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Using GIS to Evaluate of Irrigation Water Quality within the Boundaries of Tal-Afar district - Iraq

Asaad Mahmoud AL-Knoo ^{1,*}  and Abdulwahab Mohammad Younis ² 

¹ Government Media and Communication Department, Presidency of the University of Telafer, Iraq. asaad@uotealafer.edu.iq.

² Dean of the College of Applied Arts, Al-Kitab University Abdulwahab, Iraq. younis@uoalkitab.edu.iq.

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Abstract

This study was conducted for the purpose of evaluating the irrigation water within the boundaries of Tal Afar district according to the most common water classification system, which is the Richard classification of 1954, based on the relationship between the sodium adsorption ratio (SAR) and the electrical conductivity (EC). then assessing its suitability for irrigation purposes, and then indicating the origin of that water, from This study found that all irrigation water samples fall into the categories C3-S1, C4-S1, indicating that the water is very high salinity to low sodium saline based on chemical indicators of well water and spatial trends using geographic information systems. The results showed that there were variations in water quality in different locations, as the pH values ranged between (6.32-7.8), the electrical conductivity values were (0-10000) $\mu\text{m}/\text{cm}$, the chlorides were (0.27-17.21) FMEq/L , and the sulphates were (0.3-24) mmeq/l , potassium (0.52-0.02) mmeq/l , sodium (0.09-17.9) mmeq/l , calcium (0.12-22) mmeq/l , magnesium (0.64-21.6) mmeq/l , and the percentage of sodium (87) (-21) %, and the sodium adsorption rate was (0.09-11.6) mmeq/l . As for the origin of groundwater, according to the Jones index, it is water of atmospheric origin for 66% of the well data, and 34% of it is of marine origin.

Keywords: Water Quality; Tal Afar; Assessment; Geographic Information Systems.

1 | Introduction

Groundwater is one of the important sources of water in arid and semi-arid regions. However, we find that groundwater is threatened with pollution as a result of long periods of drought and various human activities. The Tal Afar district in Nineveh Governorate lacks surface water sources due to its distance from the supply sources of rivers and water bodies and therefore relies mainly on groundwater as a main source of irrigation water. This caused the groundwater level to drop. Groundwater is generally characterized by a lower degree of pollution compared to surface water, which makes it suitable for various uses, especially agricultural, as irrigation water contains varying proportions of dissolved salts and varies in its components, which may affect the cultivated crops. Therefore, the study of water quality for irrigation is very important to know the problems that result from its use in the agricultural sector. Many studies have been conducted on water quality in Iraq and, to a lesser extent, in the Tal Afar district. These studies focused on assessing groundwater based on laboratory analyses. The current study focuses on integrating various databases with geographic information systems in order to draw digital maps. Information systems are a powerful tool for developing



Corresponding Author: asaad@uotealafer.edu.iq.



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and evaluating water solutions. where he studied [16] the quality of groundwater in some regions of southern Iraq using the data of five wells, and then chemical and physical analyses were conducted on them. He studied [1] the quality of groundwater in the village of Al-Khafajiyeh using the data of 8 wells and concluded that the water from these wells is not suitable for irrigation purposes and has high concentrations of sulfates. And [14] drew a quality map of the water for the formation of Anjanah in Sinjar, using the data of 40 wells throughout the region, and noted that the wells dug in Tal Qasab and Al-Qahtaniya are not suitable for use, while the wells in the center of Sinjar are of excellent quality and suitable for drinking, while the wells located in Al-Adnaniya and Al-Jazeera are of acceptable quality. [10], who used the data of 12,000 wells throughout Iraq in order to assess their suitability for irrigation purposes using the sodium adsorption ratio and the electrical conductivity values of the water, showed that the irrigation water is of poor quality for use in most of the upper reservoirs in Iraq. And [2] showed that most of the wells located on Shirqat Island are located between wells with low sodium and high salinity and those with high sodium and high salinity, and that the pH value is low [11, 12] The water source in the village of Abi Maria was evaluated using the data of 8 wells, using the adsorption percentage of sodium and the remaining sodium carbonate. The results showed, depending on the water quality coefficient, that the water was of poor quality for the purpose of irrigation due to the high values of calcium, sulfate, and electrical conductivity. [17] investigated the groundwater characteristics of Ain Subashi in Tal Afar and discovered that the water from the spring is unfit for human consumption because it exceeds the permissible limits and that the water from the eye is C3 high salinity. He [7] pointed out that the quality of groundwater in the western part of Iraq is groundwater of atmospheric origin, that it is of good quality, that it is located between low sodium and medium salinity water (C2-S1 and C3-S1), and that the water can be used for agriculture and animal watering. Some of them are suitable for human use, and he collected data from 64 wells from 8 different geological regions. In view of the lack of studies and research on the subject of groundwater suitability in the study area for irrigation and domestic use, this research was conducted for the purposes of:

