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Estimation of the Sodium Adsorption Ratio (SAR) and SAR-Adjusted Ratio of groundwater in Siret Najem of Kuwayfiyah- North Libya

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الملخص

تقع منطقة الكويفية شمال شرق بنغازي، ليبيا .تضم بعض المناطق الزراعية. في هذه الدراسة جرت محاولة لتقييم جودة مياه الري في سيرة نجم من خلال جمع وتحديد عينات المياه لتمثيل منطقة الدراسة من 3 محطات رئيسية خلال شهر مايو2022. خصائص الجودة التي تم فحصها في هذه الدراسة هي :إجمالي الأملاح الذائبة (TDS) ودرجة الحموضة والتوصيلية والأيونات الموجبة (K^+ ,Na^+ ,Mg^{2+} Ca^{2+}) والأيونات السالبة (HCO_3, Cl^- ,SO_4, CO_3) لتقدير مؤشر امتصاص الصوديوم (SAR) والصوديوم مؤشر الامتزاز (معدل) .أظهرت النتائج في منطقة الدراسة انخفاضًا في مخاطر الصوديوم باستخدام كل من مؤشر امتصاص الصوديوم (SAR) ومؤشر امتصاص الصوديوم المعدل حيث كانت (5.167،4.54) على التوالي .ومع ذلك، فقد لوحظ أن بعض عينات المياه الجوفية ذات نوعية جيدة للري في منطقة الدراسة.

الكلمات المفتاحية: معدل امتصاص الصوديوم (المعدل)، سيرة نجم، الكويفية.

Abstract

The Kuwayfiyah district is located northeast of Benghazi, Libya. It includes some agricultural areas. In this study, an attempt was made to assess the quality of irrigation water in Siret Najem by collecting and identifying water samples to represent the study area from 3 main stations during the month of May 2022. The quality characteristics that were examined in this study were: Total Dissolved Salts (TDS), pH, conductivity, positive ions (K^+, Na^+, Mg^{2+}, Ca^{2+}), and negative ions (HCO_3, Cl^-, SO_4, and CO_3) to estimate the sodium adsorption index (SAR) and the sodium adsorption index (Adjusted). The results in the study area showed a reduced risk of sodium using both the sodium adsorption index (SAR) and the Adjusted sodium absorption index as they were (5.167, 4.54), respectively. However, some of the groundwater samples were observed to be of good quality for irrigation in the study area.

Keywords: SAR- adjusted, Siret Najem, Kuwayfiyah.

1. INTRODUCTION

Groundwater is the main supply of water for domestic, agricultural, and industrial sectors in many countries. Approximately one-third of the world's population obtains consuming water from groundwater [1]**.** The type of surface water and groundwater is dependent on a number of things, e.g. geological, biological, meteorological, hydrological, and topographical factors such as minerals, temperature, duration of contact with minerals, water-soluble carbon dioxide, etc. That being the case, any change and conversion of water when it infiltrates the ground is unavoidable as it frames one of the stages to improve groundwater quality [2]. Salts found in irrigation water can affect both soil structure and crop yield [3,4,5]. The irrigation water quality is generally specified by its salt content, bicarbonate concentration, and the presence of potentially toxic elements. Irrigation water can also contain ratable amounts of nutrients that should be factored into the overall nutrient management plan [6]. Irrigated agriculture is based on an adequate water supply of usable quality. irrigation water evaluation, emphasis is placed on the chemical and physical characteristics of the water, and any other important factors. Sodium absorption ratio (SAR) is the most serious Salinity indices that are considered for determining the suitability of irrigation water according to [7].

