Quality Assessment of Groundwater for Agriculture in the Hail Region, Saudi Arabia
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ABSTRACT

As a result of the arid climate of Saudi Arabia, groundwater is the most precious natural resource, providing reliable water supply for the resident population and the development of irrigated agriculture where surface water resources are insufficient and difficult to meet the water budget requirements of the Kingdom of Saudi Arabia. Therefore, this study was carried out to evaluate the quality of groundwater resources in selected locations of Hail region. This study focused on the important chemical analysis of the available groundwater resources in Hail region. Groundwater samples were collected from 61 wells at different locations that cover the Hail region for chemical analysis. Parameters such as pH, electrical conductivity (EC), sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), carbonate (CO$_3^-$), bicarbonate (HCO$_3^-$), chloride (Cl$^-$), and heavy metals were analyzed with the calculation of sodium adsorption ratio (SAR) to assess the suitability of groundwater for agricultural purposes. The pH values were between 7.10 and 8.23 (M = 7.66). The salinity of groundwater, as a primary indicator of water quality for irrigation, ranged between moderate and high (between 0.27 to 8.99 dS m$^{-1}$) in most studied water samples. Besides salinity, 31.1% of Hail groundwater samples have the potential risk of chloride hazard (chloride > 10 meq L$^{-1}$). SAR values were less than 9 for all groundwater samples while the heavy metals were within acceptable levels.

Key words: Groundwater, water quality, salinity, heavy metals.

INTRODUCTION

The Kingdom of Saudi Arabia, known as one of the countries with the highest water scarcity in the world, depends mostly on groundwater as the main water source due to its limited surface water resources and average annual rainfall of less than 100 mm (Al-Omrán, 2002). The quality of groundwater is a major constraint against the development of irrigated agriculture (Oster and Jayawardane, 1998). In other words, Kumaresan and Riyazuddin (2006) reported that the chemical and physical parameters of groundwater play an important role in assessing water quality. Salts affect the yield as well as the suitability of the soil for growth of plant. The suitability of particular irrigation water is highly dependent on the actual need and economic return that can be obtained from salt water irrigation compared to other options, as well as the limited conditions of use. Important conditions of use include the crop being grown, cropping management practices, various soil properties and management practices, irrigation, climatic changes. Moreover, salinization of groundwater due to overuse, increased population growth rate, high water loss by evaporation, limited recharge, and the overlap between seawater–freshwater (Sheikhy Narany et al., 2014). A study of the acidic and alkaline properties for water, gives an indication of the extent water interaction with different materials (Hem, 1985).

Ayers and Westcot (1985) reported that the greatest direct hazard of water with an abnormal pH, is the impact on irrigation equipment. So, it is necessary to choose irrigation equipment properly, when handling water of unusual pH. An adverse pH may need to be corrected by the introduction of chemical substances into the water.

In some environments, increased (Cl$^-$) concentrations have killed off the native vegetation and allowed invasive salt-tolerant species to thrive (Panno et al., 1999). Chloride can damage plants from excessive foliar absorption (sprinkler systems) or excessive root uptake (drip irrigation). The concentration of ion chloride restriction (Cl$^-$) in irrigation water with lower than 4 meq L$^{-1}$ is considered light, while it is moderate between 4 and 10 meq L$^{-1}$, and higher than 10 meq L$^{-1}$ are considered severe. The maximum limit is 30 meq L$^{-1}$ (Palacios et al., 1997).

The concentration of carbonates in natural waters is a function of the amount of dissolved carbon dioxide, temperature, pH, cations and other dissolved salts. The concentration of bicarbonate in natural waters is generally held within a moderate range by the effects of the carbonate equilibrium (Kumar et al., 2017).

Groundwater is the major resources for irrigation in most of the Hail region, where used deep wells water from the Saq Aquifer, which forms one of the major aquifers and extends for 1200 km approximately, in the northwest-southeast direction, in Northwestern Saudi Arabia (Hereher et al., 2012).