- knowledge of the origin of groundwater in the study area according to the Jones ratio.
- Evaluate groundwater and indicate its suitability for irrigation according to Richard's classification of 1954.
- predictive mapping of pH, electrical conductivity, and positive and negative ions based on geographic information systems.

Study area:

The Tal Afar district and its administrative boundaries are included in the study. The district is 69 kilometers from Mosul's city center and is situated in the northwest of the Nineveh Governorate. 31°20"-36°14'33"), and Tal Afar is limited to the north by the Tigris River, to the east by Mosul and Sinjar, to the west by the Syrian border, and to the south by Hatra as shown in the Figure 1. The district's entire area is estimated to be 4453 km².

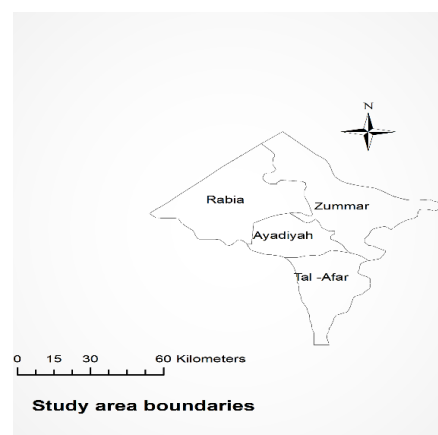


Figure 1. General location of the study area.

Geology of the study area:

Three different geological formations may be found in the research region, and they are arranged in order of age, from oldest to youngest, as shown [3].

Among these formations are the following categories:

The Lower Fars Al-Fatha Formation:

Large portions of the research region are covered by this formation, which is Middle Miocene in age.

It is made up of layers of mudstone, gypsum, limestone, sand, and silt. Clay and alluvial rocks make up the Upper Mioceneera Anjah Formation (The Supreme Knight), which spans a substantial portion of the study regions.

Deposits from the Pleistocene, the Holocene, and the Quaternary eras are all found adjacent to one another. Examples include graded gravel, sand, and clay.

Methodologies and software used

The available data on the wells includes the coordinates of the geographical location (X, Y), pH, electrical conductivity, and positive and negative ions (calcium, sodium, magnesium, chlorine, and sulfates). The coordinates of the wells were projected into the ARCGIS 10.7.1 program in the form of points, and then the chemical analyses of the wells were performed. The values were drawn with an interpolation tool and then with Shepard's Inverse Distance Weighting (IDW), which was introduced in 1968. Points where no measurements are available are indicated by [5], and the closer the point where no measurements are available to a known point, the more accurate results it gives [8], meaning every known point has a known weight that is included in the calculation. The sum of the weight is equal to one, and the value of the weight ranges from 0 to 1. As for the number of well data, it is approximately 44 wells distributed as in Figure 2 in the study area.