The sodium adsorption ratio (SAR) is often utilized as an index for assessing the sodium endanger related to an irrigation water supply. SAR ratio for soil extracts and irrigation waters is utilized to state the relative activity of sodium ions in swap reactions with soil [7,8]. Sodium can additionally have an effect on crop growth not directly through inflicting nutritional imbalances and by degrading the physical situation of the soil. High sodium levels can reason calcium, potassium, and magnesium deficiencies — and high sodium levels relative to calcium concentrations can severely minimize the price at which water infiltrates the soil, which can affect the plant due to the fact of terrible aeration [9]. The Benghazi Plain is mainly covered by limestone, and partly covered with red clay, sand, and gravel deposits. Karst (dissolution) features are prominent in this area, and dissolution channels may exist at some depth below sea level [10]. Here an attempt has been made to assess the irrigation water quality of Siret Najem in Kuwayfiyah - North Libya, which includes several underground wells used for drinking and agricultural activities. In the evaluation of irrigation water, emphasis is placed on the chemical and physical properties of the water as follows: total dissolved salts (T.D.S), pH, electrical conductivity, positive ions (K^+, Na^+, Mg^{2+}, Ca^{2+}), negative ions (HCO_3, Cl^-, SO_4^{-2}, and CO_3^{-2}), to calculate the Sodium adsorption ratio (SAR) and SAR-adjusted index.

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2. MATERIAL AND METHODOLOGY

2.1. The Study Area.

Siret Najem is located in the Kuwayfiyah area in Northeastern Libya. It is around 15km east of Benghazi and about 103 meters above sea level. Groundwater is considered the main source of water supply in the study area. Three governmental wells in the Siret Najem area feed the Kuwayfiyah area with drinking water and irrigation. They have been approved as the main sampling points to represent the study area. Table 1 shows the coordinates of water samples and location names. While figure 1. Shows the geological map of the study area.

Table 1 shows the coordination of the sampling site

N	Name	N	E
Station 1	Governmental well No. 1	32.16.5734	20.26.8160
Station 2	Governmental well No. 2	32.16.2537	20.27.2403
Station 3	Governmental well No. 3	32.16.1340	20.27.5080

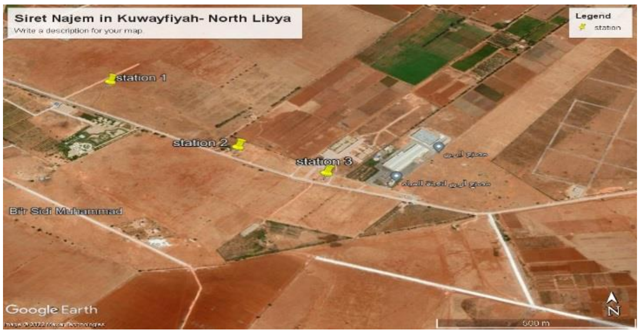

Figure 1 shows the study area and the sampling points in Siret Najem

2.2. Sampling and Analysis.

The study was conducted during the summer season of 2022 to study groundwater quality(water well) in Siret Najem in the Kuwayfiyah area to explain its suitability for agricultural exploitation in the region. The study included three sites in Siret Najem to assess the validity of irrigation. The pH, Electrical conductivity (EC) and temperature (T) were measured locally by (Multifunction Portable pH, Conductivity, and temperature) field instruments (water quality tester Company). The positive ions (K^+, Na^+, Mg^{2+}, Ca^{2+}), and negative ions (HCO_3, Cl^-, SO_4) and CO_3 were determined using a HACH-DR 3900 UV-Vis Spectrophotometer using standard methods given by the American Public Health Association[11] at the laboratory of agriculture faculty at Benghazi university. These data were used to compute SAR and the Adjusted SAR Index.

2.3. Computational Technique.

The SAR procedure includes infiltration problems due to an excess of sodium with calcium and magnesium. It does not take into account changes in calcium in the soil water that take place because of changes in the solubility of calcium resulting from precipitation or dissolution during or following irrigation [5]. According to Suarez[12] the SAR adjusted calculation included five main steps. In this study, it will be calculated according to these steps. Lesch[8] and Suarez[12] describes how to compute the adjusted SAR by utilizing the step-by-step technique to calculate the adjusted SAR as**:**

2.3.1. **Step 1**: the cation and anion measurements were in mg/L units; these values can be converted to meq/L units using the atomic weight and valence conversion factors shown in table 2.