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The Saq Aquifer it is confined or leaky in deeper layers but is unconfined in shallow layers. Except a few areas, Saq Aquifer has very good water quality. (Sharaf and Hussein, 1996). The values of TDS are ranged between 300-1000mg L$^{-1}$. The Saq groundwater is classified into different water types, the most dominant are Ca(HCO$_3$)$_2$ or NaHCO$_3$ and NaCl types (Alawi and Abdulrazzak, 1993; Mohammed et al., 2011). Sharaf and Hussein (1996) and Abdel-Aal et al. (1997) reported that the groundwater of Saudi Arabia is deteriorating at an alarming rate due to the increasing water salinity. Its electrical conductivity has increased from 1.93 dS m$^{-1}$ in 1983 to 2.76 dS m$^{-1}$ in 1997 in the Saq Aquifer; if this depletion continues unabated, the agricultural land may not be able to survive. Consequently, the assessment of the quality of such limited water resources has become an imperative tool for managing these resources in the best possible manner for any future sustainable development.

In the present study, the objective was to evaluate the quality of groundwater for irrigation in the Hail region.

**MATERIALS AND METHODS**

**Study area:**

Hail is a city in north-western Saudi Arabia. It is largely agricultural, with significant grain, date, and fruit production. A large percentage of the kingdom's wheat production comes from the Hail region. It has a continental desert climate with hot summers and cool winters. As a result of its higher altitude, it has a somewhat milder climate than other Saudi cities.

**Sampling sites**

In this study, water samples were collected from 61 wells at different locations that cover the Hail region (Map. 1). And the GPS was used to record the absolute positions of collected samples as shown in Table 1. The water samples were analyzed in the Department of Plant Production and Protection, College of Agriculture and Veterinary Medicine, Qassim University, Buriydah, Saudi Arabia. Water samples were transported immediately to the laboratory in ice boxes and chemical analyses were carried out to assess the water quality, Map 1. Location of the studied areas.

**Water quality measurements**

The pH was determined using a pH meter (pH meter Jenway 3310).

The total soluble salts were measured by using an electrical conductivity meter (EC) in dSm$^{-1}$ at 25$^\circ$C (Jenway 4310).

Chloride concentration was measured by Mohr’s titration method. Total alkalinity, Calcium and Magnesium were measured by the titration methods (Jackson, 1967)

The soluble potassium and sodium were determined using a flame photometer apparatus (PFP7, Jenway LTD, Felsted, England). The heavy metals (Zn, Cu, Ni and Pb) were determined using ICP, ThermoModel7000.

Water quality evaluation for irrigation in Hail was conducted according the criteria of (Ayers and Westcot, 1985) and U.S. salinity laboratory (Richard, 1954).

**RESULTS AND DISCUSSION**

**Water pH**

The pH of water is an indicator of its acidity or basicity, but it rarely constitutes a problem by itself. The main use of pH in water analysis is for the detection of abnormal water. The normal pH range for irrigation water is from 6.5 to 8.4. An abnormal value is a warning that the water requires further evaluation. Irrigation water with a pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion (Ayers and Westcot, 1985). The water pH values for the study area are presented in Table 2. The maximum pH value was 8.23 while the minimum was 7.10, (M = 7.66). The lowest pH value was found in location 3 while the highest value was found in location L5. It was found that the pH of water was in the normal range 6.5 – 8.4 (Ayers and Westcot, 1985).

**Water salinity**

The salinity of water was presented as EC values (dS m$^{-1}$). Highly saline irrigation water reduces osmotic potential of the soil solution, plant available water, seed germination, rooting, growth, establishment, and fruiting of plants (Duncan et al., 2009, Hillel, 2000).

Table 2 shows the irrigation water salinity (EC) of Hail farms (study area). There are a wide variations among the salinity levels in different samples. The results showed that the EC values ranged from 0.27 to 8.99 dS m$^{-1}$ in the study area. The lowest value was found in location 5, while the highest was in location 4.
Table 1. Sampling location of the study area.

