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Estimation of the Physical and Chemical Characteristics of the Water from Some Wells in Al-Budair District, Al-Diwaniyah

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ABSTRACT:

The current study was conducted to assess the seasonal variations of chemical and physical properties of groundwater in Al-Budair district of Al-Diwaniyah governorate. A field survey of the study area was conducted, where water samples were collected from selected wells seasonally from six different locations for a full year, starting from January 2022 until October 2022.The study's results were as follows: water temperatures ranged (16-28) °C respectively, Turbidity levels ranged (0.12 -83.1) NTU, Electrical conductivity ranged (488-29310) µS/cm, The pH values (6.88 to 8.1), Dissolved oxygen and the biochemical oxygen demand were recorded as(0-2.4) mg/L and (0-2.1) mg/L respectively, The total hardness of well water ranged (560- 4960) mg/L, Calcium ions ranged (160-1600) mg/L, and magnesium ions ranged (35.84-3400) mg/L, , chloride ion concentrations varied from (94.7-12435) mg/L, and sulfate ions ranged (213.95-4639.24) mg/L, Sodium and potassium ions had values ranging (103.98-1449.87) mg/L and (4.3-33) mg/L respectively, Nitrite and nitrate ions were recorded at (0.007-2.271) micrograms/L and (0.986-27.589) micrograms/L respectively, Phosphate ions ranged (0.014-1.193) micrograms/L.

Introduction

Groundwater constitutes a significant part of water resources, representing approximately 71.7% of the world's freshwater resources. It includes water from wells and springs, primarily originating from rainfall and irrigation water that infiltrates the ground, storing beneath the earth's surface in impermeable layers, forming groundwater reservoirs (Doglioni et al.,2013). The scarcity of water resources and water quality issues in Iraq and the Arab world, in general, along with increasing population growth rates, resource expansion, and the development of agricultural and industrial sectors, have made the use of groundwater one of the primary solutions to address water scarcity (Rashid et al.,2013) Estimates indicate that 80% of water usage in the Middle East is for irrigation purposes (Diwan et al.,2018). Groundwater is at risk of contamination due to prolonged periods of drought and various human activities, especially in arid, semi-arid, and arid regions (AL-Assaf et al.,2020). One of the biggest challenges facing developing countries is groundwater pollution from various sources. Pollution results in an increase in the concentrations of major positive and negative ions in most water sources and originates from various sources such as atmospheric processes, mineral sediment dissolution, volcanic activities, coal combustion, mining activities, pesticide and fertilizer usage, and liquid wastewater (Abdur et al.,2018). Additionally, improper solid waste disposal and inadequate filtering of waste in sanitary landfills and sewage wastewater contribute to the issue (Ethaib ,2019).

The aim of this research is to assess the chemical and physical characteristics of well water in the southeast region of Al-Diwaniyah Governorate. This is done to determine the suitability of this water for various uses, as the population in this area relies on this water source to meet their water needs. Additionally, some of them live on agricultural lands they own. Due to the fact that most of the agricultural lands in this region lack surface water sources due to drought and the limited water allocation from the Euphrates River, which supplies those lands, farmers have been compelled to depend on groundwater as the primary source to meet their diverse water needs.

Materials and Methods

Six wells from different locations were selected, as shown in Fig. (1) These wells were all dug by local farmers to be used as a source of water for domestic purposes. Water from these wells is extracted using electric or diesel-powered pumps. All of the wells were shallow wells, as the alluvial plain region is characterized by a high groundwater table near the surface (Al-Zubedi,2022), Water samples were collected by running the pumps on the wells for a period of 5 to 10 minutes. Subsequently, the samples were taken and stored in glass containers in accordance with the sample requirements.

Water temperature, pH, and electrical conductivity were measured on-site using a mercury-in-glass thermometer ranging from (0-200) °Celsius, a Lovibond pH meter (model: pH 200), and a HANNA H19032 conductivity meter. Turbidity was directly measured upon arrival at the laboratory using a Turbidity meter (model: LaMotte 20220). Dissolved oxygen was measured using the Azide modification method after in-field stabilization, and the biochemical oxygen demand for oxygen was determined according to the method specified in (APHA, 2017), Total hardness, calcium ion, and chloride ion were measured according to the methods specified in (APHA, 2017). Magnesium ion was measured following the procedures outlined by Abawi and Hassan (1990). Sulfate, phosphate, and nitrite ions were quantified using a UV-VIS Spectrophotometer. Nitrate ions were converted to nitrite ions using a cadmium column reduction method, following the procedure outlined in (Parsons et al., 1984). Sodium and potassium ions were measured using a Flame Photometer.

The SAS Statistical Analysis Systems (2018) software was used to analyze the data to study the impact of various factors on the measured characteristics based on a Completely Randomized Design (CRD). Significant differences between the means were compared using the Least Significant Difference (LSD) test.

