



Chemical properties and main ions of groundwater in Al-Salman district

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Abstract :

This study encompasses the analysis and evaluation of the chemical characteristics of groundwater in the study area. A total of nine (9) groundwater samples were collected through fieldwork during two distinct seasons: the wet season represented by January and the dry season represented by August (2025). The collected samples were subsequently analyzed at the U-Science Scientific Laboratory.

Based on the laboratory analytical results, a pronounced seasonal and spatial variation in the chemical characteristics was observed across most groundwater wells within the Al-Salman district. Several chemical parameters exhibited an increase during the dry period, exceeding the permissible limits established by both the World Health Organization (WHO) and the Iraqi standard specifications. Conversely, other parameters remained within the permissible limits, particularly at well eight (W8), which recorded the lowest chemical concentrations. Furthermore, the variation in chemical concentration values—whether elevated or reduced—was influenced by the geological nature of the rock formations within the region, as well as various anthropogenic activities, including agricultural practices and livestock grazing. This was further exacerbated by increased groundwater abstraction rates from the wells due to the scarcity of surface water resources, which are limited to seasonal valleys that dry up during the summer. Consequently, groundwater stands as the primary water resource in the studied region. This is also demonstrated by hydrochemical mapping, which illustrated distinct spatial variations in the distribution of chemical values

resulting from the diversity of recharge sources that descend from the southwestern toward the northern areas.

Keywords: Groundwater Quality, Hydrochemical Facies, Al-Salman District, Cations and Anions, Spatial Variation.

Introduction:

Groundwater is considered one of the most vital natural resources in the world, as it forms the primary strategic reserve of freshwater in many regions, particularly in arid and semi-arid ones. Due to its close link with geological formations and its continuous movement through rocks groundwater acquires its chemical and physical properties through direct, ongoing interaction between the water and its surrounding rocks. These hydrogeological processes, including the dissolution and weathering of minerals, lead to the formation of the water's ionic constituents and determine its chemical identity. Studying and documenting the ionic characteristics of groundwater, which include major cations such as calcium, magnesium, and sodium, and anions such as chlorides, sulfates, and bicarbonates, constitute a fundamental pillar in hydrological sciences. Understanding these properties is not only limited to knowing the nature of the water, but also extends to forming a database for understanding water movement,

groundwater recharge sources, and chemical changes resulting from geological interactions and surface human activities that may impact these aquifers.

Research Problem: The core research problem revolves around the following question: What is the nature and concentration distribution of ionic characteristics (cations and anions) in the groundwater of the study area?

Research Hypothesis: Based on the primary problem stated above, the researcher proposes a tentative solution through the following thesis: 'The ionic characteristics of groundwater in the study area are characterized by a significant spatial and temporal variation in the concentrations of major ions (such as calcium, magnesium, sodium, chloride, and sulfate), driven by the interaction of geological factors within the aquifers.

Research Significance: This research provides a baseline record of the nature and concentrations of major ions in the groundwater of the study area, enabling future researchers to

monitor any alterations in elemental concentrations.

Research Objectives: This research aims to measure and determine the concentration levels of major ions in groundwater samples, and study the spatial and temporal variation in the distribution of these chemical concentrations among different wells within the study area, in order to identify their geographic distribution patterns.

Research Methodology: This research adopts an empirical-analytical approach, relying on the collection of field groundwater samples and conducting laboratory tests to measure elemental concentrations. This is further supported by a descriptive approach to present the data and its spatial distribution.

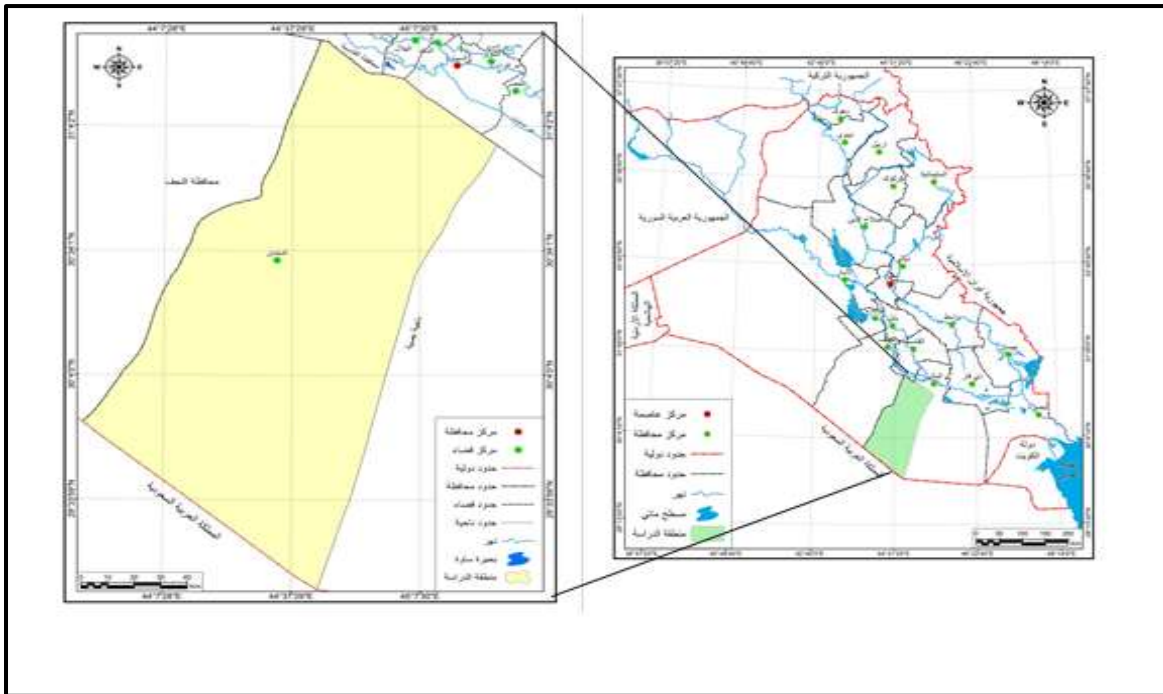
Research Boundaries: Spatial Boundaries (Geographic & Astronomical)

