Study of Some Physical and Chemical Properties of Saline Water from Several Wells in the Naameh Area

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Twelve wells distributed within the studied areas were selected, and various physical and chemical properties, including heavy elements and their effects, were examined. Microbiological factors and monthly and locational variations were also studied during the research period from September 2023 to February 2024. The depths of the wells ranged from 80 meters, considered shallow wells, to 110 meters, considered deep wells, and were drilled using modern mechanical methods.
The sample collection process began in the morning, starting with wells 1, 2, and 3, at a frequency of once per month from September 2023 to February 2024. One sample per month was collected after pumping the well water for ten minutes to remove contaminated and stagnant water. The samples were then collected directly from the wells into polyethylene bottles with a capacity of 2.25 liters for laboratory physical tests, ensuring bottles were rinsed with sample water three times before collection. A 250 ml opaque Winkler bottle was used for each well. Samples were transported in a refrigerated styrofoam container at 4-6°C. All glassware used in the analyses was initially washed with distilled water and dried using an electric oven. The analyses were conducted in the graduate studies laboratory of the Life Sciences Department at the College of Education for Women, Tikrit University, and the Central Laboratory of the Water Directorate in Salah al-Din, as well as the Environmental Engineering Department at Tikrit University. Physical tests included measuring air and water temperatures, electrical conductivity, and turbidity.
The results showed that the recorded temperatures during the study fall within a range that does not significantly negatively affect water quality for drinking purposes. However, extreme temperatures can affect the chemical and biological properties of the water. According to global standards such as the World Health Organization (WHO), turbidity should not exceed 5 NTU for drinking water. Some values recorded in the study exceed this limit. The study indicates significant variations in electrical conductivity (EC) values from month to month and between different wells.

Keywords: Groundwater quality, Heavy elements, Electrical conductivity (EC), Temperature variations, Turbidity

1. Introduction

Groundwater is crucial for the economy, irrigation, industry, and environmental conservation. It maintains river, lake, and wetland levels, especially during dry seasons when there is less rainfall (Yuzbuki & Suleiman, 2020). The quality of groundwater depends on the type of rocks it passes through (Hasan & Sabri, 2000). Its chemical properties are influenced by the environment it traverses and are subject to natural and human factors such as floods and saline pollution. Groundwater quality is a measure of its suitability for use by humans, animals, and plants and is affected by its movement. Slow movement and prolonged contact with rocks increase the concentration of dissolved substances. The global issue with groundwater policy is the increased use and random drilling of wells, causing significant losses to farmers worldwide (Tang et al., 2012).

Physical Characteristics of Water:

1. Temperature: The metabolic processes of all living organisms, such as respiration and enzyme reactions, are greatly affected by temperature. Lower temperatures increase the solubility of O2 in water, decreasing O2 levels due to increased metabolic activity (Al-Saadi, 2002). The depth of the aquifer significantly affects water temperature, dividing it into warm and cold water. Increased sodium chloride and sodium carbonate content also raises water temperature (Dardakeh, 2006).

2. Turbidity: Turbidity is the presence of suspended particles in water, including organic and inorganic materials like clay, silt, and microorganisms, which reduce light penetration and alter physical and chemical properties (APHA, 2017). It is defined as the optical property of water resulting from light scattering and absorption by suspended materials instead of traveling in a straight line through the water sample (Hamilton et al., 2019).

3. Electrical Conductivity (EC): EC is the numerical value indicating water's ability to conduct electric current, influenced by the concentration of dissolved ions (Safawi et al., 2018).

4. Salinity: Water salinity is due to the presence of various ions like carbonates, sulfates, chlorides, sodium, magnesium, calcium, and potassium. It directly affects the osmoregulation of living cells, varying for different organisms (Al-Saadi, 2002).

Chemical Properties of Water

1. Hydrogen Potential (pH)

pH is defined as the negative logarithm of the hydrogen ion concentration and is a measure of the acid-base balance. It is one of the main variables that affect water quality assessment (Al-Zuhairi and Al-Ashqi, 2020). The pH value reflects many chemical and biological processes and indicates the balance of carbonates, bicarbonates, and carbon dioxide, influencing the distribution of living organisms (Alibi et al., 2020). The pH level affects the availability of nutrients, which in turn influences biodiversity and various chemical and physical factors (Al-Azzawi, 2019). pH is a crucial variable for assessing water quality (Al-Zuhairi and Al-Ashqi, 2020) and is also important due to its close association with the biological productivity of aquatic ecosystems. It can be considered an indicator of carbon dioxide content in water, which decreases during photosynthesis and increases during respiration (Wetzel and Likens, 2021).

pH has an impact on the health and productivity of animals. When it is below 5.5, it can cause acidity-related issues, affecting milk production. Conversely, a pH above 8.5 can lead to problems related to high alkalinity, digestive issues, reduced water and food intake, vitamin B deficiency, and decreased productivity (Al-Saffawi et al., 2020).

