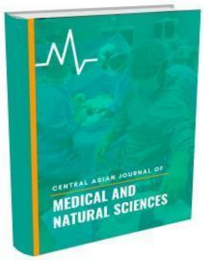

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Article

Assessment of Saline Water Properties from Jallam Area Wells

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Abstract: This study investigates the physical, chemical, and microbiological properties of well water in Salah al-Din Governorate, Iraq. Twelve wells, ranging from 80 to 110 meters in depth, were sampled monthly from September 2023 to February 2024. The study aimed to assess water quality concerning health standards, focusing on parameters like total dissolved solids (TDS), pH, salinity, total alkalinity, biological oxygen demand (BOD5), and chloride levels. Results indicated that TDS levels were above the World Health Organization's acceptable limit (500 mg/L), ranging from 1970 to 5440 ppm, while pH values were within the acceptable range (6.5 to 8.5). Salinity levels were low (0.1 to 0.22 mg/L), and total alkalinity varied from 40 to 200 mg/L. BOD5 values were low (0.93 to 2.3 mg/L), indicating minimal biodegradable organic matter. Chloride levels ranged from 13.61 to 45.20 mg/L. These findings suggest that while the water's pH, salinity, and BOD5 levels are acceptable, high TDS levels may pose a health risk. This study highlights the need for continuous monitoring and potential treatment solutions to ensure safe drinking water in the region.

Keywords: Saline Water, Physical Properties, Chemical Properties, Jallam Wells, Water Quality

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1. Introduction

Groundwater, like surface water, contains dissolved solids, gases, and suspended solids, which constantly change in quantity and quality due to geological and environmental factors and water interaction with its surroundings [1]. Deep well water is characterized by its purity, being colorless with a stable composition due to the filtration of suspended solids and reduction of microorganisms. Groundwater maintains stable temperature and density throughout the year and generally does not require treatment, making it a preferred source for drinking and other applications [2].

Groundwater is the second primary water source for humans worldwide, increasingly important in arid and semi-arid regions. Wells bring groundwater to the surface for drinking and other uses [3]. Groundwater moves from recharge areas to discharge areas, altering its physical and chemical properties due to mixing with other groundwater or interaction with soil or rock minerals, affecting its quality [4]. Groundwater purity results from filtering suspended solids during its passage through the earth's layers, reducing microorganism numbers, making deep wells clean and colorless with stable composition. However, the composition of shallow well water near the surface is similar to surface water [5].

2. Materials and Methods

Description of the Study Area: The study area is within Salah al-Din Governorate, between latitudes 35°29'25" and 34°24'25" and longitudes 46°33'43" and 34°43'46". It is bordered by the Hamrin Mountains to the east and the Tigris River to the west. The physical, chemical, and microbiological properties of well water were studied in various locations in Al-Dur district. The well depths ranged from 80 meters for shallow wells to 110 meters for deep wells, with 8-inch casing pipes and 3-4 inch diameter suction pipes. All studied wells had sealed tops and varied in age from 1 to 10 years, with diverse uses.

Key Wells Selected for the Study

Well No. 4: This well is located in Jallam Al-Dur near the Technical Institute in Al-Dur district. It is a closed well mechanically drilled to a depth of 100 meters. It irrigates 100 donums planted with wheat, corn, and eucalyptus trees. The well is 10 years old and is 22,419 meters from the Tigris River. Its primary uses include irrigation and watering crops, and it is approximately 8,875 meters from Well No. 3.

Figure 1. Well number (4) Jalam al-Dur

Well number 5: This well is located in Jalam al-Dur and is of the closed type, mechanically dug to a depth of 110 meters. It irrigates an area of 80 dunams planted with wheat, barley, alfalfa, and millet. This well is 10 years old. It is located 32,587 meters from the Tigris River, and its current main uses include watering sheep and irrigating lands and crops. It is approximately 1,168 meters away from well number 4.

