



## Assessment of Irrigation Water Quality of Some Springs in the Al-Jabal Al-Akhdar Region, Libya

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### تقييم جودة مياه الري لبعض العيون في مناطق الجبل الأخضر – ليبيا

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#### Abstract

The present study aims to assess the irrigation water quality of several springs in the Al-Jabal Al-Akhdar region, northeastern Libya, in order to determine their suitability for agricultural use, given the heavy reliance on groundwater resources in the area. Ten water samples were collected from springs distributed across several locations during the autumn of 2024. A set of physicochemical analyses was conducted, including measurements of pH and electrical conductivity (EC), as well as the concentrations of major ions such as calcium (Ca<sup>2+</sup>), magnesium (Mg<sup>2+</sup>), sodium (Na<sup>+</sup>), and potassium (K<sup>+</sup>). In addition, the Sodium Adsorption Ratio (SAR) and the Soluble Sodium Percentage (SSP%) were calculated. The results showed that pH values ranged between 6.8 and 7.9, with an average of 7.2, while electrical conductivity values ranged from 574 to 1006 µS/cm, indicating relatively moderate salinity levels. The SAR values ranged between 1.08 and 1.65, whereas SSP values varied from 31.2% to 42.3%, all of which fall within the acceptable limits for irrigation water. According to the classification of the United States Salinity Laboratory (USSL), the water samples were categorized within the classes C2-S1 and C3-S1, indicating a low sodium hazard but moderate to relatively high salinity effects. These findings suggest that the studied spring waters can be used for irrigation, provided that appropriate salinity management practices are implemented, including adequate drainage and the cultivation of relatively salt-tolerant crops. Such measures would contribute to supporting the sustainable management of water resources in the Al-Jabal Al-Akhdar region.

**Keywords:** Irrigation Water Quality, Al-Jabal Al-Akhdar, Sodium Adsorption Ratio (SAR), United States Salinity Laboratory (USSL), Water Salinity.

#### المخلص

تهدف الدراسة إلى تقييم جودة مياه الري لبعض العيون في منطقة الجبل الأخضر شمال شرق ليبيا، وذلك لتحديد مدى ملاءمتها للاستخدام الزراعي في ظل الاعتماد الكبير على المياه الجوفية في المنطقة. تم جمع عشر عينات من عيون مائية موزعة في عدة مواقع خلال خريف عام 2024، حيث أجريت عليها مجموعة من التحاليل الفيزيائية والكيميائية شملت قياس الأس الهيدروجيني (pH)، والتوصيل الكهربائي (EC)، وتركيز بعض الأيونات الرئيسية مثل الكالسيوم والمغنيسيوم والصوديوم والبوتاسيوم، إضافة إلى حساب معامل ادمصاص الصوديوم (SAR) والنسبة المئوية للصوديوم الذائب (SSP%). وأظهرت النتائج أن قيم الأس الهيدروجيني تراوحت بين (6.8-7.9) بمتوسط (7.2)، بينما تراوحت قيم التوصيل

الكهربائي بين (574–1006  $\mu\text{S}/\text{cm}$ )، مما يشير إلى ملوحة متوسطة نسبيًا. كما سجلت قيم SAR مدى يتراوح بين (1.08–1.65) وقيم SSP بين (31.2–42.3%)، وهي ضمن الحدود المقبولة لمياه الري. ووفقًا لتصنيف مختبر الملوحة الأمريكي (USSL) صنّفت المياه ضمن الفئتين (C2–S1) و(C3–S1)، مما يدل على انخفاض خطر الصوديوم مع وجود تأثير متوسط إلى مرتفع للملوحة. وتشير النتائج إلى إمكانية استخدام هذه المياه للري مع ضرورة مراعاة إدارة الملوحة وتحسين الصرف واختيار المحاصيل المتحملة نسبيًا للأملح، بما يساهم في دعم الإدارة المستدامة للموارد المائية في منطقة الجبل الأخضر.

**الكلمات المفتاحية:** جودة مياه الري، الجبل الأخضر، معامل ادمصاص الصوديوم (SAR)، مختبر الملوحة الأمريكي (USSL)، ملوحة المياه.