The study area is located in

southwestern Iraq, specifically within the southern administrative borders of Al-Muthanna Governorate. To the north, it borders the districts of Al-Khidir, Samawah, and Al-Hilal, as well as Al-Diwaniyah Governorate. Al-Busaiya sub-district occupies the eastern part outside the area's boundaries and belongs administratively to Al-Salman District. The Kingdom of Saudi Arabia represents the southern border, while Al-Najaf Governorate forms the western and northwestern borders. Astronomically, the study area lies between latitudes ($29^{\circ} 12' 23'' - 31^{\circ} 42' 26''$) North, and longitudes ($44^{\circ} 14' 29'' - 45^{\circ} 31' 54''$) East, Map (1). The total area of the district reaches $(17,463.84) \text{ km}^2$, accounting for (34%) of the total area of Al-Muthanna Governorate, which stands at $(51,753.14) \text{ km}^2$.

Temporal Boundaries: The temporal boundaries of the research are designated for the year 2025.

Map (1): Geographic Location and Administrative Boundaries of the Study Area.



1- Chemical Characteristics of Groundwater in Al-Salman District:

1.1. Hydrogen Power (pH):

It is defined as the negative logarithm of active hydrogen ion concentration (H^+). The pH serves as a measure of the acidity or alkalinity of solutions under standard conditions of temperature and pressure (Al-Hadithi & Al-Assafi, 2016). Its value ranges from (1 to 14); a pH value of less than (7) indicates that the water is acidic, whereas a value greater than (7) indicates that the water is alkaline. A value of (7) represents the neutrality point, which is the optimum level for freshwater. Nevertheless, water remains suitable for agricultural use even if it increases or decreases slightly from (7), and the pH value typically falls between (6 and 9) in most natural water (Ayed, A., et al. (2005). As the governing factor regulating the majority of reactions across diverse environments, pH

represents a vital parameter for evaluating water quality (Al-Khafaji, 2016). Several factors influence pH levels or reaction degrees, including rainfall and torrents, which dissolve natural pollutants, including substances dissolved in soil. Additionally, anthropogenic activities, such as agricultural practices, the use of various pesticides and fertilizers, as well as sewage and industrial effluents within the region, play a significant role. Furthermore, pH values are affected by the concentration of dissolved carbonate and bicarbonate compounds in the water (Al-Rimawi, 2004). Significant and distinct fluctuations in pH values adversely affect plant physiological functions, leading to root destruction when pH levels drop below 4 or exceed 9. Furthermore, such shifts disrupt the equilibrium of nutrients absorbed by the plant. An increase in water acidity or alkalinity also serves as a critical factor in deteriorating soil fertility and reducing agricultural productivity (Zaboon, 2015).

According to international standard guidelines, the specified pH range for water quality varies across regulatory frameworks; it ranges from 6.0 to 7.5 under the Japanese Standard, between 6.5 and 9.5 according to the European Union (EU) Standard, and between 6.5 and 8.5 under the US Environmental Protection Agency (EPA) Standard (Al-Quraishi, 2022). The analysis of Table (1), Map (2), and Figure (1) reveals that the pH values of groundwater well samples in the study area exhibit slight temporal variation between the wet and dry seasons. During the wet season,

represented by January, pH values ranged from 5.86 to 7.99, with a mean of 7.17. Conversely, during the dry season, represented by August, the pH values ranged from 6.40 to 7.87, with a mean of 7.08. Furthermore, pH values displayed spatial variation during the wet season (January), reaching a maximum value of 7.99 in well (W2) and a minimum value of 5.86 in well (W8). During the dry season (August), the maximum pH value was recorded in well (W6) at 7.87, while the minimum value was observed in well (W8) at 6.40.

Table (1): pH Values During the Wet and Dry Seasons

Hydrogen Power (Ph)		Latitude	Longitude	Well ID
August	January			
7.01	7.06	31° 16' 32.643" N	44° 52' 7.546" E	W1
7.04	7.99	30° 59' 35.097" N	45° 18' 28.539" E	W2
7.00	7.23	30° 59' 19.377" N	44° 47' 4.480" E	W3
7.00	7.26	30° 46' 44.554" N	44° 41' 43.355" E	W4
7.02	7.28	30° 33' 55.203" N	44° 56' 55.233" E	W5
7.87	7.58	30° 34' 58.905" N	44° 37' 39.211" E	W6
7.10	7.13	30° 27' 18.591" N	44° 31' 22.452" E	W7
6.40	5.86	30° 10' 51.678" N	44° 19' 30.060" E	W8
7.28	7.16	29° 46' 5.076" N	44° 46' 36.467" E	W9

Map (2): Spatial Distribution of pH in Groundwater During the Wet and Dry Seasons within the Study Area (2025)