2. Total Hardness and Calcium and Magnesium Hardness

Total hardness of groundwater is primarily determined by the presence of divalent ions, particularly calcium and magnesium, as stated by Al-Azzawi and Al-Azzara (2012). Carbonate rocks such as limestone (dolomite) and sulfates like gypsum are the main sources of calcium ions. The positively charged ions in groundwater alter its taste, increase hardness, and reduce soap solubility (Warrence et al., 2003).

Hussain and Fakhri (2015) noted that when magnesium ion concentration exceeds 125 mg/L, it can harm human health, especially the digestive system and intestines. High magnesium ion concentrations negatively affect the water's usability. Magnesium ion concentration is always lower than calcium ion concentration, as magnesium tends to precipitate more, remaining in dissolved form (Allen et al., 2000). Hardness refers to the condition of water with high salt content, typically caused by calcium (Ca^{2+}) and magnesium (Mg^{2+}) salts, along with dissolved salts like sulfates and bicarbonates. Calcium in hard water is present as calcium sulfate ($CaSO_4$) or calcium carbonate ($CaCO_3$) (Etiaia et al., 2020).

3. Total Alkalinity (TA)

Total alkalinity is defined as the amount of dissolved negative ions in water that resist hydrogen ions. It is a measure of the water's capacity to neutralize acidity (Moses and Ishaku, 2020). High alkalinity values in water result from wastewater discharged from sources or homes and their pollutants (Al-Tamimi, 2006). Alkalinity in water is attributed to the presence of salts with strong and weak bases, such as carbonate salts from the aquatic environment (Hamed, 2021). Excessive alkalinity gives water an unpleasant taste and can harm public health, soil, and agricultural production when used (Ndukwe, 2019).

Materials and Methods: 3-1 Study Area Description: The study area is located within the boundaries of Salah al-Din Governorate, between longitudes 35°29'25" and 34°24'25" and latitudes 46°33'43" and 34°43'46". It is bordered by the Hamrin Mountains to the east and the Tigris River to the west. Some physical, chemical, and microbiological properties of well water were studied in various locations in Al-Dur district. The wells' 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 15 years, with diverse uses.

Key Wells Selected for the Study:

- Well 1: Located in Al-Dhagh area, with flat agricultural land near Naameh. It is a closed well, mechanically drilled to a depth of 100 meters, irrigating 45 donums planted with wheat, barley, and corn. The well is one year old, located 12,245 meters from the Tigris River, mainly used for irrigation, livestock watering, and domestic use when needed.

Figure 1: Well No. 1, Al-Dhagh, Naameh

Well 2: Located in Al-Dhagh area near Naameh, it is a closed well mechanically drilled to a depth of 80 meters. It irrigates 50 donums planted with wheat and alfalfa. The

well is 15 years old and is 13,072 meters from the Tigris River. Its main uses include irrigation, livestock watering, and domestic use. It is approximately 827 meters away from Well 1.

Figure 2: Well No. 2, Al-Dhagh, Naameh

Well 3: Located in Al-Dhagh area near Naameh, it is a closed well mechanically drilled to a depth of 80 meters. It irrigates 55 donums planted with wheat. The well is 12 years old and is 13,544 meters from the Tigris River. Its main uses currently include agriculture and livestock watering. It is approximately 472 meters away from Well 2.

Figure 3: Well No. 3, Al-Dhagh, Naameh

Sample Collection: The sample collection process began in the morning, starting with wells 4 through 6, at a frequency of once per month from September 2023 to February 2024. One sample per month was collected after pumping the well water for ten minutes to remove contaminated and stagnant water. The samples were then collected directly from the wells into polyethylene bottles with a capacity of 2.25 liters for laboratory chemical tests, ensuring bottles were rinsed with sample water three times before collection. A 250 ml opaque Winkler bottle was used for each well to measure biological oxygen demand and dissolved oxygen.

Statistical Analysis: Statistical analysis was performed using SPSS (version 23).

Results and Discussions:

Water Temperature: Temperature is one of the most important indicators of water quality as it affects various organic, inorganic, and chemical components of water, as well as its taste. It also influences geochemical and chemical reactions. Temperature affects water's ability to retain oxygen and the resistance of living organisms to some pollutants (WHO, 2006).

Table 1 shows the monthly and locational changes in water temperature for the studied wells over a specific period. The table indicates that water temperature changes over different months and varies between different wells and within each well over the studied period. The highest water temperature in the wells was recorded in September 2023 (26.9°C), while the lowest was recorded in February 2024 (20.9°C). Additionally, the table shows variations in water temperatures between different months, with values ranging between wells and within each well over the months. The water can be classified as warm water, which exceeds. The slight differences in groundwater temperature may be related to the distance from the surface as the weather changes.