## Introduction

Water is one of the most important natural resources available on our planet and represents a fundamental element for sustaining life and maintaining suitable environmental conditions. It is characterized by unique physical and chemical properties that make it one of the most widely distributed natural resources on the Earth's surface, within the subsurface, and in the atmosphere (Al-Saadi, 2006). Water is also an essential resource for the growth and production of agricultural crops; without it, plant life cannot exist. It constitutes the main component of plant tissues and acts as the medium for the transport of nutrients within both soil and plants. Water resources therefore play a crucial role in global agriculture, particularly in regions where water resources are limited and where increasing population growth leads to greater water demand and consumption (Al-Hiyani, 2009).

Libya relies heavily on groundwater resources to meet its water demands, with groundwater accounting for approximately 95% of the country's total water resources. These groundwater reserves occur in both renewable and non-renewable aquifers, with renewable groundwater estimated at more than 500 million cubic meters in aquifers located in the northern part of the country (General Water Authority, 2006). The Al-Jabal Al-Akhdar region is considered one of the most important agricultural areas in Libya due to its moderate climatic conditions and relatively abundant natural water resources compared with other arid and semi-arid regions of the country. Springs and natural water outlets represent a traditional and important source of irrigation water in this region, supporting extensive rain-fed and irrigated agricultural activities, including the production of cereals, vegetables, and fruit trees. However, the sustainability of this vital resource is closely related to the quality of irrigation water, as its physical and chemical characteristics significantly influence soil fertility, nutrient uptake efficiency by plants, and crop productivity in both the short and long term (Ayers & Westcot, 1985).

Assessing irrigation water quality is therefore a critical component in water resource management in arid and semi-arid regions. Continuous use of water with high salinity or elevated sodium concentrations may lead to soil structure degradation, increased salinization and alkalinity, and reduced soil permeability, which negatively affects plant growth and productivity (FAO, 2000). The most important indicators used to evaluate irrigation water quality include electrical conductivity (EC), pH, total dissolved solids (TDS), sodium adsorption ratio (SAR), and soluble sodium percentage (SSP%), in addition to the concentrations of major ions such as calcium, magnesium, sodium, chloride, sulfate, and bicarbonate (Todd & Mays, 2005). Analyzing these parameters is essential for determining the suitability of water for agricultural use and for classifying it according to internationally recognized standards.

This study is important because it provides updated scientific data on the physicochemical characteristics of spring water in the Al-Jabal Al-Akhdar region. Such information contributes to improving the knowledge base regarding water quality and provides valuable data for decision-makers and relevant authorities responsible for sustainable water resource management in the region, particularly under conditions of limited water availability. Furthermore, the study aims to determine the suitability of spring water for irrigation and to guide farmers toward its optimal use in order to reduce the risks of soil salinization and fertility degradation, thereby protecting the agricultural ecosystem from the negative impacts associated with the use of unsuitable irrigation water. Accordingly, the present study aims to evaluate the irrigation water quality of several springs in the Al-Jabal Al-Akhdar region in order to determine their suitability for irrigation through comparison with the Sodium Adsorption Ratio (SAR), the Soluble Sodium Percentage (SSP%), and the classification system of the United States Salinity Laboratory (USSL).

## Material and methods

**Study Area:** The study area is located in northeastern Libya and covers an estimated area of approximately 2000 km<sup>2</sup>. It extends from the city of Derna in the east to Shahat in the west, and from the Mediterranean Sea coast in the north to the areas of Ain Mara, Al-Qubbah, Lamluda, and Al-Abyar in the south (Al-Rawashdeh, 2012). The region is characterized by a dry to semi-arid climate, with a relatively higher annual rainfall compared to other regions of Libya. Geographically, the study area lies between 32°56' and 32°34' N latitude and 21°50' to 22°38' E longitude, as illustrated in Figure (1).

This study was conducted during autumn 2024 on a number of springs located in the Al-Jabal Al-Akhdar region in eastern Libya, 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, with three replicates for each sample, using sterilized bottles with a capacity of 0.5 L. Samples were taken from the center of the spring at a depth ranging from 15 to 30 cm, and were then transported directly to the laboratory for analysis. The sampling locations were recorded using a Global Positioning System (GPS) device, as shown in Figure (1).



Figure (1). Locations of the studied springs in the study area.

### Physicochemical Analysis Methods

#### pH

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

#### Electrical Conductivity (EC)

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

#### Calcium and Magnesium ( $\text{Ca}^{2+}$ and $\text{Mg}^{2+}$ )

Calcium and magnesium ions in the water samples were determined using the titrimetric method by titration with EDTA, employing Eriochrome Black T (E.B.T) and Murexide indicators, according to the standard procedures described by APHA (1995).