Table 2. Atomic weights, valence numbers, and conversion factors for common ions

Ion	Element	Atomic Weight (AW)	Valence (V)
Na^+	Sodium	22.99	1
Ca^{2+}	Calcium	40.08	2
Mg^{2+}	Magnesium	24.31	2
Cl^-	Chloride	35.45	1
$SO4^{2-}$	Sulfate	96.06	2
HCO_3^-	Bicarbonate	61.02	1

2.3.2. Step 2: Calculate the sum of cations (SC) and ionic strength (IS) as:

$$Sc = Na + Ca + Mg \qquad \dots\dots\dots \quad eq\ (1).$$

$$IS = \frac{(1.3477 * Sc + 0.5355)}{1000} \qquad \dots\dots. \quad eq\ (2).$$

2.3.3. Step 3: Calculate the log(X) value (using meq/L ion measurements) as:

$$\log x = \frac{1}{3}\left[4.6629 + 0.6103\log(IS) + 0.0844\{(\log Is)^2 + 2\log\frac{Ca}{2HCO3}\right) \dots\dots. \text{ eq (3)}.$$

HCO_3 and Ca represent the bicarbonate and calcium concentrations (in mmol/L) in the irrigation water. Hence, given the HCO_3/Ca ratio and the estimated IS value, Table 3 of (12) Can be conveniently used to determine the approximate X value for input into the equation.

Table 3. Exact versus equation 3 approximated X values (approximations shown in parentheses). (8)

Ionic Strength	HCO_3/Ca Ratio (Mmol/L Basis)		
	0.1	1.0	10.0
0.001	73.4 (73.1)	15.8 (15.8)	3.41 (3.39)
0.010	84.1 (84.5)	18.1 (18.2)	3.90 (3.92)
0.100	112.0 (111.1)	24.1 (23.9)	5.20 (5.16)
0.500	144.0 (145.3)	30.9 (31.3)	6.66 (6.74)

2.3.4. Step 4: Calculate the equilibrated Ca concentration (on a meq/L unit basis) as:

$$Ca_{eq} = 2 * 10^{logx} * (P_{CO2})^{\frac{1}{3}} \quad \dots\dots\dots \quad eq\ (4)$$

P_{CO2} is the partial CO2 pressure in the near-surface soil, which is assumed to be 0.0007 atm as an average in this zone(the near-surface soil)[8].

2.3.5. Step 5: Calculate the adjusted SAR as

$$SAR_{adj} = \frac{Na}{\sqrt{\frac{Ca_{eq} + Mg}{2}}} \quad \dots\dots \quad eq \dots (5).$$

Table (4) General classifications of irrigation water based on SAR

SAR values	Sodium hazard	Comments
1-9	Low	Use of sodium-sensitive crops must be cautioned.
10-17	Medium	Amendments (such as gypsum) and leaching are needed.
18-25	High	Generally unsuitable for continuous use.
>26	Very High	Generally unsuitable for use

3. RESULTS AND DISCUSSION

3.1. Water Quality Criteria.

Cations such as sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and the anions such as nitrates (NO_3^-), bicarbonates (HCO_3^-), sulfates (SO_4^{-2}), chlorides (Cl^-) naturally occur in water and are usually determined in water quality evaluation tests. The total dissolved solids are the general nature of the salinity of the water. In all wells, the TDS values ranged from 735 to 905 ppm with an average of 804 ppm (Table 5). The pH in the groundwater varied from 7.79 to 7.8 (Table 5) in all the groundwater samples of the study area and is within the safe limit [13]. The high content of bicarbonate in the irrigation water of 500 mg /l or more may lead to the appearance of iron deficiency in the plant even if it is found in the soil. The results of the chemical analysis of water well samples used for irrigation in the study area showed the concentrations of calcium cations, where the average of those values ranged between (85 – 95 mg/l) The presence of calcium is considered in the range for groundwater, as its sources are varied according to the components of the layers of the earth, and that the increase in its concentrations may be a result of the presence of groundwater in layers. Sodium is an important cation that, in excess, can damage soil structure and reduce crop yields. If the sodium concentration in the irrigation water is high, it is easily absorbed by the clay particles, displacing Mg^{2+} and Ca^{2+} ion [14].