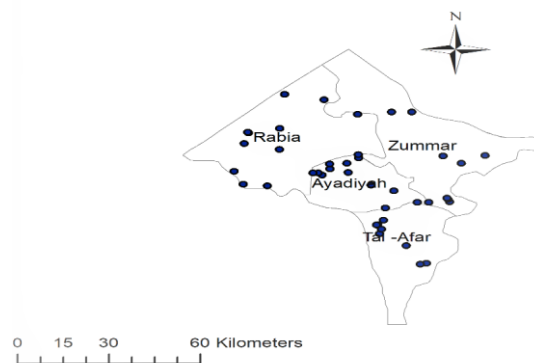


Figure 2. Locations and number of wells used in the study area.

Results and discussion:

Acidity PH:

It is a function of the effective concentration of hydrogen ions in water. whereas the pH expresses the hydrogen ion activity in the water and refers to the value of the hydrogen ion concentration in the transducer per liter. And since the water in nature tends to be alkaline, in which the PH value is more than 7, especially the ground water due to the presence of carbonates and bicarbonates, the PH values ranged between 7.8 and 6.32, with an average of 7.8 to 6.32. 7.01 It is clear from Figure 3 that there is no significant difference in the PH values for the general study area and that they did not exceed the permissible limit. The reason for this is

due to the lack of industrial activity in the study area, and when compared with the permissible limits, the water is considered suitable for agricultural use as far as water is concerned.

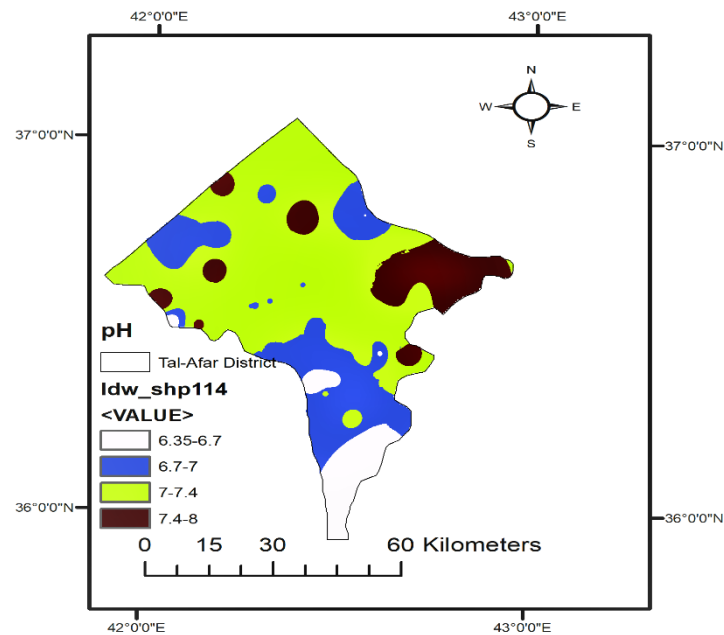


Figure 3. Spatial distribution of pH values in the study area.

Conductivity of electricity (E.C)

The ability of one cubic centimeter of water to conduct an electric current at a temperature of 25 °C is what is meant by this term. Its value in the study region ranges between (0-10000) M/cm, with a rate of 1795.7 M/cm, and it climbs by two degrees for every degree that the water temperature rises. The melting of rocks that are mostly gypsum during the formation of the hole may be the cause of the increase or accumulation of E.C values in some wells, and Figure 4 illustrates that the majority of the well water has a very high salinity that is not suitable for irrigation under normal circumstances.