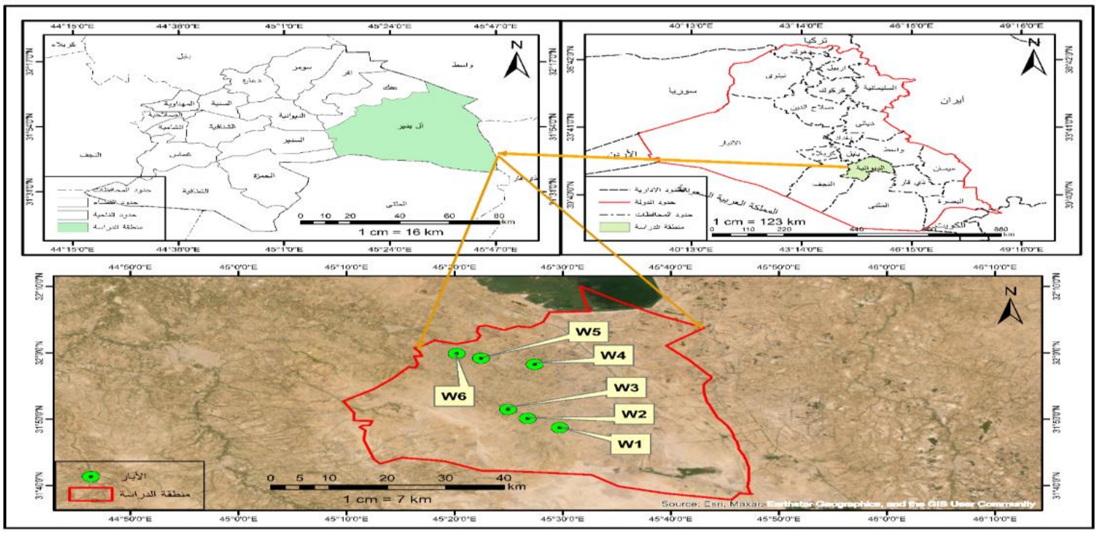

Fig. (1) location map of the study wells

Results and Discussion

1: Temperature

The results obtained from field measurements showed that the lowest average water temperature was recorded in well 1 during both the winter and summer seasons, and in well 5 during the summer season, with averages of 16°C. On the other hand, the highest average temperatures were observed in wells 4 and 6 during the autumn season, with respective values of 24°C and 28°C, as illustrated in Table 1, A significant

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difference in water temperature was not observed among the sites, which may be attributed to their proximity within the same geographic region. Additionally, groundwater is known for its relatively stable temperature, with minimal variations within a narrow range (Round, 1975). Furthermore, it was noted that the majority of the groundwater samples fell within the category of warm waters, exceeding 18°C (Al- Khashab, 1978).

The results of the statistical analysis confirmed the presence of significant spatial differences ($p \leq 0.05$) between wells 4 and 6, with values of 5.87 and 5.27, respectively. In contrast, no significant spatial differences were observed among wells 1, 2, 3, and 5. Moreover, significant temporal differences were found during the summer and autumn seasons, with values of 4.95 and 5.33, respectively, while no significant temporal differences were identified during the winter and spring seasons.

Table (1) Water temperature (°C) for wells throughout the seasons

Temp. of water(C°) / **Well NO.**	**Winter**	**Spring**	**Summer**	**Autumn**	**LSD**
1	16	20	16	20	4.05NS
2	18	20	19	18	3.07NS
3	20	21	18	20	3.16NS
4	20	20	21	28	* 5.78
5	19	20	16	20	4.16NS
6	18	21	20	24	* 5.27
LSD	4.11NS	3.07NS	* 4.95	* 5.33	---
) *P≤0.05.(					

2: Electrical Conductivity

The study results presented in Table 2 revealed that electrical conductivity in the examined wells recorded its highest values in well 1 (29310, 27580, 13940) micro-Siemens per centimeter (µS/cm) during the summer, autumn, and winter seasons, respectively. Additionally, the second well exhibited the highest value (11490 µS/cm) during the summer. In contrast, the lowest value was observed in well 6 (488 µS/cm) during the autumn season.

The elevation in electrical conductivity values in most areas can be attributed to the increased concentration of total dissolved salts in the water, resulting from the interaction of water with the soil. This interaction leads to the enhanced dissolution of salts and minerals present in the geological formations in those regions (Al-Taie, 2004).

It was observed that the highest electrical conductivity values were consistently found at the first site throughout most of the study seasons. This is attributed to the flow path of water in the subsurface layers of the earth in the southern part of the study area (Al Zubaidi, 2022). In this region, salts are leached with water from the higher adjacent lands, and the longer the groundwater flow path, the greater the salt dissolution processes, leading to an increase in electrical conductivity. Furthermore, various factors, including interactions between water and rocks, evaporative effects, and human activities in the area containing these wells, contribute to fluctuations in electrical conductivity values. Variations in electrical conductivity values between sites can be attributed to geological differences among the areas, as well as the proximity and distance of the water sources. These findings align with the research by Rizouqi.(2023)

The variation in electrical conductivity values can result from several factors, including geochemical processes like ion exchange and interactions between water and rocks. Additionally, dispersion and evaporation can increase the concentration of total dissolved salts, thereby increasing electrical conductivity. Human activities in the area can also

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have an impact by raising the concentration of total dissolved salts and, in turn, electrical conductivity (Salman & Elnazer, 2015).

The statistical analysis results confirmed the presence of significant temporal and spatial differences at a significant level for all the wells and across all study seasons. The temporal differences ranged from winter to autumn, with values of (302.76, 269.02, 296.74, 219.54), and the spatial differences were noted in the order of (355.91, 297.37, 257.71, 197.26, 237.61, 281.09) for the various locations.