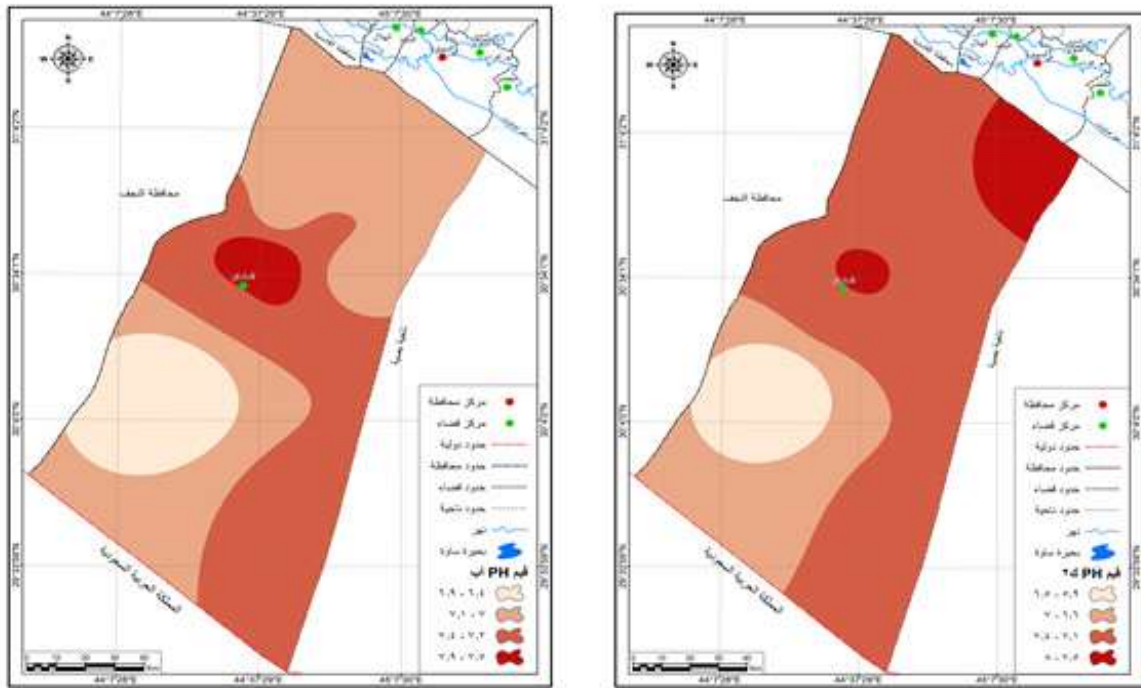
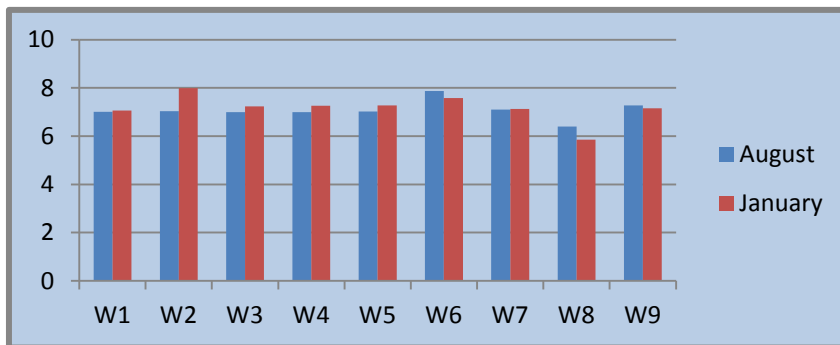


Figure (1): pH Values During the Wet and Dry Seasons



Based on the preceding findings, it can be concluded that the groundwater within Al-Salman District ranges from acidic to slightly alkaline. This minor deviation from neutrality ($\text{pH} = 7$) and the shift toward slight alkalinity are attributed to the presence of calcium

and magnesium ions, which lead to the formation of certain unneutralized salts. Additionally, the arid and hot climate of Al-Salman District drives the precipitation of bicarbonates in the water, further steering the pH values toward alkalinity.

1.2. Electrical Conductivity (EC):

It is defined as the ability of (1 cm³) of water to conduct electrical current at a temperature of (25°C). It serves as an indicator of salinity. Electrical conductivity values depend on temperature, as well as on the type and concentration of ions in the water, where the Electrical Conductivity (EC) value increases with the increase in temperature and the amount of dissolved salts (Ibshir & Selim, 2023). "The electrical conductivity of water serves as an indicator of the quantity of ionized compounds present within it; it can also result from high hardness or other forms of mineral contamination (Hem, 1985). Electrical conductivity is measured in micromhos/cm . Pure water is a non-conductive medium; however, the EC value increases with the elevated content of dissolved salts and solids in groundwater, which are responsible for conducting electricity in water. Consequently, a higher concentration of dissolved salts leads to an increase in groundwater EC values. Therefore, electrical conductivity (EC) measurement serves as a direct indicator of the total dissolved salt concentration in water. groundwater has been classified based on its electrical conductivity (EC) into the following categories (Al-Shaer & Al-Mousa, 2006):

- 1- Low-salinity water: The EC value is less than 250 $\mu\text{S/cm}$
- 2- Medium-salinity water: The EC value ranges between 250 and 750 $\mu\text{S/cm}$
- 3- High-salinity water: The EC value ranges between 750 and 2250 $\mu\text{S/cm}$
- 4- Brine (Highly saline solutions): The EC value exceeds 2250 $\mu\text{S/cm}$