The results were similar to those of Dalaas and Abduljabar (2018) in wells in Al-Alam district, Salah al-Din, showing a maximum value of 0.23°C in November and a minimum value of 19°C (Dalaas & Abduljabar, 2018). The letters attached to the monthly averages table indicate statistically significant differences between some months in water temperature. Identical letters indicate no statistically significant differences between months, while different letters show statistically significant differences between compared months at a significance level of $P \leq 0.05$.

Table 1: Monthly and locational changes in water temperature (°C) for the studied wells

Month	**Well**	**Sep 2023**	**Oct 2023**	**Nov 2023**	**Dec 2023**	**Jan 2024**	**Feb 2024**
W1	26.9	26.2	25.4	25.4	21.1	23.1	24.68 A
W2	25.7	26.0	26.0	25.2	25.5	24.0	25.40 A
W3	26.6	26.0	26.1	25.3	24.9	23.7	25.43 A
Month Averages	26.4a	26.06a	25.8ab	25.3ab	23.8bc	23.6c	

Water Turbidity: Turbidity expresses the light scattering and absorption characteristics of a water sample caused by the presence of clay, silt, suspended particles, colloids, and microorganisms (WHO, 1984). Water turbidity depends on the amount of suspended solids. It is a measure of water's light emission properties and is used to indicate the quality of waste discharge regarding colloidal matter. Natural water turbidity should be less than 5 NTU, making water with turbidity below this value usually acceptable to consumers.

Table 2 shows the monthly and locational changes in turbidity levels (NTU) in groundwater over the study period. The table indicates significant variations in groundwater turbidity levels over different months and between different wells. Some wells showed very high turbidity levels during certain months compared to their values in other months. For example, in well W9, the turbidity level was significantly high in December 2023, with a value of 14 NTU and an average of 5.12 NTU. The lowest value was 0.12 NTU. These values are due to colloids, silt, clay, humic substances, organic detritus, and various plants and animals in the water. The table also shows differences in turbidity levels between different months. For instance, January and February 2024 saw relatively high turbidity levels in most wells.

The letters attached to the monthly averages table indicate statistically significant differences between some months in turbidity levels. Identical letters show no statistically significant differences between months, while different letters indicate statistically significant differences between compared months at a significance level of $P \leq 0.05$. The results were similar to those of Dalaas and Abduljabar (2018), where the highest turbidity value was 3.95 NTU in October, and the lowest was 0.00 NTU in November (Dalaas & Abduljabar, 2018). The results obtained in this work were lower than those in Mahdi's study (2008), where turbidity values ranged from 1 to 70 NTU (Mahdi, 2008). This reduction is related to the relatively stagnant groundwater. The results were also lower than those in Jleib and Ali's study (2023), where values ranged from 2.18 to 101 NTU. These results indicate significant variations in groundwater quality during the study period and the impact of locational and temporal factors on turbidity levels.

Table 2: Monthly and locational changes in groundwater turbidity (NTU) during the study period

Month	**Well**	**Sep 2023**	**Oct 2023**	**Nov 2023**	**Dec 2023**	**Jan 2024**	**Feb 2024**
W1	0.5	0.857	0.721	8.37	2.39	0.55	2.231 D
W2	0.177	0.576	0.86	5.1	1.43	2.14	1.714 DE
W3	2.51	0.761	0.841	4.3	1.07	0.259	1.624 DE
Month Averages	1.062d	0.657b	0.807bc	5.923a	1.63B	0.983c	

Water Salinity: Table 3 shows the monthly and locational changes in groundwater salinity (measured in mg/L) during the study period. The values ranged from 0.1 to 0.22 mg/L during the study months and across the well locations. The letters attached to the monthly averages indicate statistically significant differences between some months in salinity levels. Identical letters mean no statistically significant differences between months, while different letters indicate statistically significant differences between compared months at a significance level of $P \leq 0.05$.

Table 3: Monthly and locational changes in groundwater salinity during the study period (mg/L)

Month	**Well**	**Sep 2023**	**Oct 2023**	**Nov 2023**	**Dec 2023**	**Jan 2024**	**Feb 2024**
W1	0.2	0.2	0.2	0.19	0.19	0.17	0.192 A
W2	0.21	0.22	0.22	0.21	0.22	0.21	0.215 A
W3	0.21	0.19	0.2	0.22	0.18	0.16	0.193 A
Month Averages	0.206a	0.203a	0.206a	0.206a	0.206a	0.18a	

Electrical Conductivity

Electrical conductivity (EC) is defined as the ability of a 1 cm³ volume of water to conduct electric current at 25°C. Conductivity depends on the concentration of dissolved salts and the temperature of the water (Hem, 1985).