Table (2) Electrical Conductivity of Wells Throughout the Seasons

E.C. µS/cm	**Winter**	**Spring**	**Summer**	**Autumn**	
Well NO.					**LSD**
1	13940	8620	29310	27580	* 355.91
2	4780	6730	11490	8280	* 297.37
3	2286	2482	5660	3010	* 257.71
4	2009	2439	2713	2032	* 197.26
5	1780	2657	5000	2800	* 237.61
6	7850	6520	6780	488	* 281.09
LSD	* 302.76	* 269.02	* 296.74	* 219.54	---
) *P≤0.05.(					

3: Turbidity

The results of the current study in Table 3 show that turbidity values recorded their lowest rates for wells 2, 3, and 5 during the spring season, at 0.12, 0.13, and 1.33 Nephelometric Turbidity Units (NTU), respectively. Conversely, the highest values were observed in well 6 during the winter season, at 83.1 NTU, and in well 1, at 73.4 NTU. This variation can be attributed to rainfall during these two seasons, which leads to the erosion of rocks, the washout of fine sediments, and plant residues, resulting in increased levels of organic and clay materials. Additionally, the geological nature of the study area being within an alluvial plain, the presence of agricultural activities, and the existence of microorganisms contribute to this phenomenon (Syam& Geetha,2016).

The decrease in turbidity at some sites may be attributed to the inherent stability of groundwater. Groundwater is generally known for its high clarity and low turbidity due to the natural filtration it undergoes as it passes through soil layers. This filtration process removes many suspended materials, and groundwater is characterized by its tranquility and slow movement (Al-Obaidi, 2016). The results of the statistical analysis confirmed the presence of significant temporal differences ($p \leq 0.05$) for all the wells across all seasons (winter, spring, summer, and autumn), with values of 15.74, 14.09, 9.22, and 10.69, respectively. Additionally, significant spatial differences were observed among wells 1, 2, 4, and 6, with values of 13.68, 7.44, 8.03, and 12.72, respectively. However, no significant spatial differences were found between wells 3 and 5.

Table (3) Turbidity of Wells Throughout the Seasons

Turb. NTU	**Winter**	**Spring**	**Summer**	**Autumn**	
Well NO.					**LSD**
1	.879	73.4	31.0	22.0	* 13.68
2	1.74	0.13	9.3	11.5	* 7.44

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3	5.31	0.12	3.31	3.67	5.28NS
4	4.11	22.9	7.32	5.75	* 8.03
5	5.30	1.33	5.30	2.78	4.98NS
6	83.1	7.38	4.31	52.0	* 12.72
LSD	* 15.74	* 14.09	* 9.22	* 10.69	---
) *P≤0.05.(					

4: Ph

The results in Table 4 indicate that the highest values of pH were recorded in wells 5 and 6, with averages of 8.1 and 8.04, respectively, during the autumn season. On the other hand, well 3 exhibited a slightly alkaline pH value of 6.88 during the summer season. The results suggest that the groundwater in the study area tends to be alkaline or slightly alkaline. This could be attributed to the lack of direct exposure to weather-related changes, which prevents the dissolution of carbon dioxide in the water (Talee and Al-Barhawi, 2000). Additionally, the water contains calcium and magnesium ions, which represent non-neutral salts. The water is also influenced by the region's climate, which is semi-arid, leading to the deposition of carbonates and bicarbonates from the water (Abdullah and Majid, 2015).

The statistical analysis results, using variance analysis, confirmed the presence of significant spatial differences at a significance level of ($p \leq 0.05$) for wells 2, 3, 5, and 6, with values of 0.706, 0.844, 0.701, and 0.719, respectively. However, no significant temporal differences were found across the study seasons. Additionally, there were no significant spatial differences in wells 1 and 4.

Table (4) pH Levels of Wells Throughout the Seasons

Ph / **Well NO.**	**Winter**	**Spring**	**Summer**	**Autumn**	**LSD**
1	7.44	7.08	7.25	7.57	0.661NS
2	7.52	7.10	7.02	7.84	* 0.706
3	7.53	7.06	6.88	7.91	* 0.844
4	7.61	7.26	7.45	7.85	0.676NS
5	7.53	7.29	7.32	8.1	* 0.701
6	7.56	7.27	7.33	8.04	* 0.719
LSD	0.562NS	0.458NS	0.503NS	0.620NS	---
) *P≤0.05.(					

5- Dissolved Oxygen (DO)

The results, as shown in Table 5, reveal that the lowest dissolved oxygen concentration was recorded in well 1 during the summer season, with a value of 0, while the highest values were observed in wells 4 and 2 during the spring season, at 2.4 and 2.3 milligrams per liter (mg/L), respectively.