| Location | Altitude | Location | Altitude | Location | Altitude |
|----------|----------|----------|----------|----------|----------|
| *L1** P1 | N27 19 29.1 | L2P6 | N27 03 158 | L3P6 | N28 02 383 |
|          | E43 14 55.0 |        | E42 50 480 |        | E41 55 372 |
| L1P2     | N27 20 48.6 | L2P7 | N27 06 189 | L3P7 | N28 01 585 |
|          | E43 14 42.8 |        | E42 46 175 |        | E42 02 212 |
| L1P3     | N27 22 29.1 | L2P8 | N27 07 209 | L3P8 | N27 55 523 |
|          | E43 15 02.8 |        | E42 47 446 |        | E41 50 191 |
| L1P4     | N27 26 40  | L2P9 | N27 09 077 | L3P9 | N27 53 041 |
|          | E43 18 23.6 |        | E42 42 459 |        | E41 48 245 |
| L1P5     | N27 25 82.9 | L2P10 | N27 13 276 | L3P10 | N27 51 287 |
|          | E43 19 37.8 |        | E42 38 124 |        | E41 42 430 |
| L1P6     | N27 28 0.1 | L2P11 | N27 13 120 | L3P11 | N27 51 189 |
|          | E43 25 35.3 |        | E42 43 181 |        | E41 38 017 |
| L1P7     | N27 34 29.9 | L2P12 | N27 15 407 | L3P12 | N27 49 133 |
|          | E43 23 14.3 |        | E42 39 847 |        | E41 34 087 |
| L1P8     | N27 36 36.6 | L2P13 | N27 16 153 | L4P1 | N27 51 375 |
|          | E43 11 48.3 |        | E42 44 153 |        | E42 00 017 |
| L1P9     | N27 40 43  | L2P14 | N27 16 043 | L4P2 | N27 06 035 |
|          | E43 06 34.5 |        | E42 58 203 |        | E42 00 17 |
| L1P10    | N27 23 17.8 | L2P15 | N27 10 568 | L4P3 | N27 59 577 |
|          | E43 02 21.2 |        | E42 59 038 |        | E42 12 063 |
| L1P11    | N27 19 25.7 | L2P16 | N27 12 044 | L5P1 | N27 48 194 |
|          | E43 06 30.4 |        | E43 07 404 |        | E42 33 502 |
| L1P12    | N27 16 33.2 | L2P17 | N27 11 299 | L5P2 | N27 47 181 |
|          | E43 05 37.3 |        | E43 05 546 |        | E42 34 345 |
| L1P13    | N27 21 19.8 | L2P18 | N27 13 470 | L5P3 | N27 43 039 |
|          | E43 00 32.3 |        | E43 04 324 |        | E42 34 246 |
| L1P14    | N27 18 23.5 | L2P19 | N27 15 596 | L5P4 | N27 40 555 |
|          | E43 01 28.3 |        | E43 13 596 |        | E42 32 205 |
| L1P15    | N27 17 35.7 | L2P20 | N27 14 438 | L5P5 | N27 37 215 |
|          | 43 12 24.9E |        | E43 06 492 |        | E42 36 050 |
| L1P16    | N27 16 18.9 | L2P21 | N27 16 101 | L5P6 | N27 35 170 |
|          | E43 14 12.5 |        | E43 14 115 |        | E42 37 577 |
| L2P1     | N27 15 383 | L3P1 | N27 58 045 | L5P7 | N27 32 116 |
|          | E43 21 262 |        | E41 38 426 |        | E42 33 470 |
| L2P2     | N27 06 43.9 | L3P2 | N27 59 017 | L5P8 | N27 29 049 |
|          | E43 02 542 |        | E41 40 193 |        | E42 29 524 |
| L2P3     | N27 07 235 | L3P3 | N27 59 103 | L5P9 | N27 24 560 |
|          | E43 00 508 |        | E40 41 566 |        | E42 24 1001 |
| L2P4     | N27 07 342 | L3P4 | N28 00 580 |        |        |
|          | E43 00 418 |        | E41 43 405 |        |        |
| L2P5     | N27 01 355 | L3P5 | N28 00 551 |        |        |
|          | E42 50 046 |        | E41 48 508 |        |        |

*L=location, **P= position of well
Map 1. The map of the study area was prepared using Arc GIS 9.3 software.