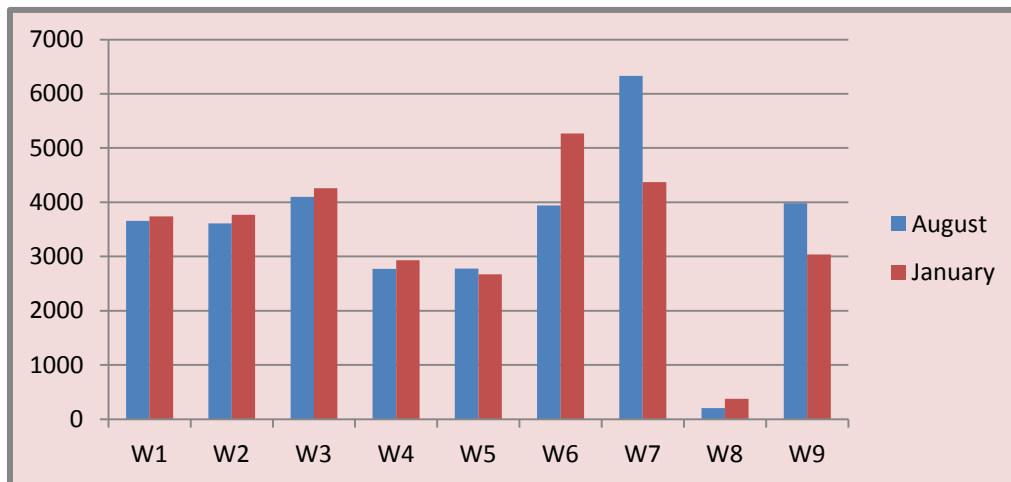
The analysis of Table (2), Map (3), and Figure (1) demonstrates that the recorded electrical conductivity (EC) values of the studied well water samples exhibit both temporal and spatial variations. During the wet season, the EC values ranged from 37.6 to 5270 $\mu\text{S/cm}$, with a mean of 3343.067 $\mu\text{S/cm}$. Conversely, during the dry season, the EC values ranged between 207 and 6330 $\mu\text{S/cm}$, with a mean of 3486.33 $\mu\text{S/cm}$. Spatially, during the wet season (January), the maximum EC value was recorded in well (W6) at 5270 $\mu\text{S/cm}$, while the minimum value was observed in well (W8) at 37.6 $\mu\text{S/cm}$. Similarly, during the dry season (August), the maximum values were recorded in wells (W3) and (W7) at 6330 and 4100 $\mu\text{S/cm}$, respectively, whereas the

minimum value was observed in well (W8) at 207 $\mu\text{S}/\text{cm}$.

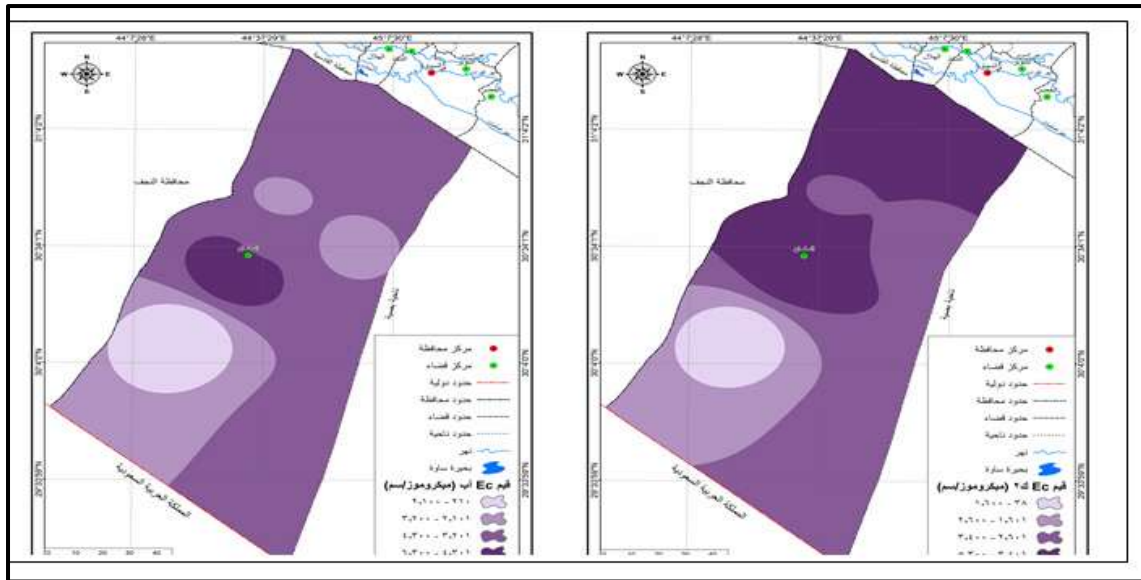
Table (2): Electrical Conductivity (EC) $\mu\text{S}/\text{cm}$ Values During the Wet and Dry Seasons

Electrical Conductivity (EC) $\mu\text{S}/\text{cm}$		Well ID
August	January	
3660	3740	W1
3610	3770	W2
4100	4260	W3
2770	2930	W4
2780	2670	W5
3940	5270	W6
6330	4370	W7
207	376	W8
3980	3040	W9

Figure (2): Electrical Conductivity (EC) $\mu\text{S}/\text{cm}$ Values During the Wet and Dry Seasons.



Map (3): Spatial Distribution of Electrical Conductivity (EC) $\mu\text{S}/\text{cm}$ Values in Groundwater During the Wet and Dry Seasons within the Study Area (2025)



Based on the aforementioned findings, the increase in electrical conductivity (EC) values of groundwater samples within the study area during the dry season is attributed to elevated temperatures and enhanced evaporation rates. Furthermore, the scarcity and fluctuation of rainfall during this period result in a reduction of groundwater volume within the wells, thereby concentrating total dissolved salts and consequently increasing EC values. Conversely, during the wet season, the increase in EC values in certain well waters is due to the dissolution of salt-bearing rocks by precipitation, which subsequently mixes with the groundwater, thereby elevating the water's electrical conductivity.

1.3.Total Dissolved Solids (TDS): Electrical conductivity (EC) values and total dissolved

solids (TDS) concentrations are positively correlated, making them functionally inseparable. The mean concentration of total dissolved solids (TDS) varies significantly; it is negligible in fresh water, whereas it exceeds 10,000 ppm in saline water and reaches approximately 35,000 ppm in seawater. For drinking water, TDS concentrations should not exceed 500 ppm (Al-Saadi, 2004). Furthermore, TDS is a crucial property that heavily influences irrigation water quality, as it comprises the primary nutrients required for plant growth. However, elevated concentrations lead to several challenges, particularly affecting plant water uptake and soil water infiltration, both of which deteriorate with increasing salinity levels (Kazem & Saad, 2022).