The study results demonstrate a noticeable decrease in dissolved oxygen levels in most of the wells. This decline can be attributed to the characteristics of the wells themselves. When the wells are closed, there is limited water flow from these wells into the external environment. This restricted flow reduces the interaction of well water with the external surroundings, resulting in reduced oxygen exchange between the water and the air. Additionally, the elevated water temperature, categorized as warm water, decreases the solubility of oxygen in the water. Famiglietti (2014) also pointed out that groundwater typically exhibits low concentrations of dissolved oxygen, and in some cases, it can be entirely absent. This is because the process of organic matter decomposition during the groundwater cycle leads to a decrease in dissolved oxygen levels. The variations in dissolved oxygen values may be attributed to factors such as well depth and proximity to the Earth's surface, as well as local weather conditions like temperature and rainfall. For example, higher

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temperatures increase the activity of microorganisms, leading to increased oxygen consumption and organic The results of the statistical analysis, using the analysis of variance, indicate significant spatial differences in all well locations (p≤0.05). These differences are observed in all locations except for the first well, which did not show significant spatial matter decomposition in water (Alexander et al., 2019).

variations. Furthermore, significant temporal differences were found for the spring and autumn seasons, with values of 0.877 and 0.709, respectively, while no significant temporal differences were observed for the winter and summer seasons.

Table (5) Dissolved Oxygen of Wells Throughout the Seasons

DO)mg/L(	**Winter**	**Spring**	**Summer**	**Autumn**	
Well NO.					**LSD**
1	0.1	0.1	0	0.2	0.20NS
2	0.4	2.3	0.1	1.3	* 0.881
3	0.4	2.2	0.2	1.2	* 0.877
4	0.3	2.4	0.4	2.1	* 0.902
5	0.1	2.1	0.1	1.1	* 0.856
6	0.1	2.2	0.1	1.2	* 0.821
LSD	0.406NS	* 0.877	0.420NS	* 0.709	---
) *P≤0.05.(					

6: The Biochemical Oxygen Demand (BOD)

The results recorded in Table (6) showed that the concentration of the biochemical oxygen demand (BOD) had its lowest values in Wells 1 during the spring and summer seasons, with a rate of (0) milligrams per liter (mg/L), as well as in Wells 2, 5, and 6 during the winter season, also with a rate of (0) mg/L. However, Wells 2 and 6 recorded the highest rates during the spring season with values of (1.8 and 2.1 mg/L) respectively. The reason for this decrease is attributed to the filtration processes that occur within the rock layers and the distance of the wells from sewage sources. These processes contribute to preventing groundwater pollution by microorganisms and algae, which consume significant amounts of oxygen. Consequently, wells that are distant from sewage sources and undergo effective filtration processes are usually less polluted and have lower values of biochemical oxygen demand. This finding is in line with the conclusions of (Al-Faragi, 2022) in their study.

The statistical analysis results confirmed the presence of significant spatial differences at a probability level of (p ≤ 0.05) for all well sites, starting from Site 2 (0.899, 0.902, 0.873, 0.822, 0.849), except for Well 1, which did not record significant differences. Moreover, significant temporal differences were found during the spring and autumn seasons, with values of (0.806, 0.788) respectively, while there were no significant temporal differences for the wells during the winter and summer seasons.

Table (6) Biochemical Oxygen Demand of Wells Throughout the Seasons.

BOD)mg/L(	**Winter**	**Spring**	**Summer**	**Autumn**	
Well NO.					**LSD**
1	0.7	0	0	0.1	0.702NS

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2	0	1.8	0.1	0.9	* 0.899
3	0.3	1.7	0.2	0.8	* 0.902
4	0.2	1.6	0.2	1.1	* 0.873
5	0	1.5	0.1	0.7	* 0.822
6	0	2.1	0.1	0.2	* 0.849
LSD	0.711NS	* 0.806	0.204NS	* 0.788	---
) *P≤0.05.(					

7:
Total hardness

The study results, as shown in Table 7, indicated that the first well exhibited consistently high levels of total hardness throughout the study period, with values of 4960 in winter, 4466 in summer, 4400 in autumn, and 4230 in spring, milligrams per liter (mg/L). Similarly, during spring, the second well had a total hardness value of 3531 mg/L. On the other hand, the fourth well recorded the lowest total hardness values, with 560 mg/L in summer and 680 mg/L in autumn. The variations in total hardness values in groundwater are attributed to the geological composition of the Earth and the components that dissolve in the water. As groundwater flows through rock layers and soil, it can interact with minerals and compounds present in these formations. These components may include calcium, magnesium, sulfates, chlorides, and others, which align with the findings of Rizouqi (2023). The variation in the concentration of total hardness in groundwater from one area to another can be attributed to several factors. These factors include the extraction and pumping of groundwater for domestic purposes, which can affect hardness concentrations. Additionally, the geological composition of the region can also influence total hardness concentrations. Some wells may contain deposits rich in limestone and calcium sulfate, which are considered significant sources of hardness.

Statistical analysis results confirmed the presence of significant spatial and temporal differences in all wells and across all seasons at a probability level of $p \leq 0.05$. Spatial differences were observed starting with the first well (187.52, 237.96, 179.36, 186.20, 207.74, 194.26). Temporal differences were, in turn, evident starting from the winter season (261.84, 208.51, 219.94, 202.57).