Table 2. Descriptive statistics of the chemical properties of water from Hail region.

| L. | pH  | EC  | Na  | Ca  | Mg  | K  | HCO₃⁻ | alkalinity | Cl  | SAR |
|----|-----|-----|-----|-----|-----|----|-------|------------|-----|-----|
|    |     | dS m⁻¹ | meq/L | meq/L | meq/L | meq/L | meq/L | mg/L | meq/L | |
| L1 | Mini. | 7.12 | 0.55 | 3.14 | 1.02 | 1.01 | 0.15 | 1.02 | 51 | 2.03 |
|    | Maxi. | 8.11 | 3.66 | 15.8 | 17.2 | 5.55 | 0.56 | 2.23 | 111 | 14.0 |
|    | M- SD | 7.78- | 0.83 | 1.18- | 2.65- | 4.08- | 1.99- | 0.33- | 1.44- | 72-21.5 |
| L2 | Mini. | 7.53 | 0.69 | 3.43 | 2.18 | 0.52 | 0.12 | 1.1 | 55 | 4.1 |
|    | Maxi. | 7.94 | 3.57 | 18.4 | 9.91 | 10.9 | 0.53 | 2.54 | 127 | 25.2 |
|    | M- SD | 7.77- | 0.114 | 1.74- | 8.72- | 5.41- | 4.16- | 0.21- | 1.68- | 82-22.5 |
| L3 | Mini. | 7.10 | 0.89 | 4.03 | 3.08 | 1.35 | 0.11 | 1.13 | 56.5 | 4.02 |
|    | Maxi. | 7.63 | 5.94 | 25.2 | 20.3 | 17.7 | 0.28 | 2.13 | 106 | 34.0 |
|    | M- SD | 7.42- | 0.194 | 1.91- | 1.4- | 9.59- | 6.3- | 4.61- | 0.16- | 1.76- | 88-18 |
| L4 | Mini. | 7.55 | 1.24 | 6.65 | 3.4 | 3.3 | 0.12 | 1.08 | 54 | 4.85 |
|    | Maxi. | 7.66 | 8.99 | 50.9 | 26.6 | 23.5 | 1.48 | 2.34 | 117 | 48.5 |
|    | M- SD | 7.59- | 0.056 | 5.67- | 31.7- | 16.8- | 16.7- | 0.93- | 1.88- | 94-34.5 |
| L5 | Mini. | 7.72 | 0.27 | 0.74 | 0.39 | 0.11 | 0.05 | 0.03 | 1.5 | 0.65 |
|    | Maxi. | 8.23 | 6.8 | 38.6 | 20.0 | 22.2 | 0.76 | 1.98 | 99 | 40.3 |
|    | M- SD | 7.68- | 0.147 | 1.77- | 9.2- | 5.6- | 4.6- | 0.18- | 1.04- | 52-26.5 |
|    |     |     |     |     |     |     |     |     |     |     |

L: Location, Mini: Minimum, Maxi: Maximum, M-SD: Mean-Standard Deviation.
Figure 1 shows that there are no water samples with a salinity concentration of less than 0.25 dSm\(^{-1}\), which can be classified according to the US Department of Agriculture (Richard, 1954) to Low Salinity Water (C1). The results also indicated that 18.7% of water samples with salinity ranged between 0.25 and 0.75 dSm\(^{-1}\), can be classified according to the US Department of Agriculture (Richard, 1954) to (C2) moderate Salinity Water.

It is also clear that 52.5% of saline water samples are located between 0.75 and 2.25 dSm\(^{-1}\), which can be classified as high salinity water (C3) and 28.8% of water samples have salinity concentration greater than 2.25 dSm\(^{-1}\), which can be classified as very high salinity water (C4) according to the US Department of Agriculture (Richard, 1954). This water is not suitable for irrigation under normal conditions, but it can be used under specific conditions, such as high permeability and good drainage conditions. Ayers and Westcot (1985) reported that the salinity of water is greater than 3 dSm\(^{-1}\) becomes difficultly for using it in irrigation systems.

However, throughout the world under widely different conditions of soil, irrigation, yields and climate, waters of many different compositions ranging in salinity up to at least 6000 mg/l TDS (8 dSm\(^{-1}\)) are being used productively for irrigation in numerous places (Rhoades et al., 1992).

The results depicted in Figure 1, exhibited higher values of water salinity in location 2 compared to other locations. This represents a very rapid and severe water quality deterioration in location 2. This is due to the continuous agricultural expansion and development in this part compared to other locations and the increased demands on water supplies, which is manifested in more groundwater abstraction and deterioration.