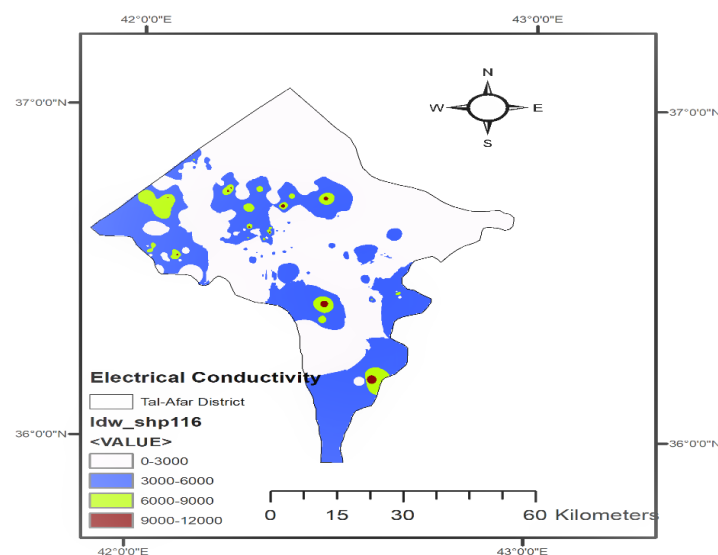


Figure 4. Spatial distribution of electrical conductivity values in the study area.

Chloride (CL^-)

The spontaneous breakdown of igneous and sedimentary rocks in water results in chloride being present in the majority of water sources. Plant toxicity is brought on by an increase in chloride ions, and it manifests as the drying and burning of leaf tissues. Although chloride has no impact on the physical characteristics of the soil, an abundance of it causes salinization. Sulfate levels in the soils were greater, with values ranging from 0.27 to 17.22 mmeq/l. The abundance of gypsum rocks in the research area, where the overall rate is calculated to be 6.396 mmeq/l and the maximum permissible level is 30 mmeq/l, is thought to be the cause of the variance in well water toxicity. The regional distribution of is depicted in Figure.(5) shows the spatial distribution of chloride. From the figure, it appears that most of the well water is suitable for plants, with some symptoms appearing for some plants and crops. And, using the general rate, it falls into level 3 of the [6] classification, indicating that it is medium chloride, as shown in Table 1.

Table 1: Irrigation water is classified based on its chloride content, depending on the classification [6].

Chloride Level	Concentration (m.meq/lit)	Chloride Hazard
Low	2	It is usually safe to use with all plants
Moderate	2-4	Sensitive plants usually get light to moderate damage
Medium	4-8	medium tolerant plants usually get slight to moderate damage
Severe	8	resistant plants receive minor to moderate damage

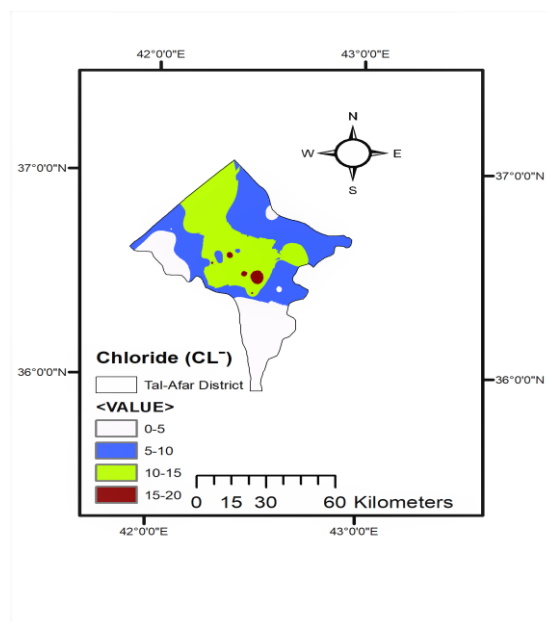


Figure 5. Spatial distribution of chloride ion values in the study area.

Ion sulfate (SO_4^{2-})

Gypsum, anhydrite, and sodium sulfate are some of the most significant sources of sulfate in groundwater. The existence of the sulfate ion in sedimentary rocks is ascribed to the oxidation of sulfur. Sulfate ion concentrations ranged from (0.3 to 24) mmeq/l and were produced by the melting of gypsum rocks and sediments from the Quaternary period. Because it is possible for evaporite rocks to melt in contact with groundwater, at a rate of 8.588 mmeq/l, the concentration of sulfate ions in groundwater frequently rises with depth. Sulfate ion concentration has a detrimental effect on groundwater investment in all areas, especially agriculture, as sulfate ion concentration increases result in soil salinization. Figure (6) shows the spatial distribution of the sulfate ion in the study area.