Table (7) Total hardness of Wells Throughout the Seasons

Total hardness)mg/L(/ Well NO.	**Winter**	**Spring**	**Summer**	**Autumn**	**LSD**
1	4960	4230	4466	4400	* 187.52
2	2240	3531	2560	2280	* 237.96
3	1440	1572	1720	1800	* 179.36
4	1240	1275	560	680	* 186.20
5	1280	1434	1160	960	* 207.74
6	2240	2330	1240	1040	* 194.26
LSD	* 261.84	* 208.51	* 219.94	* 202.57	---
) *P≤0.05.(					

8: Calcium and magnesium ions

The study results, as shown in Table 8, indicate that the highest values of calcium ions were observed in wells 1, 3, 2, and 6, with respective concentrations of 1600, 1280, 1120, and 1040 mg/L during the winter. Conversely, the lowest calcium ion values were recorded in well 4 during both the autumn and summer seasons, with concentrations of 160 and 240.4 mg/L,

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respectively. The increase in calcium ion concentration during the winter may be attributed to precipitation, where water accumulates on the Earth's surface and gradually infiltrates the subsurface layers. During this process, a chemical interaction occurs between the water and the surrounding rocks, leading to the dissolution of calcium carbonate ($CaCO_3$) minerals present in the rocks. This observation aligns with the findings of (Kazem and Mansour, 2015). The variation in calcium ion concentrations can be attributed to the geological nature of each region and the location of each well. The direction of water flow can have a significant impact on the calcium ion concentration in groundwater. In areas where water flows through calcium-rich rock formations, there may be an increase in calcium concentration in those areas compared to others. Furthermore, the quantity of water extracted from a well within a specific timeframe can also affect the calcium ion concentration. When large amounts of water are drawn from a well in a short period, it may influence the concentration of calcium and other elements in the groundwater (Saeed et al., 2018).

Additionally, the use of chemical fertilizers in agriculture can introduce significant amounts of calcium into the soil. Consequently, it may dissolve and accumulate in the flowing groundwater in those regions (Atta et al., 2016). The results of the statistical analysis, using the analysis of variance, confirmed significant spatial differences in calcium ion concentrations at a significance level of $p \leq 0.05$ for all wells, with values as follows: 127.82, 108.55, 176.48, 98.37, 147.02. However, the fifth well did not exhibit significant differences. Additionally, significant temporal differences were found for all seasons of the study, starting with winter (155.97, 126.06, 107.37, 133.72).

As for the magnesium ion, the highest values were recorded in the first and second wells during the summer at rates of 3400 and 1360 milligrams per liter, respectively. The lowest value was observed in the third well during the winter at a rate of 35.84 milligrams per liter, while in the fourth and fifth wells, the lowest values were during the autumn at rates of 44.8 and 62.8 milligrams per liter, as shown in Table (9). The high magnesium ion concentrations in the groundwater can be attributed to the presence of dolomite minerals in the natural geological structure of the area. Dolomite is a sedimentary rock primarily composed of calcium and magnesium carbonate ($CaMg(CO_3)_2$), making it a strong source of magnesium ions in the groundwater.

Increased levels of magnesium ions were observed during the summer, as high temperatures in the summer season enhance chemical weathering processes of rocks and minerals. This weathering leads to the release of minerals such as magnesium from rocks and soil, increasing the concentration of magnesium in groundwater. Additionally, higher temperatures increase the rate of evaporation of water present on the Earth's surface and in the soil, concentrating salts, including magnesium salts (Aboud and Tawfiq, 2012). The statistical analysis for magnesium ion concentration showed significant spatial differences in all the wells at a significance level of ($p \leq 0.05$), with values of 97.22, 102.75, 95.36, 88.29, 96.17, and 116.27, respectively. Significant temporal differences were also found for all seasons, with values of 114.95, 98.44, 91.78, and 86.05, respectively, starting from winter.

Table (8) Calcium ions of Wells Throughout the Seasons

Ca^+ (mg/L) Well NO.	Winter	Spring	Summer	Autumn	LSD
1	1600	256.5	400	801.6	* 127.82
2	1120	817.6	480	580	* 108.55
3	1280	336.6	500	421.8	* 176.48
4	416	344.6	160	240.4	* 98.37
5	400	320.6	324	336.9	82.57NS
6	1040	400.8	400	367.2	* 147.02
LSD	* 155.97	* 126.06	* 107.37	* 133.72	---

) *P≤0.05.(

Table (9) Magnesium ions of Wells Throughout the Seasons

Mg^{+}(mg/L) **Well NO.**	**Winter**	**Spring**	**Summer**	**Autumn**	**LSD**
1	752.64	890	3400	420	* 97.22
2	250.88	607.9	1360	242.9	* 102.75
3	35.84	276.7	580	102	* 95.36
4	184.57	208.5	262	44.8	* 88.29
5	197.12	249.4	366	62.8	* 96.17
6	268.8	432.2	310	83.4	* 116.26
LSD	* 114.95	* 98.44	* 91.78	* 86.05	---
) *P≤0.05.(					

9: Chloride ion (Cl-)

The results of the current study, as shown in Table (10), indicated that the highest concentration of chloride ions was found in wells one, two, and three during the summer, with concentrations of 12,435, 10,932, and 8,933 milligrams per liter (mg/L), respectively. In contrast, wells five and six recorded the lowest values during the winter, with concentrations of 94.7 and 97.3 mg/L, respectively. The study's results highlight variations in chloride ion concentrations in well water, which can be attributed to seasonal climatic changes and their impact on chloride levels in both the soil and groundwater. Reduced groundwater replenishment by rainfall during the study period could be one of the potential reasons for the increase in chloride ion concentrations in some wells. Moreover, the high concentration of chloride ions in certain wells may be attributed to their direct contact with geological formations that contain halite, which is sodium chloride. Halite is highly soluble in water, especially when sodium is present near the surface of the earth and exposed to groundwater movement. This observation is consistent with the findings of Nafish (2011) and Al-Faraji (2022) in their respective studies.