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

The table also shows that some wells exhibit high levels of electrical conductivity in some months while showing lower levels in others. The highest value of electrical conductivity was 5230 µS/cm in January 2024, while 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 (SDWF, 2008).

The results of this study are consistent with those of Dalaas and Abduljabar (2018), where conductivity values ranged from 2210 µS/cm in October to 6350 µS/cm in December (Dalaas & Abduljabar, 2018). Additionally, our current results align with those of Al-Obaedy, which ranged from 1920 to 7675 µS/cm in northern Salahuddin province (Al-Obaedy, 2010). Our results also align with the studies by Al-Jabrili (2006) and Al-Safawi (2008), but are higher than those found in the study by Kamel and Al-Shwani (2014).

The letters attached to the monthly averages table indicate statistically significant differences between some months in the level of electrical conductivity. 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 $P \leq 0.05$.

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
W1	4910	4830	4920	4600	4520	4160	4657 A
W2	5000	5210	5180	5210	5230	4960	5132 A
W3	5120	4600	4800	5200	4410	3970	4683 A
Monthly Averages	3657a	3486bc	3540ab	3510ab	3531ab	3381c	

Total Dissolved Solids

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.

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.

The variations can be attributed to slight increases in ion concentration and human activities such as agricultural drainage, sewage, and industrial wastewater (WSC, 2008). Limestone dissolution also increases salinity (Al-Lami et al., 2002; Saadi et al., 2000), classifying well water as moderately saline according to Brouwer (1978). 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 $P \leq 0.05$.

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**
W1	5200	4550	3990	4220	4120	4500	4430 A
W2	5440	5340	4580	4680	4100	5190	4888 A
W3	5090	4660	4250	4400	4550	4750	4617 A
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 Av
W1	0.2	0.2	0.2	0.19	0.19	0.17	0.192 A
W2	0.21	0.22	0.22	0.21	0.22	0.21	0.215 A
W3	0.21	0.19	0.2	0.22	0.18	0.16	0.193 A
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) (Crawford, 1985). Our current study results differ slightly from those of Ghaeeb (2010), which ranged from 7.49 to 7.83 (Ghaeeb, 2010), but align with the study by Kamel and Al-Shwani (2014) on wells in Kirkuk city, where pH values ranged from 6.96 to 7.63. Additionally, our study aligns with the results of Gleib and Ali (2023) on wells in Qalat al-Sukar in Al-Diwaniyah province, which recorded values between 7.713 and 8.223.

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
W1	9.5	7.74	7.43	7.26	7.29	7.44	7.777 A
W2	8.2	7.52	7.4	7.43	8.08	6.54	7.528 A
W3	8.7	7.66	7.46	6.64	7.76	7.81	7.672 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 (Al-Amar, 2015). This can be linked to the high rate of organic matter degradation by bacteria and the increase in carbon dioxide (CO2), leading to the formation of bicarbonates (Ghaeeb, 2010).

The results differ from those of Dalaas and Abduljabar (2018), which ranged from 60 mg/L to 35 mg/L (Dalaas & Abduljabar, 2018). 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
W1	100	100	60	80	60	100	83.3 BC
W2	80	80	70	100	40	60	71.7 D
W3	120	60	60	80	50	40	68.3 E
Monthly Averages	119.2a	70.8c	65.0d	72.5c	51.7e	81.7b	

Conclusions:

1. The recorded temperatures fall within a range that does not significantly negatively affect water quality for drinking. However, extreme temperatures can affect the chemical and biological properties of the water.

2. According to global standards such as WHO, turbidity should not exceed 5 NTU for drinking water. Some recorded values exceed this limit, indicating that water may need treatment before use as drinking water.

3. The study indicates significant variations in EC values from month to month and between different wells. High EC values suggest high salinity content, potentially making the water unpalatable or even unsuitable for human consumption if it exceeds certain limits.

Recommendations: Based on the results and analyses presented in the study, several recommendations can be made to improve water quality and ensure its safety for human consumption and other uses:

1. Regular Monitoring: Periodic monitoring of temperature and turbidity in different wells is essential to track seasonal changes and the impact of human activities. Monitoring should be expanded to include other pollutants such as heavy metals, nitrates, bacteria, and organic materials.

2. Establish and Expand Monitoring Networks: Creating and expanding monitoring networks to continuously assess water quality is crucial. Focus on indicators such as salinity, pH, total dissolved solids, and biological oxygen demand. This will help in the early detection of any changes or pollution.

3. Utilize Advanced Treatment Technologies: Using technologies like reverse osmosis, advanced filtration, and disinfection systems can significantly improve water quality before distribution, especially if the water is intended for drinking purposes.

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