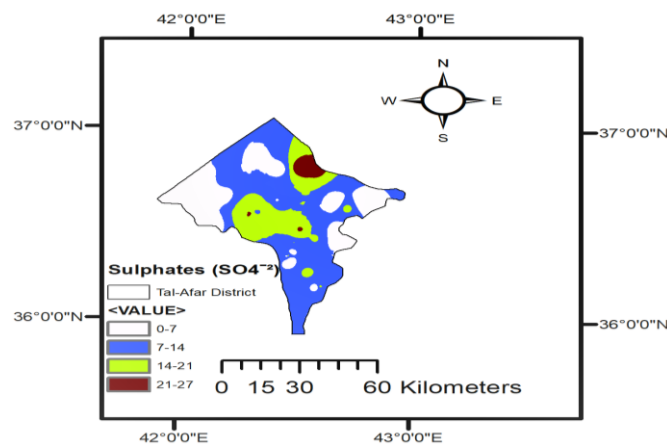


Figure 6. Spatial distribution of sulfate ion values in the wells of the study area.

Ion of potassium (K)

Because potassium absorbs more readily than sodium does and because potassium levels are low, sodium adsorption is slowed down, the presence of potassium elements in irrigation water at high concentrations lowers sodium concentrations. According to the findings, the potassium ion concentrations varied between (0.02-0.52) mmeq/l at a rate of 0.1 mmeq/l. Potassium levels in the research area have decreased because clay minerals readily absorb potassium, and these levels are below the permitted limit of 2 mmeq/L. The regional distribution of potassium values in the research area's well water is depicted in Figure 7) shows the spatial distribution of potassium values in the well water of the study area.

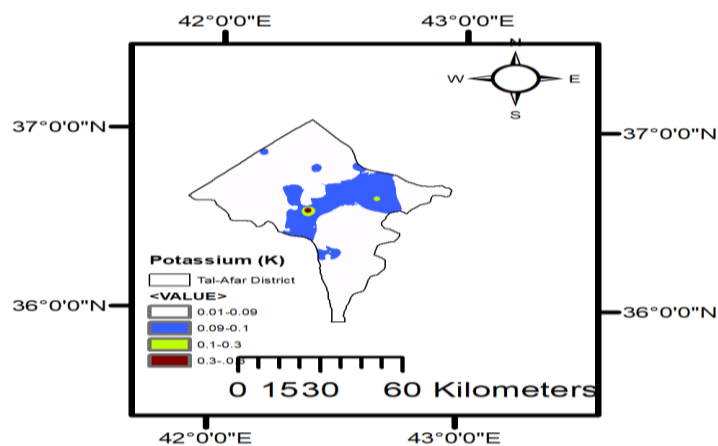


Figure 7. Spatial distribution of potassium ion values in the wells of the study area.

Sodium ion (Na)

The largest supply of sodium comes from the mineral halite, which is widely distributed in the rocks of the Fatah formation and the quaternary sediments. Halite, also known as NaCl, is a source of sodium. The research area has sodium concentrations ranging from 0.09 to 17.9 mmeq/l, or 6.425 mmeq/l overall. The core regions are to blame for the elevated sodium levels. The sodium readings in the southern one are less than 40 mmeq/l, which is the maximum permitted level, and are affected by the sodium concentration since it is a geological formation (the hole) that contains halite rocks. The sodium ions' geographical distribution in the research region is depicted in Figure 8.