#### Sodium and Potassium ( $\text{Na}^+$ and $\text{K}^+$ )

Sodium and potassium concentrations were measured using a flame photometer (Models PFP7 and PFP7/JENWAY) in accordance with the procedures outlined by APHA (1995).

#### Calculation of Soluble Sodium Percentage (SSP%)

The Soluble Sodium Percentage (SSP%) was calculated as the percentage of sodium ions relative to the total concentration of major cations expressed in milliequivalents per liter (meq/L) using the following equation according to APHA (2005).

$$Na\% = \frac{Na}{Ca + Mg + Na + K} \times 100$$

### Calculation of Sodium Adsorption Ratio (SAR)

The Sodium Adsorption Ratio (SAR) was calculated based on the concentrations of sodium ( $\text{Na}^+$ ), calcium ( $\text{Ca}^{2+}$ ), and magnesium ( $\text{Mg}^{2+}$ ), expressed in milliequivalents per liter (meq/L), using the following equation according to Richards (1954).

$$\text{SAR} = \frac{\text{Na}}{\sqrt{\frac{\text{Ca} + \text{Mg}}{2}}}$$

## Results and discussion

### pH

The pH is one of the most important chemical properties of irrigation water, as it indicates the degree of acidity or alkalinity of water. The pH value generally ranges between 0 and 14, where values lower than 7 indicate acidic conditions, values higher than 7 indicate alkaline conditions, and a value of 7 represents neutrality (WHO, 2017). The results showed that the highest pH value was 7.9 in Tri Spring, while the lowest value was 6.8 in Al-Ajal Spring, with an overall average of 7.2, as presented in Table (1). The slight variation in pH values is likely attributed to groundwater movement and its interaction with different geological formations through which the water flows, in addition to mixing with various water sources. Accordingly, all spring waters are considered safe for irrigation use and are unlikely to cause salinity or alkalinity problems that could negatively affect plant growth or soil properties, as reported by Al-Hadithi and Al-Assafi (2016). These findings are consistent with those reported by Masoud et al. (2020).

### Electrical Conductivity (EC)

Electrical conductivity (EC) is an important indicator used to indirectly estimate the concentration of dissolved salts in water. It depends on the ability of a solution to conduct electric current and is directly proportional to the concentration of dissolved ions; thus, EC values increase as the concentration of dissolved salts increases (Al-Bahar, 2021). The results presented in Table (1) show variation in EC values among the studied springs. The highest EC value was recorded in Al-Ajal Spring at 1.06 dS/m, whereas the lowest value was observed in Al-Hafra Spring at 0.57 dS/m, with an overall mean of 0.81 dS/m.

According to the Food and Agriculture Organization classification (FAO, 1985), irrigation water with EC values ranging from 0.7 to 3.0 dS/m may present slight to moderate salinity problems, while values exceeding 3.0 dS/m can cause significant problems for soil and plant growth. Based on this classification, all the studied spring waters fall within the category of slight to moderate salinity hazard when used for irrigation. These results are consistent with those reported by Al-Azraq (2023).

**Table (1).** Chemical analysis results of the studied parameters.

Spring Name	pH	Ec d.s/m	Ca Mg/l	Mg Mg/l	Na Mg/l	K Mg/l
Al-Ajal	6.8	1.06	97.6	18.1	81.6	3.9
Abulo	7.5	0.86	73.2	15.9	63	5.6
Al-Haddadiya	7	0.73	74.5	14.7	52	0.5
Al-Ikhwan	7	0.86	85.7	15.6	75.6	1.3
Al-Hashan	7.2	0.88	83.4	15.9	83.1	4.6
Tari	7.9	0.72	71.3	11.4	73.7	2
Ono	7.4	0.74	68	14.7	72	1.9
Al-Hafra	7.6	0.57	59.4	11.1	67.5	3.7
Dawi	7.5	0.84	78.2	16.8	80.5	4.5
Balkhana	7	0.87	80.5	13.9	70.4	1.7
Mean	7.2	0.81	77.1	14.8	71.9	2.9
Minimum	6.8	0.57	59.4	11.1	52	0.5
Maximum	7.9	1.06	97.6	18.1	83.1	5.6

### Sodium Adsorption Ratio (SAR)

The Sodium Adsorption Ratio (SAR) is one of the most important irrigation water quality indicators used to assess the potential harmful effects of sodium on soil structure and permeability. SAR represents the relationship between sodium ions and the concentrations of calcium and magnesium ions, reflecting the tendency of irrigation water to participate in cation exchange reactions in soil. High SAR values may lead to sodium toxicity symptoms in plants due to elevated sodium concentrations, which negatively affect plant growth and productivity (Asadi et al., 2020).