Figure 2. Well number (5) Jalam al-Dur

Well number 6: This well is located in Jalam al-Dur near Beit al-Tella and is of the closed type, mechanically dug to a depth of 100 meters. It irrigates an area of 30 dunams planted with wheat and corn. This well is 10 years old. It is located 25,250 meters from the Tigris River, and its current main uses include watering sheep and goats, and irrigating lands. It is approximately 1,663 meters away from well number 5.

Figure 3. Well No. (6) Jalam Al-Dur

Sample Collection: The sample collection process started in the morning, beginning from well No. 4 and continuing to well No. 6, at a rate of once a month from September 2023 until February 2024. One sample was collected each month after pumping well water for ten minutes to remove contaminated and stagnant water. Subsequently, the bottles were filled directly from the wells with minimal air space to preserve the chemical properties of the water during transportation. Polyethylene bottles with a capacity of 2.25 liters were used for laboratory chemical tests, ensuring that all bottles were rinsed with the sample water three times before collecting the sample. A 250 ml opaque Winkler bottle was used for each well to measure the biochemical oxygen demand (BOD) and dissolved oxygen.

3. Results and Discussion

pH: The pH of aquatic systems is a good indicator of water quality and the extent of pollution. The table shows the monthly and site-specific variations in the pH level of groundwater during the study period.

Table (1) shows a variation in pH levels between different wells and different months. The pH values vary between wells and months, with the highest pH value being 9.5 in well 1 during September 2023, and the lowest being 6.5 in well 12 during the same month. The monthly averages indicate slight changes in pH levels during the study period, with values ranging from 7.5 to 8, a narrow range indicating slightly basic water, which falls within the acceptable range for living organisms (6.5–8.5). The current study's results differ slightly, which reported pH values of 7.49-7.83 in some wells in Tikrit City. Our study results are consistent with those in Kirkuk City, with pH values ranging from 6.96 to 7.63. Additionally, our current study agrees in Al-Diqar Governorate, with pH values between 7.713-8.223[6-7].

Iraqi soils are rich in calcium salts, contributing to the basic nature of Iraqi waters. The letters attached to the monthly averages indicate no statistically significant differences between the months in pH level at a significance level of $P \leq 0.05$.

Table 1. Monthly and site-specific variations in groundwater pH during the study period.

Well/Month	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Well Averages
W4	8.4	7.81	7.53	7.29	7.94	6.93	7.650 A
W5	8.0	7.37	7.56	6.84	8.0	7.88	7.608 A
W6	7.9	7.7	7.54	7.83	7.97	8.28	7.870 A
Month Averages	8.1a	7.62a	7.54a	7.31a	7.97a	7.69a	

Total Alkalinity: Table (2) shows the monthly and site-specific variations in Total Alkalinity (mg/L) in groundwater during the study period. The table illustrates differences in Total Alkalinity between different wells and different months, reflecting the variations in groundwater composition and sources[8].

The table shows variations in Total Alkalinity levels between wells and months, with values ranging from 40 to 200 mg/L, indicating significant variations in Total Alkalinity during the study period. Most carbonates and bicarbonate ions in groundwater are derived from soil carbon dioxide[9]. This can be attributed to the increased rate of organic matter degradation by bacteria and increased carbon dioxide (CO_2), leading to bicarbonate formation. The results differ which reported alkalinity values of 60 to 35 mg/L.

The letters attached to the monthly averages indicate statistically significant differences between some months in Total Alkalinity at a significance level of $P \le 0.05$.

Table 2. Monthly and site-specific variations in Total Alkalinity (mg/L) during the study period.

Well/Month	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Well Averages
W4	120	60	70	60	60	60	71.7 D
W5	140	40	60	60	60	80	73.3 D
W6	80	60	60	80	60	100	73.3 D
Month Averages	113.3a	53.3c	63.3d	66.6c	60e	80b	

Total Alkalinity values vary between wells and months, reflecting changes in the composition and sources of groundwater. The values ranged from 40 to 200 mg/L, showing significant variation in Total Alkalinity during the study period [10-11].