Table (3): Total Dissolved Solids (TDS) mg/L Values During the Wet and Dry Seasons within the Study Area (2025)

Total Dissolved Solids (TDS) mg/L		Well ID
August	January	
2379	2244	W1
2346.5	2262	W2
2665	2556	W3
1800.5	1758	W4
1807	1602	W5
2561	3162	W6
4114.5	2622	W7
124.2	22.56	W8
2587	1824	W9

Map (4): Spatial Distribution of Total Dissolved Solids (TDS) mg/L Values in Groundwater During the Wet and Dry Seasons within the Study Area (2025)

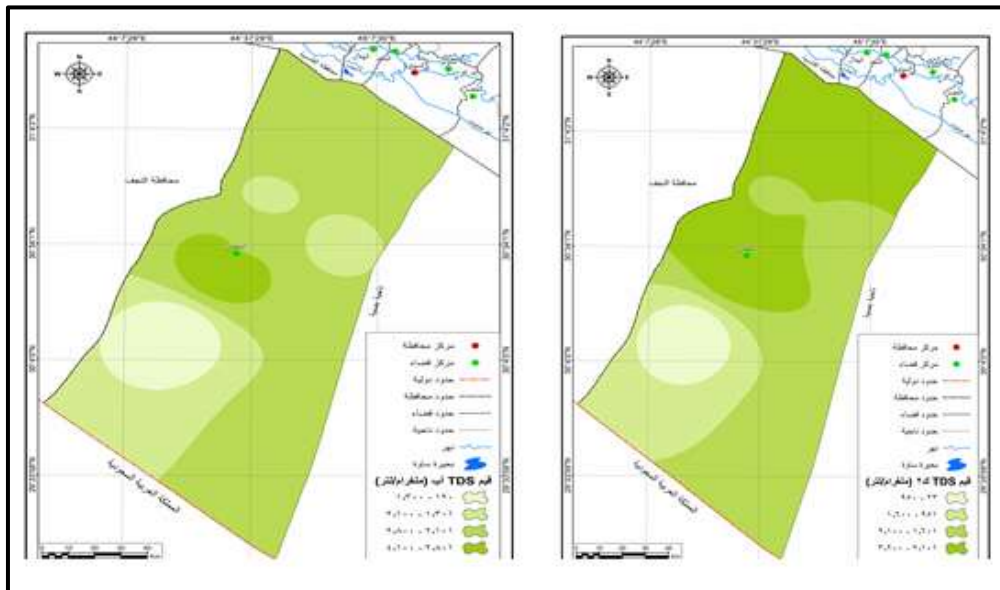
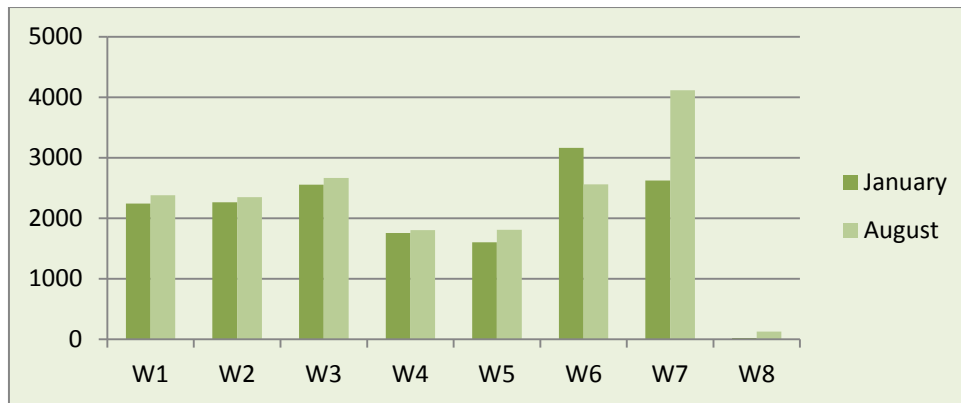


Figure (3): Spatial Distribution of Total Dissolved Solids (TDS) mg/L Values in Groundwater During the Wet and Dry Seasons within the Study Area (2025).



Observation of Table (3), Map (4), and Figure (3) reveals that Total Dissolved Solids (TDS) in the groundwater samples exhibit slight temporal and spatial variations. During the wet season (January), TDS concentrations ranged from 22.56 to 3162 mg/L, with well (W6) recording the maximum concentration at 3162 mg/L, while the minimum concentration was observed in well (W8) at 22.56 mg/L. Similarly, during the dry season, TDS values ranged between 124.2 and 4114.5 mg/L; the maximum concentration was recorded in well (W7) at 4114.5 mg/L, whereas the minimum concentration was observed in well (W8) at 124.2 mg/L.

2- Major Ions of Groundwater in Al-Salman District:

2.1. Cations (Positive Ions):

These are ionized and dissolved

salts in groundwater that carry a positive charge, and they include the following ions:

1.2.1.1. Calcium Ion (Ca^{2+}): It is one of the most widely distributed metallic elements and is considered one of the most important cations in groundwater. Furthermore, it represents an essential and fundamental nutrient for both plants and animals (Hussein, 2020). The primary sources of calcium ions are calcareous rocks (limestone), as well as evaporite rocks such as gypsum and anhydrite, which possess a high solubility in water. This solubility subsequently increases the concentration of dissolved calcium in well water. Additionally, the weathering of minerals—such as pyroxene and amphibole—alongside sedimentary rock minerals, including calcite and dolomite, represents a major source of this ion. Furthermore, the process of dolomitization serves as another source of calcium ions.