Table 5: Chemical composition of groundwater Siret Najem in the Kuwayfiyah area

Parameter	Station 1	Station 2	Station 3	Mean	Standard of (FAO) Irrigation
Electroconductivity (EC)	1467 µS/cm	1574 µS/cm	1805 µS/cm	1615.3 µS/cm	
Total Dissolved Soiled	735 mg/l	773 mg/l	905 mg/l	804.3 mg/l	0-2000 mg/l
pH	7.79	7.78	7.8	7.79	6.5-8.5
Temperature (C)	26.2 C	27.2 C	26.7 C	26.7 C	-
Total Hardness	365 mg/l	388 mg/l	443 mg/l	398.67 mg/l	-
Ca- Hardness	188 mg/l	205 mg/l	235 mg/l	209.3 mg/l	-
Sodium (Na)	212 mg/l	215 mg/l	212 mg/l	213 mg/l	0-40 meq/l
Calcium (Ca)	85 mg/l	85 mg/l	95 mg/l	88.3 mg/l	0- 20 meq/l
Magnesium (Mg)	46 mg/l	46 mg/l	55 mg/l	49 mg/l	0-5 meq/l
HCO_3	239 mg/l	239 mg/l	243 mg/l	240.3 mg/l	0- 10 meq/l
Chloride (Cl)	317 mg/l	340 mg/l	385 mg/l	347.3 mg/l	0- 30 meq/l
Nitrite (No_2)	1 mg/l	0.5 mg/l	1 mg/l	0.83 mg/l	-
Nitrate (No_3)	2.6 mg/l	1.4 mg/l	1.3 mg/l	1.76 mg/l	0-10 mg/l

