quality of spring water and its suitability for drinking and irrigation in Al Jabal Al Akhdar. Their findings showed that all measured parameters were within both international and local standards.

**Total Dissolved Solids (TDS)**

The results indicate that the highest TDS value was recorded at Ain Al-Ajal (644 mg/L), while the lowest value was observed at Ain Al-Hafra (369 mg/L). According to WHO (2017) and Libyan drinking water standards (2015), the maximum permissible limit for TDS is 1000 mg/L. The results show that all sampled springs fall within the acceptable limits for drinking water. The findings of this study are comparable to those reported by El-Shawaihdi et al (2022) who investigated the geochemical and biological pollution of Ain Massa spring water in Al Jabal Al Akhdar.

**Total Hardness (TH)**

The results show that the highest total hardness value was recorded at Ain Al-Ajal (115.7 mg/L), while the lowest value was observed at Ain Al-Hafra (70.5 mg/L). These values are within the permissible limit of 500 mg/L established by Libyan standards (2015) and WHO guidelines (2017). The relatively elevated hardness values observed in some springs may be attributed to geological factors, including the dissolution of gypsum, anhydrite, limestone, and dolomite formations. These findings are lower than those reported by Al-Safawi (2018), who attributed higher hardness values to similar geological conditions.

**Nitrate ( $\text{NO}_3^-$ )**

The results indicate that the highest nitrate concentration was recorded at Ain Al-Ajal (57.8 mg/L), while the lowest value was observed at Ain Al-Hafra (20.3 mg/L). According to WHO (2017) and Libyan drinking water standards (2015), the permissible limit for nitrate is 45 mg/L. Most springs fall within acceptable limits, except Ain Al-Ajal, which exceeded the recommended value. This elevated nitrate concentration may be attributed to agricultural activities, particularly the use of nitrogen-based fertilizers that infiltrate groundwater through soil, as well as the discharge of wastewater in nearby areas.

These findings are consistent with previous studies conducted in the Al-Jabal Al-Akhdar region (Idris, 2000; Nasser, 1998), which reported elevated nitrate levels in certain springs. Similarly, Al-Haen et al. (2026) reported nitrate contamination in groundwater due to agricultural and hydrological factors. Elevated nitrate levels in drinking water pose significant health risks, including methemoglobinemia (blue baby syndrome), certain cancers, and developmental disorders (Ward et al., 2018).

**Chloride ( $\text{Cl}^-$ )**

The results show that the highest chloride concentration was recorded at Ain Balkhna (270.6 mg/L), while the lowest value was observed at Ain Tri (121.8 mg/L). According to WHO (2017) and Libyan drinking water standards (2015), the maximum permissible limit for chloride is 250 mg/L. Most springs fall within acceptable limits, except Ain Balkhna, which exceeded the standard limit. This elevated chloride concentration may be attributed to the spring's proximity to coastal areas, where seawater intrusion may occur due to groundwater abstraction and hydraulic pressure differences (Al-Manharawi, 1997; Kaalouh et al., 2012).

**Sulfate ( $\text{SO}_4^{2-}$ )**

The results indicate that the highest sulfate concentration was recorded at Ain Al-Ajal (104.3 mg/L), while the lowest value was observed at Ain Al-Hafra (79.6 mg/L). According to WHO (2017) and Libyan drinking water standards (2015), the maximum permissible limit for sulfate is 400 mg/L. All measured values fall within acceptable limits. Sulfate concentrations in natural waters are primarily influenced by geological formations and the mineral composition of aquifer rocks. Lower sulfate concentrations are generally associated with uncontaminated water sources. These findings are consistent with previous studies conducted in the region (Lamloum, 2008; Al-Abdali, 2020; Arjiha, 2022)

**Water Quality Index (WQI)**

The Water Quality Index (WQI) is an important and widely used tool that provides a simplified and comprehensive assessment of the overall water quality status of aquatic systems in a single value, facilitating effective decision-making for water resource management (Tyagi et al., 2013). In the present study, the WQI values for the investigated spring water ranged from 75.91 to 101.2, as shown in Table

(3). Based on the water quality classification presented in Table (2), the results indicate that water quality ranged from good to poor.

According to the WQI classification, all studied springs, except Ain Al-Ajal, were categorized as having good water quality suitable for domestic, agricultural, and industrial uses. In contrast, Ain Al-Ajal was classified as having poor water quality and is considered suitable only for irrigation purposes. This classification is mainly attributed to the elevated nitrate concentration exceeding permissible limits, indicating contamination from agricultural fertilizers, surface runoff, and other anthropogenic activities. Such contamination poses potential risks to human health and limits the suitability of this water source for drinking, recreational, and agricultural uses without prior treatment. Therefore, improving the water quality of this spring requires the implementation of appropriate management strategies, such as reducing the discharge of untreated domestic wastewater into the aquatic system (Abou Abbass et al., 2024).

Furthermore, the higher WQI values obtained in this study compared to those reported by Lamloom et al. (2023), who assessed the same springs in 2017 using the WQI method, indicate potential recent exposure of these springs to additional contamination sources. Variations in WQI values among springs classified as having good water quality may be attributed to differences in the concentrations of the analyzed physicochemical parameters, which are influenced by natural environmental and geological factors. These findings are consistent with previous studies (Karunanidhi et al., 2021; Reda, 2015). However, the present results indicate better water quality compared to the findings of Kneh et al. (2021), who reported that groundwater quality in their study area was generally classified as poor.

**Table (2). Classification of water quality based on the Water Quality Index (WQI)**

Water Quality Index Value	Water Quality Classification
< 50	Excellent water
50 – 100	Good water
101 – 200	Poor water
201 – 300	Very poor water
> 300	Unsuitable for use

Source: Abbas Abdul (2016)

**Table (3). Water Quality Index (WQI) values and classification in the study area**

Spring Name	Water Quality Index Value	Water Quality Classification
Ain Al-Ajal	101.2	Poor water
Ain Abolo	84.13	Good water

Spring Name	Water Quality Index Value	Water Quality Classification
Ain Al-Hadadiya	75.91	Good water
Ain Al-Ikhwan	79.04	Good water
Ain Al-Hashan	80.39	Good water
Ain Tri	84.12	Good water
Ain Uno	79.76	Good water
Ain Al-Hafra	87.03	Good water
Ain Dui	82	Good water
Ain Balkhna	79.23	Good water

**CONCLUSION**

This study aimed to assess the water quality of selected natural springs in the Al-Jabal Al-Akhdar region, eastern Libya, using the Water Quality Index (WQI), in order to determine their suitability for various uses, particularly drinking and irrigation, given the increasing reliance on these resources as important water sources. The results indicated that most of the investigated physicochemical parameters, including pH, total dissolved solids, total hardness, and sulfate, were within the permissible limits established by local and international standards, suggesting acceptable water quality in most of the studied springs. The calculated WQI values ranged from 75.91 to 101.2, indicating that the majority of the springs fall within the good water quality category suitable for domestic, agricultural, and industrial uses. However, one spring was classified as having poor water quality due to elevated nitrate concentrations, which are likely associated with agricultural activities and surrounding environmental factors. Nevertheless, the findings of this study are limited to a specific number of springs and a defined sampling period, which may not fully represent temporal variations or all potential sources of contamination. This study contributes to improving the scientific understanding of spring water quality in the Al-Jabal Al-Akhdar region and highlights the importance of using the Water Quality Index as an effective tool for evaluating natural water resources. Furthermore, it supports sustainable water resource management efforts and emphasizes the need to protect these vital water sources from contamination and degradation

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