Calcium ions bind with bicarbonate ions HCO_3 to form calcium bicarbonate $\text{Ca}(\text{HCO}_3)_2$, which is responsible for temporary hardness. The concentration of this compound in water increases in response to elevated temperatures and pressure (Abed-Al-Ibrahimi &

Al-Janabi, 2018). The concentrations of calcium ions (Ca^{2+}) reach up to 13 mg/L in river water, and approximately 80 mg/L in rainwater, whereas they reach up to 50 mg/L in groundwater (Al-Tamimi, 2002).

Table (3): Calcium Ion (Ca^{2+}) mg/L Values During the Wet and Dry Seasons

Calcium Ion (Ca^{2+}) mg/L		Well ID
August	January	
512	512	W1
504	520	W2
512	536	W3
432	464	W4
480	448	W5
640	584	W6
720	552	W7
35.2	4	W8
520	368	W9

Map (5): Spatial Distribution of Calcium Ion (Ca^{2+}) mg/L in Groundwater During the Wet and Dry Seasons within the Study Area (2025)

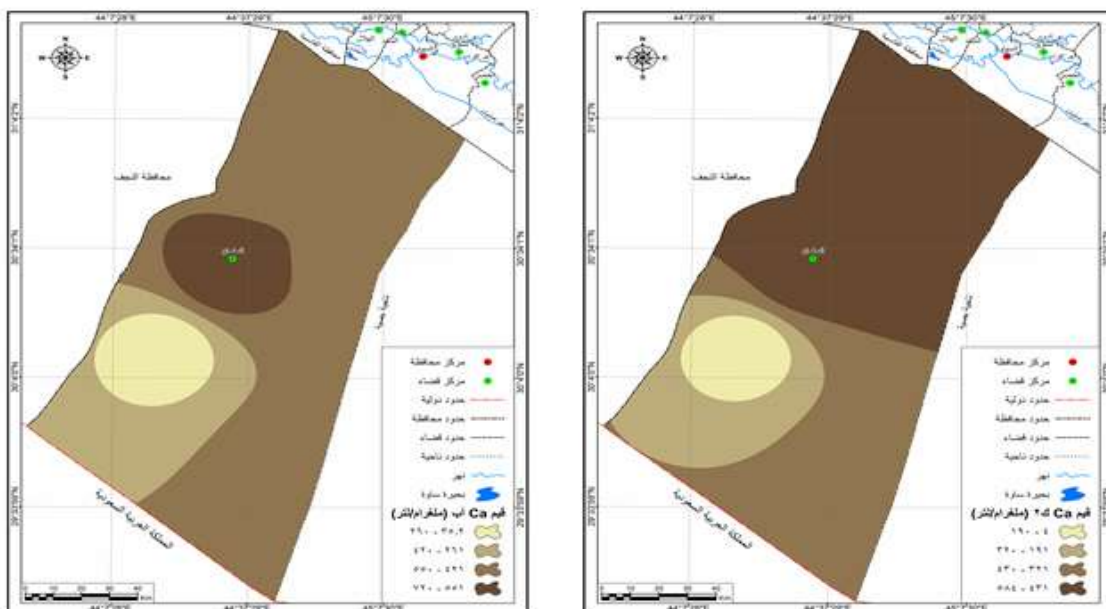
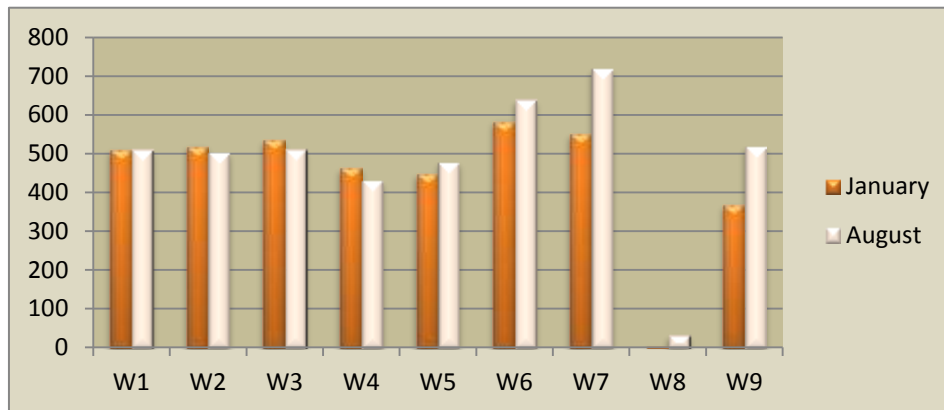


Figure (4): Calcium Ion(Ca^{2+}) mg/L Values During the Wet and Dry Seasons



The data in Table (3), Map (5), and Figure (4) indicate that calcium ion (Ca^{2+}) concentrations ranged from 4 to 584 mg/L during the wet season, whereas they ranged between 35.2 and 720 mg/L during the dry season. It is also evident that calcium ion concentrations increased during the dry season due to decreased rainfall. Conversely, they decreased during the wet season, a decline attributed to dilution processes within the aquifers resulting from precipitation (Al-Khafaji, 2016).

1.2.1.2. Anions (Negative Ions):

These are the negatively charged species dissolved in groundwater, and they include the following ions:

1.2.1.2.1. **Chloride ions (Cl^-):** The source of chloride ions (Cl^-) in arid desert regions, within which the study area is located, is attributed to the halite

solution. Additionally, the infiltration of agricultural runoff carrying saline residues into the soil serves as another source (Al-Fatlawi, 2021). "It is considered one of the major essential chemical anions found in natural waters. It imparts a salty taste to water, and when bound with sodium ion, it forms sodium chloride (NaCl). Chloride salts are characterized by their high capacity for dissociation and dissolution in water; consequently, their presence in high concentrations has toxic effects on crops (Lashhab et al., 2014). "Chloride is present in water suitable for human consumption; however, the salty taste resulting from chloride (Cl^-) varies depending on the chemical characteristics of the water. Water containing 250 mg/L of chloride ions exhibits a distinctly salty taste, particularly when the

predominant ion is sodium (Na^+). Conversely, this salty taste disappears in water containing a chloride ion concentration of 1000 mg/L if the prevailing ions are calcium (Ca^{2+}) or magnesium (Mg^{2+}). The concentration of chloride

ions in natural waters is typically less than 30 mg/L, whereas in the groundwater of arid regions, it is less than 100 mg/L, and in seawater, it is approximately 50–80 mg/L (Al-Fatlawi, 2021).