The results presented in Table (3) indicate that SAR values ranged from 1.08 to 1.65 meq/L, with the highest value recorded in Uno Spring and the lowest value in Al-Hadadiyah Spring. The variation in SAR values is mainly attributed to differences in calcium and magnesium concentrations relative to sodium concentrations in the water samples (Adejumo et al., 2018). Comparing these results with internationally recognized irrigation water classifications (Table 2) shows that the SAR values of the studied springs fall within the S1 category (low sodium hazard) according to the classification of the United States Salinity Laboratory (USSL, 1954). Therefore, no significant sodium-related problems are expected when these waters are used for irrigation. These findings are consistent with the results reported by Al-Safawi and Talat (2019) in their study of groundwater quality in Al-Hamdaniya, Iraq.

**Table (2).** US Salinity Laboratory classification of irrigation water based on SAR values .

Water Class	SAR	Specifications
Low Sodium S1	$0 < SAR < 10$	Can be used for irrigation in most soils, with slight accumulation of exchangeable sodium.
Medium Sodium S2	$10 < SAR < 18$	May cause sodium hazard in fine-textured soils; however, it can be used in coarse-textured soils with good drainage and high permeability..
High Sodium S3	$18 < SAR < 26$	Represents a high sodium hazard; requires good drainage, soil leaching, and the addition of amendments such as agricultural gypsum..
Very High Sodium S4	$SAR > 26$	Generally unsuitable for irrigation except under very special conditions with intensive treatment of both soil and water.

(Richards, 1954).

**Table (3).** Results of irrigation water classification based on SAR and USSL system.

Spring Name	EC μ sem/cm	USSL 1954	SSP %	SAR
Al-Ajal	1006	C3-S1	35.3%	1.48
Abulo	864	C3-S1	34.8%	1.31
Al-Haddadiya	734	C2-S1	31.2%	1.08
Al-Ikhwan	865	C3-S1	36.9%	1.48
Al-Hashan	880	C3-S1	39.1%	1.64
Tari	728	C2-S1	41.2%	1.59
Ono	742	C2-S1	40.1%	1.65
Al-Hafra	574	C2-S1	42.3%	1.58
Dawi	840	C3-S1	39.2%	1.63
Balkhana	879	C3-S1	36.9%	1.42

### Soluble Sodium Percentage (SSP%)

Irrigation water contains varying concentrations of major cations such as calcium, sodium, magnesium, and potassium. The Soluble Sodium Percentage (SSP%) is used to evaluate sodium hazards in irrigation water. High sodium concentrations relative to calcium and magnesium increase the likelihood of soil alkalinity problems and may negatively affect soil structure and plant growth. It has been reported that when SSP values exceed 60%, irrigation water may become harmful to soil and crops (MamRasoul, 2000).

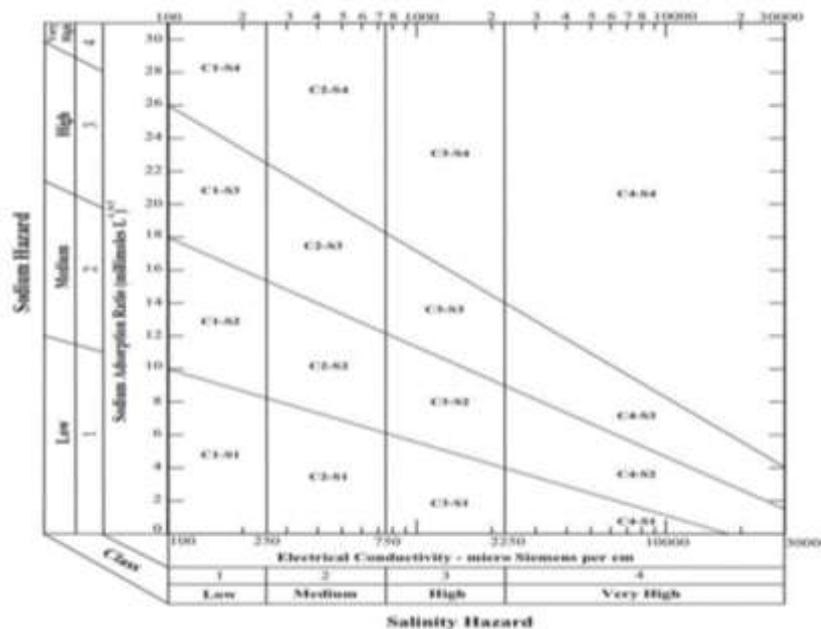
The results presented in Table (3) show that SSP values ranged between 31.2% and 42.3%, with the highest value recorded in Al-Hafra Spring and the lowest value in Al-Hadadiyah Spring. Since all recorded values are below 60%, the spring waters are considered suitable for irrigation and unlikely to cause sodium-related hazards. These findings agree with the results reported by Qablan (2018) in the evaluation of groundwater quality in some districts of Mosul City, where SSP values were also below the critical limit.