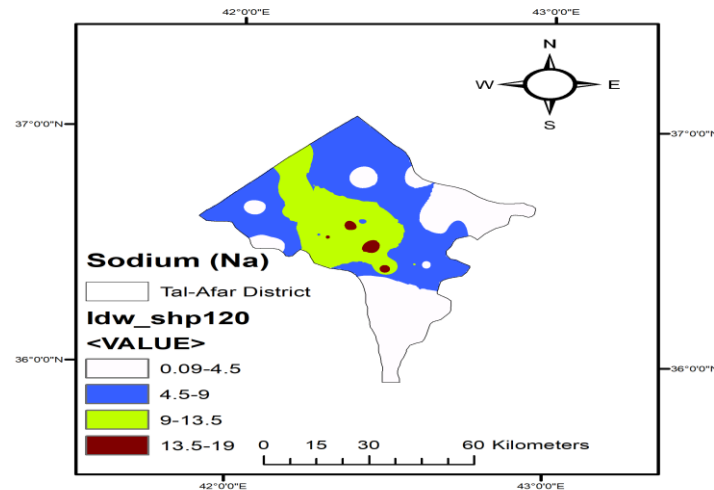


Figure 8. The spatial distribution of sodium ion in the study area.

Calcium (CA)

One of the many alkaline elements found in the crust of the Earth is calcium, which is also a crucial part of plants. Because it is moving through or being kept for well water, calcium causes melt operations for the sedimentary and closed rocks of the formation of the hole and Angana. Its value ranges between 22 and 0.1 millimeters per liter at a rate of 6.636 millimeters, and its nature is related to the presence of sodium and magnesium ions due to ion exchanges. The spatial distribution of calcium ions in the research area's waters is depicted in Figure 9 shows the spatial distribution of calcium ion in the well water of the study area.

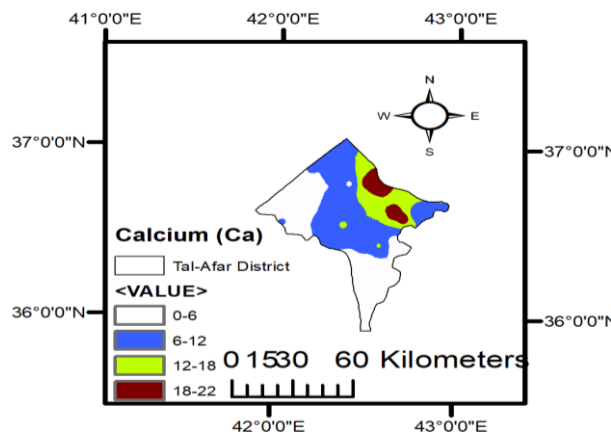


Figure 9. Spatial distribution of calcium ion values in the study area.

Ion Magnesium (MG)

The limestone rocks in the research area are the primary source of the magnesium ions, which are often spreading across the earth's crust. His existence is associated with the dissolution of the geological formation that has a value, and that value ranges from 21.6 to 0.64 millimeters l at an average of 7.68 mm l. The geographical distribution of magnesium ions is depicted in Figure 10.

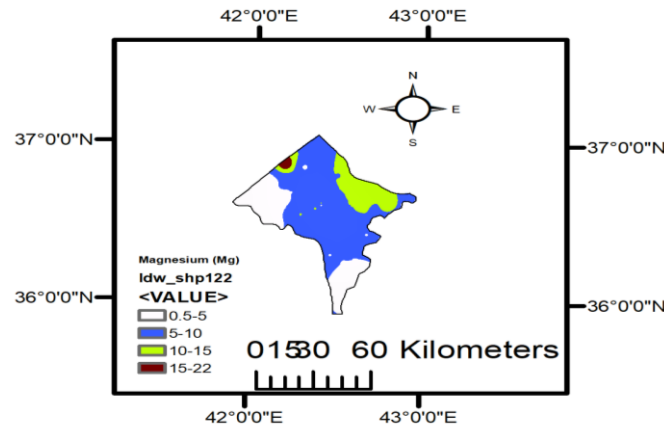


Figure 10. shows the spatial distribution of the magnesium ion

Classification of groundwater in the research area

The source of groundwater and how it is used are two highly intricate issues. There are two basic causes for this.