Table (4): Chloride Ion (Cl^-) mg/L Values During the Wet and Dry Seasons.

Chloride Ion (Cl^-) mg/L		Well ID
August	January	
754.6	499.8	W1
529.2	499.8	W2
784	744.8	W3
323.4	294	W4
343	303.8	W5
539	911.4	W6
1195.6	695.8	W7
39.2	14.7	W8
715.4	490	W9

Map (6): Spatial Distribution of Chloride Ion (Cl^-) in Groundwater During the Wet and Dry Seasons within the Study Area (2025)

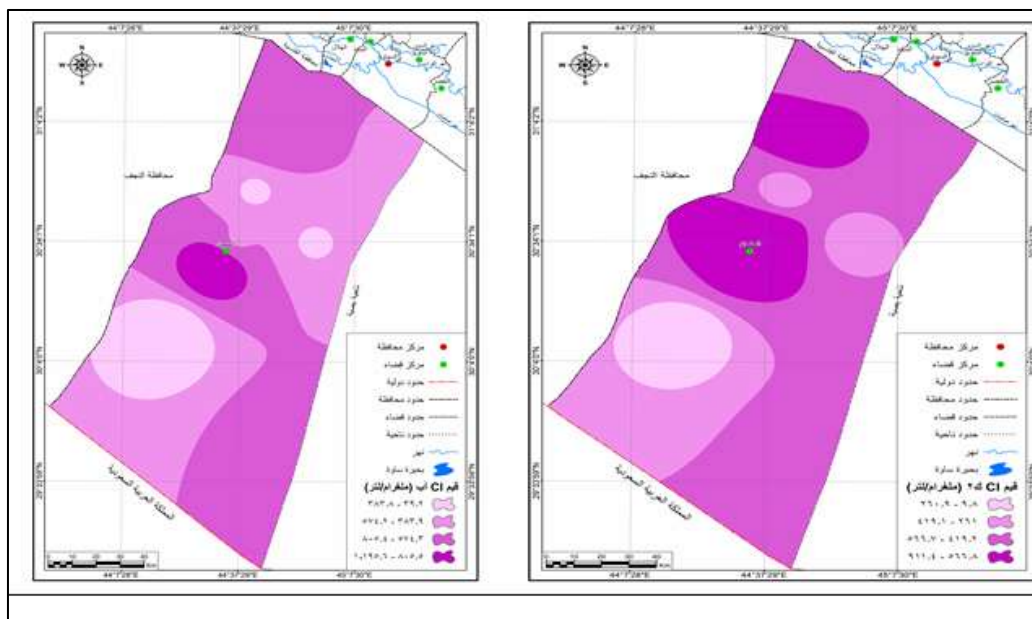
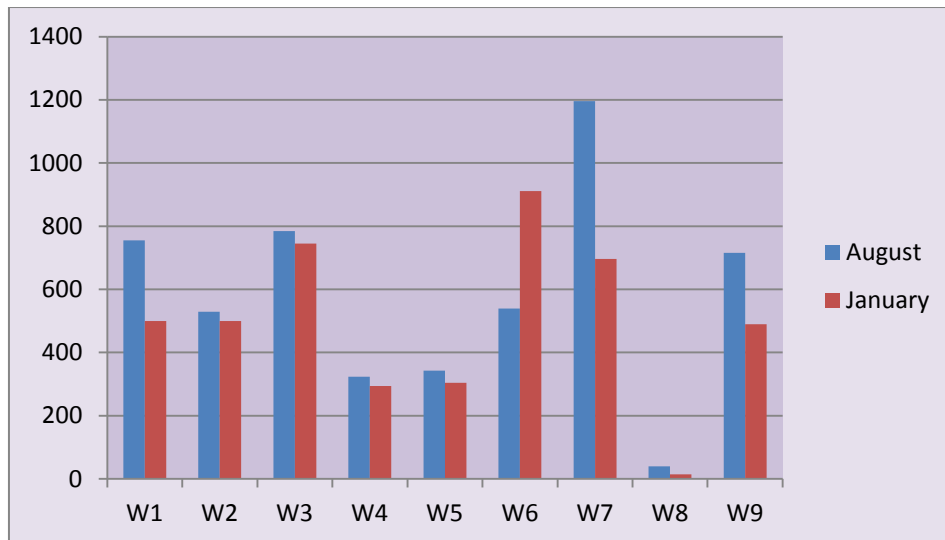


Figure (5): Chloride Ion (Cl^-) Values During the Wet and Dry Seasons



The analysis of Table (4), Map (6), and Figure (5) reveals a clear variation in chloride ion (Cl^-) concentrations within the groundwater samples during both the wet and dry seasons. During the wet season (January), chloride ion concentrations ranged from 14.7 to 911.4 mg/L. The minimum chloride concentrations were recorded in wells (W8) and (W4) at 294 and 14.7 mg/L, respectively, while the maximum concentration reached 911.4 mg/L in well (W6) during the same period. Conversely, during the dry season (August), chloride ion (Cl^-) concentrations ranged between 39.2 and 1195.6 mg/L; the maximum concentration was recorded in well (W7) at 1195.6 mg/L, whereas the minimum concentration was observed in well (W8) at 39.2 mg/L. The increase during the dry season is attributed

to the prevailing climate in the study area, which is characterized by elevated temperatures, low humidity levels, high evaporation rates, and scarce precipitation. These factors collectively lead to a reduction in water volume within the region, alongside diminished groundwater recharge. Additionally, the intensive extraction of groundwater to meet various domestic demands and agricultural irrigation further concentrates chloride ions in the groundwater, ultimately escalating its salinity.