**Cations**

In Hail groundwater, the major cations’ abundance order is \(K^+ < Mg^{2+} < Ca^{2+} < Na^+\), where the main composition of groundwater is highly affected by the lithology of rocks rather than human activities (Toumi et al., 2015).

The calcium ion concentrations ranged between 0.39 and 26.6 meq L\(^{-1}\) (Table 2). Ingram (2014) and Will and Faust (1999) reported that calcium levels below 40 mg/L will typically need fertilizers containing calcium to prevent deficiency while high levels of calcium above 100 mg/L may lead to antagonism and result in the deficiency of phosphorus and or magnesium. High levels of calcium may also lead to clogged irrigation equipment due to scale formation (CaCO\(_3\) and other compounds precipitating out of solution). Consequently, 9.83% of farms require fertilization with calcium.

The magnesium ion concentrations ranged from 0.11-23.5 meq L\(^{-1}\) (Table 2). Ingram (2014) and Will and Faust (1999) reported that like calcium, magnesium in water tends to originate from the rock and generally only causes problems when it is below 25 mg/L, necessitating the addition of a magnesium fertilizer. Consequently, there are 47.5% of farms which require fertilization with magnesium.

![Figure 1. Status of salinity in irrigation water of Hail region.](image-url)
The sodium ion concentrations ranged from 0.74 to 50.9 meq L\(^{-1}\) with a mean value of 16.0 meq L\(^{-1}\). The main reasons for the increase in Na\(^+\) level in groundwater are the cation exchange through water–rock interaction supported by human activities (Ramkumar et al., 2013).

The sodium/alkali hazard is expressed as the sodium adsorption ratio (SAR). This index quantifies the proportion of sodium to calcium and to magnesium ions in a sample. The sodium hazard of water can be properly predicted by determining the SAR. SAR values were calculated following to SAR= Na/ (Ca+Mg) 0.5 (Richard, 1954). Table 2 shows that there is no sodicity problem in all locations (all water samples had SAR values of less than 9) excluding one sample in location 4 which had a severe sodicity problem (SAR > 9).

**Total Alkalinity, Bicarbonates, and Carbonates**

Alkalinity is a measure of the dissolved materials in water that can buffer or neutralize acids. These include carbonates (CO\(_3\)^{2-}\), bicarbonates (HCO\(_3\)^{-}\), and hydroxides (OH\(^{-}\), rarely present in that form).

The concentration of bicarbonate (CO\(_3\)^{2-}\) and carbonate (HCO\(_3\)^{-}\) in groundwater resulted from the dissolution of carbonate weathering and carbonic acid in the aquifers (Kumar et al., 2009). The observed average value of bicarbonate concentration obtained in Hail was 1.52 meqL\(^{-1}\), and ranged between 0.03 and 2.54 meqL\(^{-1}\). The carbonate ion was not detected in all water samples (Table 2). Also, the alkalinity ranged between 1.5 and 127 mg/L. Ingram (2014) and Will and Faust(1999) reported that the ideal range for total alkalinity is approximately 30 to 100 mg/L but levels up to 150 mg/L may be suitable for many plants. High alkalinity above 150 mg/L tends to be problematic because it can result to elevated pH of the growth media which can cause various nutrient problems (e.g., iron and manganese deficiency, calcium and magnesium imbalance) (Leinauer and Devitt, 2013). Consequently, bicarbonate values were in the safe and normal range.

**Chloride**

In Hail groundwater, the order of abundance of the major anions was as follows: Cl\(^-\) > HCO\(_3\)^{-} > CO\(_3\)^{2-}. A similar trend was found by Tanvir et al. (2017).

Chlorides are leached from various rocks into the soil and water by weathering. The chloride ion is highly mobile and is transported to closed basins or oceans (WHO, 1996). Chloride behaves as a conservative ion in most aqueous environments, meaning its movement is not retarded by the interaction of water with soils, sediments, and rocks. Therefore, chlorides were common of natural water. As expected, the trend of chloride distribution follows the water salinity trend. The observed average value of chloride concentration obtained in Hail was 15.5 meq L\(^{-1}\), and ranged between 0.65 and 48.5 meqL\(^{-1}\) (Table 2). In fact, 31.1% in Hail groundwater samples have the potential risk of chloride hazard (chloride > 10 meq L\(^{-1}\)) (Ayers and Westcot, 1985).