Additionally, elevated chloride concentrations were noted in most study areas. There may be additional sources of chloride salts, besides evaporite deposits, that can affect chloride concentrations. Chloride levels can also be influenced by soil leaching through irrigation with chloride-contaminated water. Over time, chloride can accumulate in the groundwater flowing from these areas. Furthermore, most of the study areas are agricultural lands treated with insecticides that contain various types of organic chloride compounds.

The results of the statistical analysis confirmed the presence of significant spatial differences at the significance level ($p \leq 0.05$) for all wells during the seasons, with values varying as follows: starting from winter ,116.37 ,102.66 ,186.78 ,193.06 ,278.95) (164.09 Significant temporal differences were also observed for all study seasons, with values as follows, starting from winter (176.71, 115.94, 236.57, 181.22).

Table (10) Chloride ion of Wells Throughout the Seasons

Cl^{-} (mg/L) **Well NO.**	**Winter**	**Spring**	**Summer**	**Autumn**	**LSD**
1	4758	1899.4	12435	6498	* 278.95
2	993	1279.6	10932	1599	* 193.06
3	110.3	119.9	8933	499	* 186.78

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4	97.3	319.9	454	319	* 102.66
5	94.7	443.8	5416	490	* 116.37
6	1083	1199.6	2921	680	* 164.09
LSD	* 176.71	* 115.94	* 236.57	* 181.22	---
) *P≤0.05.(					

10: Sulfate ions

The results presented in Table (11) show that sulfate ion concentrations reached their peak at the first well during the fall and summer seasons, with values of (4639.24, 3868.35) milligrams per liter (mg/L). In the second well, the sulfate ion concentration peaked during the fall season, with a value of (1892.94) mg/L. The lowest sulfate ion values were recorded at the fourth well during the summer and fall seasons, with values of (213.95, 302.33) mg/L.

The significant increase in sulfate ion concentrations at all study locations can be attributed to the geological nature of the study area, which is rich in deposits of sulfur compounds such as gypsum (calcium sulfate). Additionally, sulfates can be generated from the oxidation of pyrite and marcasite minerals in shale and clay rocks (Nassif and Jawad, 2015). Another reason for the increase in sulfate ions is human activities associated with agricultural practices, including the use of fertilizers, pesticides, and the decomposition of organic materials from animal waste in livestock areas.The variation in ion concentrations in well waters can be attributed to several factors, including bacterial activity in soil layers, which play a role in redox reactions of sulfur phases resulting from chemical interactions between groundwater and other solid materials, such as rocks and sediments (At-Temimi, 2016).

The results of the statistical analysis confirmed the presence of significant spatial differences in all wells within the study area at a significance level of ($p \leq 0.05$), except for well number five, which did not register any significant differences. The spatial differences were observed across the wells in the study area, starting with well number one ,187.55 ,236.08) .(183.08 ,167.92 ,157.83

Furthermore, significant temporal differences were also recorded for all seasons of the study, spanning from winter to autumn (217.53, 192.47, 167.40, 207.24).

Table (11) Sulfate ions of Wells Throughout the Seasons

SO_4)mg/L(/ Well NO.	**Winter**	**Spring**	**Summer**	**Autumn**	**LSD**
1	1062.55	1141.98	3868.35	4639.24	* 236.08
2	1223.21	1311.65	1067.8	1892.94	* 187.55
3	598.97	639.23	739.78	954.68	* 157.83
4	365.4	444.0	213.95	302.33	* 167.92
5	482.3	509.93	423.29	543.94	137.43NS
6	769.83	848.57	960.65	664.75	* 183.08
LSD	* 217.53	* 192.47	* 167.40	* 207.24	---
) *P≤0.05.(					

11: Phosphate ions (PO_4)

The results of the current study indicate that phosphate ion concentrations reached their highest values at wells one, two, and six during the autumn, with values of 1.193, 1.018, and 0.994 micrograms per liter, respectively. The lowest concentration was recorded at well three during the spring season, with a value of 0.03 micrograms per liter, and at well five during both the summer and spring seasons, with values of 0.014 and 0.04 micrograms per liter, as shown in Table 12.

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The presence of phosphate ions in the studied well waters can be attributed to several factors. The area has an agricultural character, and phosphate fertilizers are commonly used in the cultivation of surrounding lands. During rainfall or excessive irrigation, these fertilizers can dissolve and leach phosphate ions into the groundwater reservoir. Additionally, phosphate is a component of soil and rocks. Some detergents and cleaning products contain triphosphate ions, which can interact with water and transform into phosphate ions when these products are used and subsequently washed or disposed of in drains. This can result in phosphate ions seeping into the groundwater (Al-Safawi & Al-Assaf, 2018).

The decrease in phosphate values can be attributed to the phosphate's tendency to precipitate as calcium phosphate, in addition to its adsorption by clay mineral surfaces, reducing its transfer to the aquatic environment. This is also influenced by the pH value. pH plays an important role in the availability and solubility of elements such as phosphorus and nitrogen. This aligns with the findings of Rizouki .(2023)

The statistical analysis results confirmed the presence of significant spatial differences at a level of ($p \leq 0.05$) for all wells, with values of 0.534, 0.572, 0.437, 0.398, 0.451, and 0.458, respectively. There were also significant temporal differences for the spring, summer, and autumn seasons, with values of 0.411, 0.392, and 0.554, while there were no temporal differences for the winter season.