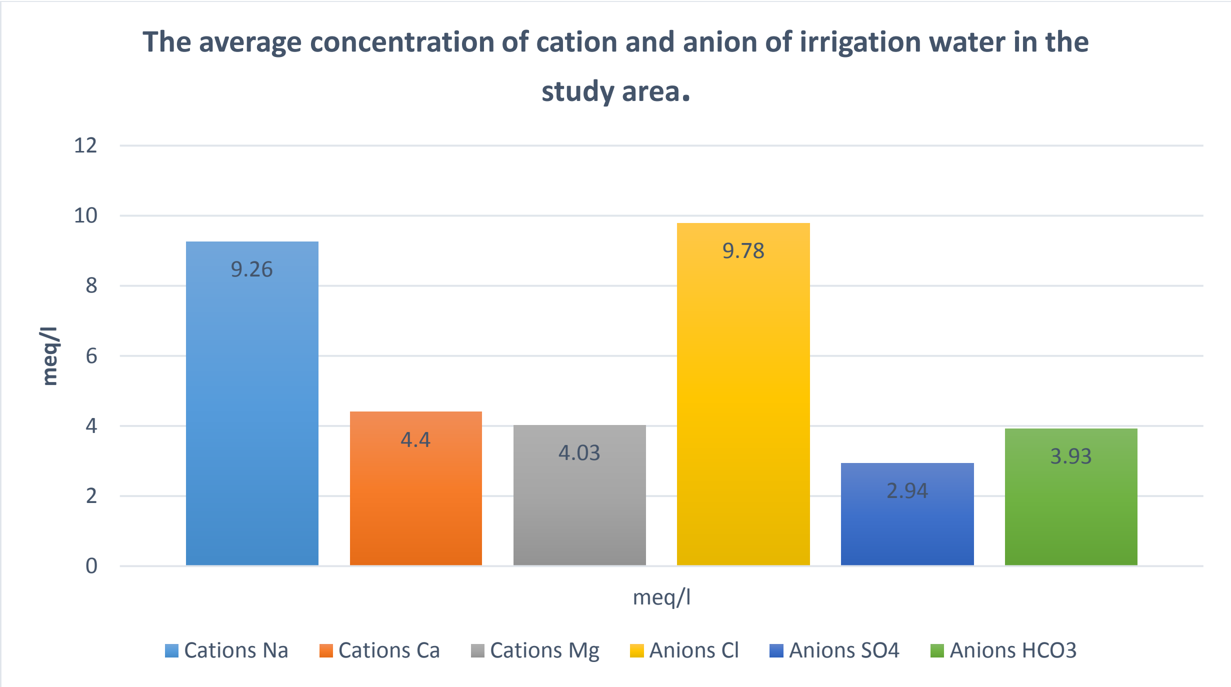

Figure 2: The average concentration of cation and anion of irrigation water in the study area.

3.2. SAR -unadjusted and SAR adjusted.

The sodium adsorption ratio (SAR) is commonly used as an index for evaluating the sodium hazard associated with an irrigation water supply. The sodium hazard is typically expressed as the sodium adsorption ratio (SAR). This index quantifies the proportion of sodium (Na^+) to calcium (Ca^{++}) and magnesium (Mg^{++}) ions in a sample. Numerous guidelines for the assessment of the sodium adsorption ratio (SAR) of irrigation water have been published [15] in table (4). The actual values of SAR (irrigation water) were calculated from chemical analysis using the step-by-step procedure to calculate the adjusted SAR [8]. The computed value of SAR -unadjusted is 4.54 for the groundwater collected from the study area. The SAR- adjusted is 5.167 of the groundwater collected from the study area. Table 6 summarizes the results obtained from the process of applying the previous equations.

Table 6: Computed values of SAR, and SAR-adjusted in the study area

	Cations			Anions		
	Na	Ca	Mg	Cl	SO_4	HCO_3
mg/l	**212**	**88.3**	**49**	**347.3**	**141.6**	**240.3**
meq/l	**9.26**	**4.4**	**4.03**	**9.78**	**2.94**	**3.93**
Sum of Cations (SC)	**17.69**					
Ionic Strength (IS)	**0.0243**					
log(X) value	**1.131**					
Ca_{eq}	**2.398**					
SAR- adjusted	**5.167**					

4. CONCLUSION.

The results of the chemical analysis of water well samples used for irrigation in the study area showed the measured value of EC varied from 1467 to 1805 µS/cm. The pH in the groundwater varied from 7.79 to 7.8 in all the groundwater samples of the study area and is within the safe limit [5,13]. The average of the values of the concentrations of calcium cations ranged between (85 – 95 mg/l).

The sodium adsorption ratio (SAR) is commonly used as an index for evaluating the sodium hazard associated with an irrigation water supply. The computed value of SAR -unadjusted is 4.54 for the groundwater collected from the study area. The SAR- adjusted is 5.167 of the groundwater collected from the study area. They are located in a low sodium hazard area by using both the adjusted SAR and SAR.

The results of the chemical analyses showed that the groundwater is generally of a chemical quality suitable for agricultural use. All groundwater samples were observed to be of good quality for irrigation in the study area. The soil receiving this water is not particularly susceptible to developing sodicity-related problems. Agricultural systems must be monitored in terms of the quality of irrigation methods to ensure the least use of water and the greatest return on production to protect the soil from excessive water.

5. RECOMMENDATIONS.

In the future, there should be a detailed monitoring of groundwater quality in Siret Najem of Kuwayfiyah; this should be given the main priority of using the microbiological parameters with physic-chemical parameters in irrigation water quality index (IWQI) calculations.

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