Most carbonates and bicarbonate ions in groundwater are derived from carbon dioxide in the soil. This can be attributed to the increased rate of organic matter degradation by bacteria and the increase in carbon dioxide (CO_2), which leads to bicarbonate formation . The where alkalinity values ranged from 60 mg/L to 35 mg/L. The letters attached to the monthly averages indicate statistically significant differences between some months in Total Alkalinity levels at a significance level of P≤0.05.

Chemical Content of Oxygen: Table (3) shows the monthly and site-specific variations in the chemical content of oxygen in groundwater during the study period. It illustrates significant variations in oxygen content between different wells and months, reflecting changes in the composition and quality of groundwater.

Oxygen content values in groundwater ranged from 0 to 156 mg/L, indicating significant variation in the chemical quality of the water. Studies on groundwater usually indicate that oxygen levels can vary greatly based on factors such as geographic location, depth, temperature, and geochemical interactions. Compared to similar studies, the variations observed in your study may align with results from other areas or show specific differences due to local environmental conditions [12].

The letters attached to the monthly averages indicate statistically significant differences between some months in oxygen content levels at a significance level of P≤0.05.

Table 3. Monthly and site-specific variations in the chemical content of oxygen in groundwater during the study period (mg/L)

Well/Month	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Well Averages
W4	22	0	0	0	0	156	29.67 A
W5	10	0	82	0	1	0	15.50 E
W6	8	11	18	0	0	5	7.00 GH
Month Averages	13.3b	3.6d	33.3a	0d	0.3c	53.6a	

Electrical Conductivity (EC)

Electrical conductivity (EC) is defined as the ability of a 1 cm^3 volume of water to conduct an electric current at 25°C. Conductivity depends on the concentration of dissolved salts and the temperature of the water.

Table 4 shows the monthly and site-specific variations in electrical conductivity (EC) levels in groundwater during the study period, expressed in microsiemens per centimeter (μS/cm). The table indicates variability in EC levels between different wells and within each well over the specified months.

The table also shows that some wells exhibit high EC levels in some months while showing lower levels in others. The highest EC value was 5230 μS/cm in January 2024, and the lowest value was recorded in October 2023 at 2444 μS/cm. This slight increase in values is attributed to a slight rise in the amount of salts, as well as the saline content of the soils that host the river [13].

The results of this study are consistent with those of Dalaas and Abduljabar (2018), where EC values ranged from 2210 μS/cm in October to 6350 μS/cm in December. Additionally, our current results align with those of Al-Obaedy, which ranged from 1920 to 7675 μS/cm in northern Salahuddin province.

The letters attached to the monthly averages table indicate statistically significant differences between some months in EC levels. Identical letters indicate no statistically significant differences between the months, while different letters indicate statistically significant differences between the compared months at a significance level of P≤0.05.

Table 4. Monthly and site-specific variations in electrical conductivity (µS/cm) in groundwater during the study period

Well	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Well Averages
W4	3100	2748	3230	3190	3580	3360	3201 B
W5	3960	3200	3140	3240	3160	3720	3403 B
W6	3650	3470	3620	3340	3400	3440	3487 B
Monthly Averages	3657a	3486bc	3540ab	3510ab	3531ab	3381c	

Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) consist of organic materials and inorganic salts originating from sources such as wastewater, liquid waste discharge, urban runoff, or natural bicarbonates, chlorides, sulfates, nitrates, sodium, potassium, calcium, and magnesium. The World Health Organization (WHO, 1984) and Bruvold classified drinking water palatability based on TDS levels, considering less than 500 mg/L as excellent and greater than 1700 mg/L as unacceptable [14].

Table 5 shows the variations in TDS concentrations in water over an approximately 18-month study period, from September 2023 to February 2024. TDS concentration was measured in several different wells (W1 to W12) each month. The numbers in the table show variations in TDS concentration across different months, ranging between 1970 and 5440 ppm across different wells [15].