According to Palacios et al. (1997) the effect of chloride concentration on usable water in cultivation was analyzed. The degrees of restriction for irrigation water samples are presented in Table 3. The degree of ion chloride restriction (Cl\(^-\)) in irrigation water with concentrations lower than 4 meq L\(^{-1}\) is considered light (13.3%), between 4 and 10 meq L\(^{-1}\) is moderate (55.7%), and concentrations higher than 10 meq L\(^{-1}\) are considered severe (24.5%). The maximum limit is 30 meq L\(^{-1}\) (6.5%).

**Heavy metals**

Heavy metals are the one of the most important pollutants and when entering the food chains they can cause serious problems to human health (Mkude, 2015). Table 4 presents the descriptive statistical data. The order of metal levels in groundwater of Hail was as follows: Pb > Zn > Cu > Ni. The concentrations of Pb, Zn, Cu and Ni concentrations ranged from 1.29 to 94.5, 1.05 to 63.3, 1.98 to 83.8 and 0.75 to 9.21 μg L\(^{-1}\), respectively. The highest heavy metals concentrations were obtained in location 4. The results concluded that in all areas, heavy metals in groundwater were within the acceptable levels, according to Ayers and Wesotcot (1985).

Table 5 showed the correlation coefficients between some chemical properties of groundwater and groundwater EC. Groundwater EC correlated positively with Cl, Mg, Ca and Na at a significance level of 1%.

EC (dS/m) is correlated with Cl, Na\(^+\) , K\(^+\), and SAR (ranges from 0.985 to 0.585) while EC is poorly correlated with pH. pH is poorly negatively correlated with EC, Na\(^+\), K\(^+\), Ca\(^{2+}\) Mg\(^{2+}\),Cl\(^-\), and HCO\(_3\)^{-} (ranges from -0.323 to -0.05). This result coincides with the study of Bodrud-Doza et al. (2016). A highly positive correlation was observed between Cl and Mg, Ca, Na and HCO\(_3\)^{-}. A similar relation was observed between Mg and Ca, Na and HCO\(_3\)^{-}. Calcium was highly positively correlated with both Na and HCO\(_3\)^{-}. Sodium was highly positively correlated with HCO\(_3\)^{-}. Similar results were obtained by Ashiyani et al. (2015).
**Table 3. Status of chloride in water irrigation of the Hail region.**

| Approx. water chloride, meq L⁻¹ | Light  | Moderate | Severe | The maximum limit |
|---------------------------------|--------|----------|--------|-------------------|
| Location 1                      | <4.0   | 4-10     | 10-30  | >30               |
| Location 2                      | -      | 9.0      | 2.0    | -                 |
| Location 3                      | -      | 11.0     | 10.0   | -                 |
| Location 4                      | -      | 9.0      | 2.0    | 1.0               |
| Location 5                      | 3.0    | 4.0      | 1.0    | 1.0               |
| Total(samples)                  | 8.0    | 34       | 15.0   | 4.0               |

**Table 4. Descriptive statistics of the heavy metals (ug L⁻¹) of groundwater from Hail region.**

| L.    | Zn  | Cu  | Ni  | Pb  |
|-------|-----|-----|-----|-----|
| L1    | 4.7 | 4.33| 1.98| 3.83|
| Mini. | 33  | 51.3| 6.95| 78.4|
| Maxi. | 17.3| 16.9| 3.7 | 25.8|
| Mean  | 1.05| 4.76| 0.75| 2.87|
| Maxi. | 3.57| 35.8| 31.1| 54.9|
| Mean  | 17.7| 24.3| 6.04| 20.8|
| L2    | 1.07| 1.98| 0.95| 1.53|
| L3    | 25.1| 41.6| 7.44| 34.2|
| Mean  | 12.9| 18.1| 4.7 | 13.7|
| L4    | 11.9| 12.4| 1.59| 11.8|
| Maxi. | 60.4| 83.8| 9.21| 94.5|
| Mean  | 35.5| 46.5| 6.68| 50.9|
| L5    | 12.1| 11.7| 1.27| 1.29|
| Maxi. | 63.3| 33.1| 8.33| 78.1|
| Mean  | 26.6| 17.6| 5.55| 23.7|

Acceptable levels: 5ppm Zn, 0.2ppm Cu, Ni, Pb.