Conclusions:

- 1- The study reveals an increase in the values of certain chemical characteristics during the dry season compared to the wet season, such as electrical conductivity (EC), as well as magnesium and calcium ions. This rise is attributed to elevated temperatures, rainfall

scarcity, and increased evaporation rates, along with intensified groundwater pumping for agricultural irrigation and other domestic uses.

- 2- A decrease in the concentrations of certain elements, such as calcium, during the wet season, resulting from their adsorption onto the clay rocks present in the area.
- 3- An elevation in total dissolved solids (TDS) concentrations was observed in most wells within the study area during both the wet and dry seasons, resulting from increased ion concentrations, specifically sodium and chloride. An exception was noted in certain wells, such as well (W8), which recorded the lowest TDS concentration because it serves as the Al-Salman water desalination project, making its water fresh
- 4- The majority of the well water samples within the study area exceeded the permissible limits for drinking water quality established by both the World Health Organization (WHO) and the Iraqi Drinking Water Standards.

Recommendations :

1. The study recommends monitoring the relationship between declining groundwater levels and the rise in ion concentrations, as intensive groundwater extraction often leads to well salinization and the

upcoming of saline water from deeper strata. Furthermore, it highlights the importance of evaluating the potential for rainwater and floodwater harvesting within seasonal valleys and depressions to artificially recharge the aquifers. This approach would effectively increase groundwater reserves and promote the dilution of dissolved salts and ion concentrations within the aquifer system.

2. implementing strict regulations on groundwater extraction rates is crucial to prevent critical drawdowns in aquifer water levels.
3. Controlling the use of chemical fertilizers and pesticides in the region to reduce the leaching of dissolved chemical compounds into the aquifer, which alters the natural characteristics of the water.

References

1. **Abed-Al-Ibrahimi, S. N., & Al-Janabi, F. J. M. (2018).** Spatial analysis of groundwater abundance variation in Al-Mu'tasim sub-district using Geographic Information Systems (GIS). *Qadisiya Journal for Human Sciences*, 21(4), pp. 309-321.
2. **Al-Fatlawi, D. A. K. N. (2021).** *Groundwater and Its Impact in Developing the Agricultural*

- Production in the Desert of Kerbala Center District* [Unpublished master's thesis]. College of Education for Human Sciences, University of Kerbala.
3. **Al-Hadithi, Y. K. H., & Al-Assafi, R. B. Z. (2016).** Studying the groundwater quality of selected wells in Al-Anbar Governorate and their suitability for agricultural purposes. *Anbar Journal of Agricultural Sciences*, 14(2), p. 103.
 4. **Al-Khafaji, S. M. H. (2016).** *Groundwater and the potential for its investment in the Al-Rehab area - Al-Muthanna Governorate* [Unpublished master's thesis]. College of Arts, University of Kufa.
 5. **Al-Quraishi, F. A. A. H. (2022).** *Evaluating the quality characteristics of water in the Badra-Jassan project in Wasit Governorate using Geographic Information Systems (GIS)* [Unpublished master's thesis]. College of Education for Human Sciences, Wasit University.
 6. **Al-Rimawi, O. (2004).** *Fundamentals of Ecology* (1st ed.). Dar Wael for Publishing and Distribution.
 7. **Al-Saadi, M. A. A. S. (2004).** *Environmental assessment of groundwater in the Al-Rahaliya area - Al-Anbar Governorate* [Unpublished master's thesis]. College of Science, University of Baghdad.
 8. **Al-Shaer, J. A., & Al-Mousa, F. A. (2006).** *Hydrology Science*. University of Aleppo Publications.
 9. **Al-Tamimi, D. A. M. A. (2002).** *A chemical and environmental study of groundwater for Sulaymaniyah city and its surroundings* [Unpublished master's thesis]. College of Science, University of Baghdad.
 10. **Ayed, A., et al. (2005).** *Fundamentals of Ecology* (2nd ed.). Dar Wael for Publishing and Distribution. p. 205.
 11. **Hem, J. D. (1985).** *Study and interpretation of the chemical characteristics of natural water* (Water-Supply Paper 2254). U.S. Department of the Interior, U.S. Geological Survey. p. 260.
 12. **Hussein, S. J. (2020).** The effect of geological formations on the quality characteristics of groundwater in the badia of Al-Muthanna Governorate and its suitability for agricultural purposes. *Cambridge Journal for Scientific Research*, (5).

13. **Ibshir, F. S., & Selim, A. M. (2023).** Spatial variation of the characteristics of groundwater in the locality of Al-Aman in the Al-Mahjoub area – Misurata using GIS. *Abhat Journal*, 15(2), pp. 169-183.
14. **Kazem, Z. K., & Saad, K. S. (2022).** Analyzing the quality characteristics of groundwater and its role in agricultural development in the eastern region of Maysan Governorate. *Journal of Education for Human Sciences Constants*, 2(6).
15. **Lashhab, S. R. H., et al. (2014).** Studying some indicators of groundwater pollution within the scope of Al-Marj city. *Journal of Sciences and Human Studies*, University of Benghazi.
16. **Zaboon, N. H. A. (2015).** *Groundwater and the potential for expanding its investment in Al-Mada'in District* [Unpublished master's thesis]. College of Arts,