First, because groundwater is susceptible to movement, there is a chance that it could combine with other types of water or sources.

Second: the variety of chemical compositions and physical characteristics of different formations that include water.

According to [13], groundwater is typically categorized into three major kinds based on its source: air water, sea water, and virgin water. Specialists have divided the groundwater into several ratios and standards in order to categorize it according to where it comes from. They perform better than others due to their strong attraction to water, and when present in large quantities in water, they solidify

Jones Ratio (JR)

One of the finest pieces of evidence for identifying the source of the groundwater is this proportion. It differs from one in water of MARINE origin in that it has a lower value than one in water of METERIC origin. [9] As chloride is one of the factors least impacted by the physical and chemical variables, this proportion is utilized in the following calculation to determine the Jones ratio

$$JR = \frac{Na +}{Cl^-} \quad (1)$$

whereas:

JR: Jones ratio

NA: Sodium concentration is equivalent/ l

CL: Chlorine concentration is equivalent/ l

The groundwater in the majority of the research area's wells had an atmospheric source, according to the Johns ratio values, which varied from 2.75 to 0.06 at a rate of 1.14. study space

The viability of using groundwater for irrigation

The types and variations of irrigation water are determined using a variety of criteria and indicators, which reflect the reliability and applicability of this water for irrigation and agricultural uses. Irrigation water is one of the most commonly used systems in the world to date, and this system takes into account the main tissues in the evaluation of irrigation water, which are the EC electrical connection that affects the ability of the plant

to absorb water and the proportion of organic matter in the soil. While the criteria used should identify the variables that have the potential to cause harmful changes in the properties of the soil or a harmful effect on the growth of the crop, irrigation water is considered one of the most widely used systems in the world to date (SAR)

The percentage of sodium (Na%). Sodium plays a major role in determining the validity of irrigation water, and therefore the percentage of sodium ion is one of the most important properties that play an essential role in evaluating irrigation water, and [15] has created the proportion of sodium in a metaphysical form of the cattering group, which is shown by Table 2 using the following equation:

$$Na\% = \frac{(Na + K)}{Ca + Mg + Na + K} \times 100 \quad (2)$$

whereas:

NA%: The percentage of sodium

K: Potassium ion concentration is equivalent /l

NA: Sodium ion concentration is a millimeter /l

:MG concentration of millimeter magnesium /l /l

CA: Calcium ion concentration is a millimeter /l

Table 2: Classification of water used for irrigation according to the percentage of sodium.

Na%: the percentage of sodium	Water quality and degree of problem
20%	excellent
20%-40%	very good
40%-60%	medium
60%-80%	High Sodium
80%	very high

The percentage of sodium in the study area ranged between 87 and 2 percent at a rate of 30.3 percent, and the Figure 11 shows the validity of the groundwater wells because the percentage of sodium is located in the good water field.

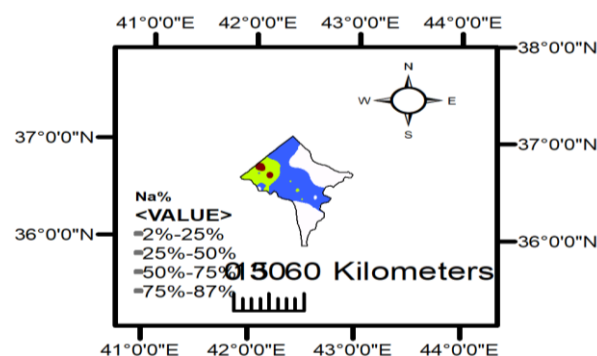


Figure 11. The spatial distribution of the percentage of sodium ion in the study area.