The variations can be attributed to slight increases in ion concentration and human activities such as agricultural drainage, sewage, and industrial wastewater. Limestone dissolution also increases salinity, classifying well water as moderately saline. Our study's results align with those of Gleib and Ali (2023) on wells in Qalat al-Sukar in Al-Diwaniyah province, where TDS values ranged between 1568 and 7404 ppm.

The letters attached to the monthly averages indicate statistically significant differences between some months in TDS levels. Identical letters mean no statistically significant differences between the months, while different letters indicate statistically significant differences at a significance level of P≤0.05.

Table 5. Monthly and site-specific variations in TDS (mg/L) in groundwater during the study period

Well	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Well Averages
W4	2480	2420	2400	2410	2620	2800	2522 B
W5	3490	2450	2450	2450	2710	3320	2812 B
W6	2820	2750	2750	2600	3050	2850	2803 B
Monthly Averages	3144a	2994a	2804a	2780A	2880a	3125a	

Salinity

Table 6 shows the monthly and site-specific variations in salinity levels in groundwater during the study period, measured in milligrams per liter (mg/L). The values ranged from 0.1 to 0.22 mg/L during the study months and different well sites. The letters attached to the monthly averages indicate statistically significant differences between some months in salinity levels, with identical letters indicating no statistically significant differences and different letters indicating significant differences at $P \leq 0.05$.

Table 6. Monthly and site-specific variations in salinity (mg/L) in groundwater during the study period

Well	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Well Averages
W4	0.13	0.11	0.13	0.13	0.15	0.14	0.132 B
W5	0.16	0.13	0.13	0.13	0.13	0.15	0.138 B
W6	0.15	0.14	0.15	0.14	0.14	0.14	0.143 B
Monthly Averages	0.152a	0.144a	0.145a	0.144a	0.145a	0.139a	

pH

The pH of water systems is a good indicator of water quality and pollution levels. Table 7 shows the monthly and site-specific variations in pH levels in groundwater during the study period. The table shows variations in pH levels between different wells and months, with the highest pH value of 9.5 recorded in September 2023 in well 1 and the lowest value of 6.5 in well 12 during the same month.

The monthly averages indicate slight changes in pH levels during the study period, ranging between 7.5 and 8, indicating a slight alkalinity within the range of acceptable values for aquatic life (6.5–8.5). Our current study results differ slightly from those of Ghaeeb, which ranged from 7.49 to 7.83, but align with the study by Kamel and Al-Shwani on wells in Kirkuk city, where pH values ranged from 6.96 to 7.63. Additionally, which recorded values between 7.713 and 8.223 [16].

The letters attached to the monthly averages indicate no statistically significant differences between the months in pH levels at $P \leq 0.05$.

Table 7. Monthly and site-specific variations in pH in groundwater during the study period

Well	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Well Averages
W4	8.4	7.81	7.53	7.29	7.94	6.93	7.650 A
W5	8	7.37	7.56	6.84	8	7.88	7.608 A
W6	7.9	7.7	7.54	7.83	7.97	8.28	7.870 A
Monthly Averages	7.892a	7.554a	7.523a	7.508a	7.855a	7.819a	

Total Alkalinity

Table 8 shows the monthly and site-specific variations in total alkalinity levels in groundwater during the study period. The table indicates variations in total alkalinity levels between different wells and months, with significant differences between wells and months.

The values of total alkalinity ranged between 40 and 200 mg/L, reflecting changes in groundwater composition and sources. Most of the carbonates and bicarbonate ions in groundwater are derived from carbon dioxide in the soil [17]. This can be linked to the high rate of organic matter degradation by bacteria and the increase in carbon dioxide (CO_2), leading to the formation of bicarbonat.

The results which ranged from 60 mg/L to 35 mg/L . The letters attached to the monthly averages indicate statistically significant differences between some months in total alkalinity levels at $P \leq 0.05$.