Table (12) Phosphate ions of Wells Throughout the Seasons

PO_4)mg/L(/ Well NO.	**Winter**	**Spring**	**Summer**	**Autumn**	**LSD**
1	0.231	0.541	0.067	1.193	* 0.534
2	0.098	0.122	0.053	1.018	* 0.572
3	0.14	0.03	0.518	0.618	* 0.437
4	0.044	0.021	0.036	0.676	* 0.398
5	0.030	0.04	0.014	0.673	* 0.451
6	0.88	0.171	0.189	0.994	* 0.458
LSD	0.228NS	* 0.411	* 0.392	* 0.554	---
) *P≤0.05.(					

12: Nitrite and Nitrate Ions

The current study's results revealed that the highest concentration of nitrite ions was observed in wells six and two during the summer season, with values of 2.271 and 1.697 micrograms per liter (µg/L), respectively. The lowest nitrite concentration was recorded in well two during the autumn season, with a value of 0.007 µg/L, and in well five during the spring season, with a value of 0.008 µg/L, as shown in Table 13.

As for nitrate ions, the highest concentration was found in well one during both the autumn and summer seasons, with values of 27.589 and 23.503 µg/L, respectively. The lowest nitrate concentration was reached in well four during the autumn season, with a value of 0.986 µg/L, as presented in Table 14.

An increase in nitrite and nitrate ions was observed at some study sites during the dry season and elevated temperatures. This increase can be attributed to the heightened activity of nitrifying bacteria that produce nitrite and nitrate. Additionally, the concentration of nitrite and nitrate ions in water increases due to various factors, including the decomposition of organic materials, agricultural activities, the use of nitrogen-based fertilizers, and the leaching of animal waste in the area.

Animal waste and organic fertilizers used as manure leach into the soil and seep into the surrounding water sources, which aligns with findings by Al-Hilaly

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(2022). Nitrite and nitrate ions are highly soluble, allowing them to quickly reach groundwater sources. Their elevated levels in well water can pose an environmental challenge because they are considered contaminants of groundwater resources (Jalili et al., 2018; Sharon et al., 2017). The decrease in nitrate levels in some well waters can be attributed to various factors, including a reduction in decomposing plant residues, which are a significant source of organic nitrogen that can convert to nitrate in groundwater. Additionally, it is believed that the anaerobic conditions in the area play a role in transforming nitrates into gaseous forms through a process known as denitrification. This aligns with the findings by Razzouqi (2023).

The results of the statistical analysis confirmed the presence of significant spatial differences ($p \leq 0.05$) for nitrite at wells one, two, five, and six, with values of 0.327, 0.504, 0.307, and 0.679, respectively. No significant spatial differences were found for wells three and four. Additionally, significant temporal differences were observed across all seasons of the study, with values of 0.277, 0.326, 0.672, and 0.437, respectively.

For nitrates, the statistical analysis revealed both significant spatial and temporal differences ($p \leq 0.05$) across all wells and seasons during the study. Spatial differences ranged from 7.51 to 4.68 starting from well one. Temporal differences were represented by values of 6.02, 6.55, 7.917, and 7.88, beginning with the winter season.

Table (13) Nitrite ions of Wells Throughout the Seasons

NO_2)mg/L(**Well NO.**	**Winter**	**Spring**	**Summer**	**Autumn**	**LSD**
1	0.189	0.246	0.223	0.963	* 0.327
2	0.018	0.136	1.697	0.007	* 0.504
3	0.082	0.155	0.055	0.092	0.149NS
4	0.038	0.046	0.062	0.114	0.113NS
5	0.096	0.008	0.310	0.126	* 0.307
6	0.301	0.350	2.271	0.576	* 0.679
LSD	* 0.277	* 0.326	* 0.672	* 0.437	---
) *P≤0.05.(					

Table (14) Nitrate ions of Wells Throughout the Seasons

NO_3)mg/L(**Well NO.**	**Winter**	**Spring**	**Summer**	**Autumn**	**LSD**
1	2.512	3.714	23.503	27.589	* 7.51
2	6.341	7.701	13.795	16.762	* 6.96
3	7.622	8.682	5.240	1.719	* 5.39
4	12.101	14.453	1.588	0.986	* 6.34
5	6.210	8.317	1.483	2.218	* 5.02
6	7.123	10.236	4.326	9.702	* 4.68
LSD	* 6.02	* 6.55	* 7.91	* 7.88	---
) *P≤0.05.(					

13: Sodium and potassium ions

The results of the current study, as presented in Table 15, showed an increase in sodium ion concentrations

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in well one during both the summer and fall seasons, with values of 1449.87 and 1414.11 mg/L, respectively. Conversely, well three exhibited the lowest sodium ion concentrations during the winter and spring seasons, with values of 103.96 and 121.98 mg/L, respectively. This observed rise in sodium concentrations in specific study areas, especially during the dry season, can be attributed to the presence of saline areas containing minerals like halite (NaCl) and clay minerals such as illite. These areas often come into contact with groundwater, leading to the transfer of sodium ions from these minerals to the groundwater (Abdul Hamza, 2015). Additionally, evaporation processes and low rainfall can lead to the accumulation of sodium salts in these regions, further affecting sodium ion concentrations in groundwater. The use of chemical fertilizers in agriculture, such as sodium nitrate, can contribute to the accumulation of sodium ions in the soil, which can then leach into the groundwater (Al-Kilabi, 2013).