### Irrigation Water Classification According to the United States Salinity Laboratory (USSL)

The irrigation water classification system proposed by the United States Salinity Laboratory (USSL) was developed in the early 1950s and formally published in 1954. It remains one of the most widely used systems worldwide for evaluating irrigation water suitability. This system considers two primary parameters: electrical conductivity (EC), which represents total salinity affecting plant water uptake, and the Sodium Adsorption Ratio (SAR), which indicates sodium hazard affecting soil properties and sensitive crops. Sodium is considered one of

the most critical elements determining irrigation water suitability because of its direct impact on soil physical properties. The USSL system integrates EC and SAR values into a diagram that classifies irrigation water into 16 different categories (Richards, 1954), as illustrated in Figure (2). The results show variations in EC values among the studied springs (Table 3), where the highest EC value was 1006  $\mu\text{S}/\text{cm}$  in Al-Ajal Spring, while the lowest value was 574  $\mu\text{S}/\text{cm}$  in Al-Hafra Spring, with an overall average of 811.2  $\mu\text{S}/\text{cm}$ .

Based on the USSL classification, the spring waters were classified within the categories C2–S1 and C3–S1. This classification indicates low sodium hazard but relatively high salinity levels. Water classified as C3–S1 can be used for irrigation in soils with moderate to good permeability, provided that adequate leaching is applied to prevent salt accumulation. Such water can be used for crops that are relatively tolerant to salinity, with appropriate management practices (Al-Hadithi & Al-Assafi, 2016). The remaining springs were classified as C2–S1, indicating moderate salinity and low sodium hazard. In terms of sodium hazard, all water samples fall within the low sodium risk category, suggesting that the water quality is generally suitable for irrigating most crops. These results are consistent with those reported by Al-Shoushan (2022) in the evaluation of groundwater quality in Lamluda, Al-Jabal Al-Akhdar, for drinking and irrigation purposes.



**Figure (2).** U.S. Salinity Laboratory diagram for the classification of irrigation water (Richards, 1954)

## Conclusion

This study aimed to evaluate the water quality of several springs in the Al-Jabal Al-Akhdar region in northeastern Libya in order to determine their suitability for agricultural irrigation based on a set of physicochemical indicators and irrigation water quality classification standards. The results showed that pH values ranged from 6.8 to 7.9, with an average of 7.2, while electrical conductivity values ranged between 574 and 1006  $\mu\text{S}/\text{cm}$ , indicating relatively moderate salinity levels. The Sodium Adsorption Ratio (SAR) ranged from 1.08 to 1.65, whereas the Soluble Sodium Percentage (SSP%) ranged from 31.2% to 42.3%, all of which fall within the acceptable limits for irrigation water. According to the classification of the United States Salinity Laboratory (USSL), the studied waters were categorized within the classes C2–S1 and C3–S1, indicating a low sodium hazard with moderate to relatively high salinity effects. These results suggest that the studied spring waters can be used for irrigation provided that appropriate salinity management practices are applied, including adequate drainage and the cultivation of relatively salt-tolerant crops, particularly in areas where higher salinity levels were observed. However, the findings of this study are limited to the analyzed samples and locations during the study period, and further investigations covering a wider spatial and temporal range are recommended to obtain a more comprehensive assessment. Overall, this study contributes valuable scientific data on spring water quality in the Al-Jabal Al-Akhdar region, supporting sustainable water resource management and guiding the optimal agricultural use of these water resources.

## Compliance with ethical standards

### Disclosure of conflict of interest

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

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