Table 8. Monthly and site-specific variations in total alkalinity (mg/L) in groundwater during the study period

Well	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Well Averages
W4	120	60	70	60	60	60	71.7 D
W5	140	40	60	60	60	80	73.3 D
W6	80	60	60	80	60	100	73.3 D
Monthly Averages	119.2a	70.8c	65.0d	72.5c	51.7e	81.7b	

Chemical Content of Oxygen

Table 9 shows the monthly and site-specific variations in the chemical content of oxygen in groundwater during the study period. The table indicates significant variations in oxygen content between different wells and months, reflecting changes in groundwater composition and quality.

Oxygen content values ranged between 0 and 156 mg/L, showing significant variations in water quality. Studies on groundwater typically indicate that oxygen levels can vary significantly based on factors such as geographic location, depth, temperature, and geochemical reactions. Comparing with similar studies, the variations observed in your study align with results from other areas or show specific differences that may be due to local environmental conditions.

The letters attached to the monthly averages indicate statistically significant differences between some months in oxygen content levels at $P \leq 0.05$.

Table 9. Monthly and site-specific variations in the chemical content of oxygen (mg/L) in groundwater during the study period

Well	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Well Averages
W4	22	0	0	0	0	156	29.67 A
W5	10	0	82	0	1	0	15.50 E
W6	8	11	18	0	0	5	7.00 GH
Monthly Averages	23.25b	4.42d	25.42a	4.00d	8.50c	26.67a	

Biological Oxygen Demand (BOD5)

BOD5 is described as the amount of oxygen required to aerobically decompose organic matter. As the organic matter in water increases, BOD5 also increases. It is an experimental test to estimate the relative oxygen demand in wastewater, sewage, flowing water, and polluted water.

Table 10 shows the monthly and site-specific variations in BOD5 in groundwater during the study period, with significant variations between different wells and months. In some wells, no BOD5 values were found during certain months, indicating minimal microbial activity affecting those wells during that period [18].

The average BOD5 values ranged from 2.3d to 0.93 mg/L, indicating significant variations in biological activity in groundwater. These values are higher than those found in Fahd's study on the concentration of heavy elements in surface and groundwater in southern Iraq, where BOD5 ranged from 0.11 to 0.22 mg/L. These results indicate that the water is relatively clean and suitable for human consumption.

The wide range in BOD5 values indicates significant differences in biological activity between wells and months. These differences may reflect the effects of various factors such as soil type, surrounding ecosystem, and different human activities affecting groundwater pollution. The absence of BOD5 values in some wells and months may indicate relatively clean water during those periods, meaning there was no significant load of degradable organic matter by microorganisms. This could be due to the lack of surface runoff of pollutants or improvements in pollution source management [19].

The letters attached to the monthly averages indicate statistically significant differences between some months in BOD5 levels at $P \leq 0.05$.

Table 10. Monthly and site-specific variations in BOD5 (mg/L) in groundwater during the study period

Well	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Well Averages
W4	0	0	0	0	0	0	0.00 F
W5	5	0	0	0	0	0	0.833 E
W6	0	6	3	0	0	0	1.500 D
Monthly Averages	2.333a	1.583b	2.833a	0.00d	0.917c	0.917c	

4. Conclusion

The pH of the water within the natural range (6.5 to 8.5) is considered acceptable for drinking water. The values mentioned in the study fall within this range, indicating that the water quality in this aspect meets health standards. The values indicate a variation in alkalinity but remain within a range often considered acceptable for drinking water, considering other parameters such as TDS and EC. Salinity was very low (0.1 to 0.22 mg/L), which is very favorable as low salinity typically indicates the absence of significant salt accumulation, making the water suitable for drinking. The variation in Total Alkalinity from 40 to 200 mg/L reflects natural interactions in groundwater and does not indicate harmful levels of alkalinity.

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