Sodium Absorption Ratio (SAR)

Sodium is one of the most dangerous elements in irrigation water, as it affects the physical properties of the soil by breaking up its granules, which turns it into a soil with weak permeability and thus the growth of something for the plant, as it negatively affects the plant due to its toxic accumulation in its leaves. The risk

of sodium is determined in the irrigation water according to the American Laboratory Category of Salinity by estimating the percentage of sodium to both calcium and magnesium according to the following equation:

$$SAR = \frac{Na}{\sqrt{\frac{(Ca + Mg)}{2}}} \quad (3)$$

whereas:

SAR: Sodium Advance rate

NA: Sodium ion concentration is a millimeter/ l

:MG concentration of millimeter magnesium/ l/ l

CA: Calcium ion concentration is a millimeter/ l

.

Table 3 shows the types of irrigation water according to this percentage.

Table 3: Classification of irrigation water according to the percentage of sodium adsorption [4].

Mode	SAR	Na content	Uses
1	0-10	Low	can be used for all soils
2	10-18	medium	preferably used for coarse or well-permeable soils
3	18-26	High	Can cause side effects
4	>26	Very high	Not suitable for agricultural purposes

The proportion of sodium admission in the waters of the study area is classified as low, and it constitutes 95.45% of wells to a medium percentage, and constitutes 4.55% of wells. The value of SAR in most well-known study area ranged between (11.642-0.09), at a rate of 2.618 and Figure 12 showing this. Thus, it can be used for all types of soil, while Table 4 shows the limits of Richard, 1954 classification.

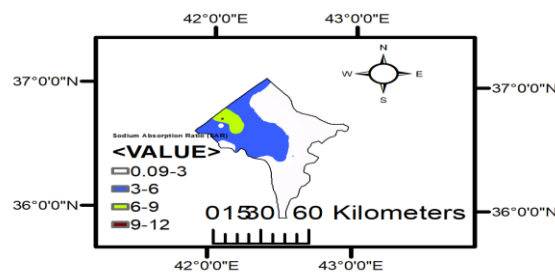


Figure 12. Spatial distribution of the adsorption percentage of sodium.

Table 4: shows the classification of well water based on average values.

SAR	Index	EC	Index
S1	≤ 10	C1	≤ 250
S2	$> 10 - \leq 18$	C2	$> 250 - \leq 750$
S3	$> 18 - \leq 26$	C3	$> 750 - \leq 2250$
S4	> 26	C4	> 2250

Depending on the rates of EC and SAR in the table above, they found that the groundwater extracted from the wells is from the C3-S1 class, meaning it is high salinity with a few sodium ions and is used to irrigate all agricultural crops except for sensitive crops such as citrus fruits, and the C4-S1 class, i.e., very high salinity. - Low sodium is used only with medium-sized lands and roughness with good drain.

2 | Conclusions

1. The investigation of the groundwater properties in the research region revealed that the PH values were increasing at a rate that reached 7.01, indicating that the water is basic.
2. Depending on the Johns-Ratio, either freshwater or marine groundwater is the source of the groundwater in the research area. Almost 66 percent of the 34 wells selected for the study have a marine origin.
3. By developing digital models that might help the appropriate authorities in decision-making regarding the exploitation of well water, the maps made using geographic information system technology presented a clear image of the distribution of the qualitative qualities of well water.
4. About 38.6% of the data from the selected wells were found to be in the "A" part of the Wilcox classification, which divided the groundwater of the study area into four categories based on the percentage of sodium ion concentration. 6.9% of wells represent high-sodium wells and 25% of medium well data fall into the category of variation that is excellent for agricultural use.
5. The majority of the chosen wells' SAR ratios were less than 10, placing 95.45% of them in the low categorization. Also, 4.55 percent of the well data fell into the intermediate category.
6. According to Richard's rating from 1954, which took into account the absence of the growth of salinity crops, the groundwater in the research area is suitable for irrigation. Its categorization was (C4-S1, C3-S1) between very high salinity and high salinity with a low sodium level.
7. The geological formation in the study area had an impact on the water's quality, as shown by the fact that calcium and sulfate concentrations rose as we traveled north and south. This is proof of the influence of geological formation brought on by the Quartet's sediments and the formation of Anjana and Al-Fattaha.

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Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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