L: Location, Mini: Minimum, Maxi: Maximum. Acceptable levels according to (Ayers and Westcot, 1985).

**Table 5. Simple correlation between EC and chemical properties.**

|        | EC    | Cl    | K     | Mg    | Ca    | Na    | HCO₃⁻   |
|--------|-------|-------|-------|-------|-------|-------|---------|
| Cl     | 0.976 |       |       |       |       |       |         |
| K      | 0.595 | 0.511 |       |       |       |       |         |
| Mg     | 0.966 | 0.960 | 0.567 |       |       |       |         |
| Ca     | 0.976 | 0.941 | 0.572 | 0.914 |       |       |         |
| Na     | 0.985 | 0.953 | 0.636 | 0.950 | 0.947 |       |         |
| HCO₃⁻  | 0.000 | 0.976 | 0.596 | 0.966 | 0.976 | 0.985 |         |
| pH     | -0.322| -0.285| -0.050| -0.303| -0.321| -0.280| -0.323  |

*Significant correlation between EC & TDS, EC & Salinity, TDS & Salinity, TDS & Turbidity, TH & Chloride
CONCLUSION

The quality of groundwater resources in the selected Hail regions indicated that the groundwater salinity for irrigation was relatively high in most studied water samples, and the EC values ranged from 0.27 to 8.99 dS m⁻¹ in the study area. The lowest value was found in location 5, and the highest was found in location 4. However, pH values, SAR and heavy metals in groundwater in all areas were within acceptable levels.

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تم تقييم جودة المياه الجوفية للزراعة بمنطقة حائل بالملكة العربية السعودية من خلال تحليل الكيميائي للموارد المتاحة، حيث تم جمع عينات من 61 بئر في مختلف مواقع في منطقة حائل للتحليل الكيميائي. تم تقديرت pH، التوصيل الكهربائي (EC)، الصوديوم (Na⁺)، البوتاسيوم (K⁺)، الكالسيوم (Ca²⁺)، المغنيسيوم (Mg²⁺)، الكربونات (HCO₃⁻)، بيكربونات (CO₃²⁻)، كلوريد (Cl⁻)، نسبة الصوديوم المدمص (SAR) والعناصر الثقيلة لتقييم مدى ملاءمة المياه الجوفية للأغراض الزراعية. كانت قيم pH تتراوح بين 7.10 و8.23 وتراوحت ملوحة المياه الجوفية كمؤشر أولي لنوعية المياه لأغراض الزراعة، حيث كانت متوسطة وعالية في معظم عينات المياه المدروسة. وإلى جانب الملوحة، فإن 31.1% من عينات المياه الجوفية في حائل لديها مخاطر محتملة لخطر الكلوئيد (KCl > 10 ملليمكافئ في اللتر). كانت قيم SAR أقل من 9% من جميع عينات المياه الجوفية بينما كانت المعايير التقليلة في حدود المستويات المقبولة.

نتيجة للمناخ الجاف في المملكة العربية السعودية، تعد المياه الجوفية أهم مورد طبيعي، حيث تتوفر موارد مياه موثوقة للسكان المحليين وتتطور الزراعة المرموقة حيث موارد المياه السطحية غير كافية وقليلة لتنبؤ متطلبات المياه المائية للمملكة العربية السعودية. لذلك أجريت هذه الدراسة لتقييم جودة موارد المياه الجوفية في مواقع مختلفة من منطقة حائل. ركزت هذه الدراسة على التحليل الكيميائي للهام لموارد المياه الجوفية المتاحة في منطقة حائل. تم جمع عينات المياه الجوفية من 61 بئر في مواقع مختلفة تغطي منطقة حائل للتحليل الكيميائي. تم تقدير ال pH، التوصيل الكهربائي (EC)، الصوديوم (Na⁺)، البوتاسيوم (K⁺)، الكالسيوم (Ca²⁺)، المغنيسيوم (Mg²⁺)، الكربونات (HCO₃⁻)، بيكربونات (CO₃²⁻)، كلوريد (Cl⁻)، نسب الصوديوم المدمص (SAR) والعناصر الثقيلة للتقييم مدى ملاءمة المياه الجوفية للأغراض الزراعية. 

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