The results of the statistical analysis confirmed the presence of significant spatial differences ($p \leq 0.05$) in wells one, two, and six, with respective values of 189.02, 166.56, and 176.02. No significant spatial differences were recorded in wells three, four, and five. Furthermore, significant temporal differences were found across all wells and throughout the study seasons, starting with the winter season (174.26, 169.55, 193.05, 188.42). As for potassium ions, the study recorded the highest concentrations at well two during the summer and spring seasons, with values of 31 and 33 mg/L, respectively. The lowest potassium concentrations were recorded at well four during the autumn and spring seasons, with values of 4.3 and 5 mg/L as presented in table (16). The increase in potassium ion concentrations in groundwater can be attributed to processes such as weathering of sedimentary rocks in the study area, which leads to the breakdown of minerals and chemical elements, including potassium. The presence of clay minerals like illite can also play a role in increasing potassium ion concentrations in groundwater, as these minerals are typically rich in potassium. When they interact with water, potassium ions are released into the aqueous solution (Saha et al., 2019). Additionally, waters leaching from agricultural lands, where chemical fertilizers are used, may introduce potassium into the soil (Al-Kilabi, 2013).

The statistical analysis results confirmed the existence of significant spatial differences at a significance level of $p \leq 0.05$ for wells one, two, three, and six, with values of 8.46, 7.55, 7.69, and 5.89, respectively. No significant spatial differences were observed for wells four and five. Furthermore, significant temporal differences were found for all wells across all seasons, starting from the winter with values of 7.21, 6.96, 6.90, and 7.44, respectively

The current study's results reveal an increase in the concentration of sodium compared to potassium in groundwater. This is noteworthy despite the abundance of potassium in the Earth's crust. Sodium's high mobility allows it to move easily and transfer to the aqueous medium more effectively than potassium. This implies that sodium ions can flow more rapidly through the soil and percolate into groundwater.

In contrast, potassium displays relatively greater stability when compared to sodium. It is less susceptible to chemical reactions, oxidation, and fermentation. This increased stability allows potassium to remain in its original form for a more extended period. Additionally, potassium is absorbed to a greater extent by clay minerals in the soil, which reduces its concentration in groundwater (Abdullah and Majid 2015).

Table (15) Sodium ions of Wells Throughout the Seasons

Na^+)mg/L(/ Well NO.	Winter	Spring	Summer	Autumn	LSD
1	724.31	688.16	1449.87	1414.11	* 189.02
2	312.54	471.23	599.97	545.14	* 166.56
3	103.96	121.98	138.67	126.75	84.53NS
4	250.88	280.51	319.85	212.57	102.64NS

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5	210.83	245.95	256.67	243.56	87.35NS
6	498.5	681.03	617.85	508.19	* 176.02
LSD	* 174.26	* 169.55	* 193.05	* 188.42	---
) *P≤0.05.(					

Table (16) potassium ions of Wells Throughout the Seasons

K^+)mg/L(	**Winter**	**Spring**	**Summer**	**Autumn**	
Well NO.					**LSD**
1	20	18	31	13.14	* 8.46
2	28	31	33	20.53	* 7.55
3	16	20	11	7.7	* 7.69
4	7	5	8	4.3	4.63NS
5	12	10	10	8.6	4.07NS
6	8	11	14	9.4	* 5.89
LSD	* 7.21	* 6.96	* 6.90	* 7.44	---
) *P≤0.05.(					

Conclusions

- Groundwater from the wells was typically warm and had low oxygen content due to narrow and often enclosed boreholes.
- Most of the well waters were of moderate to somewhat pure turbidity, except for some locations during rainy seasons.
- pH measurements indicated that the water was generally slightly alkaline to mildly basic in some wells.
- The majority of the wells had high salinity levels and high electrical conductivity.
- Elevated hardness levels were observed, with significant concentrations of calcium, magnesium, and chloride ions.
- Sodium ion concentrations were higher than potassium ions in most cases.
- Sulfate ion concentrations were generally high in most locations and throughout the year.
- Phosphate ion concentrations were elevated in some locations, likely due to the agricultural nature of the area and the extensive use of phosphate fertilizers.
- Nitrate ion concentrations exhibited variations among locations, with higher concentrations in the first location.

Recommendations

- Implementing scientific and engineering-based well drilling practices, ensuring the selection of suitable locations that are distant from potential sources of contamination, such as sewage disposal areas and animal breeding zones, with a minimum separation distance of at least 50 meters.
- Promoting the responsible use of chemical fertilizers and pesticides containing high levels of nitrates, phosphates, and chlorides by farmers. This involves educating farmers about the proper application and dosage of these chemicals to prevent groundwater pollution.

- Conducting field and laboratory studies to understand the interactions between well water and adjacent rivers, as well as their impact on cultivated crops. This research can help in making informed decisions about land and water management, leading to sustainable agriculture practices.

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