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Evaluation of the water quality of some groundwater wells in Salah al-Din Governorate.

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ABSTRACT

The study aims to evaluate the quality of groundwater of wells spread in Salah al-Din Governorate/Tuz Khurmatu for drinking, irrigation, livestock and poultry purposes. The study area is located between latitudes (34º, 53’,59’’-34º ,52’,46’’) N and longitudes (44º, 44’,32’’-44º, 36’,41’’) E. with a total area of (191801.65) hectares. 25 wells were randomly selected in the study area during the dry season (September 2024) and the wet season (March 2025). After that, water samples were taken to the laboratory to conduct physical and chemical analyses. There are three types of WQI for drinking water in the dry season. The first type is excellent for drinking, and it reached 16% of the total wells. The second type is good for drinking, and it reached 44%. The third type is poor and not suitable for drinking, and it occupied 40%. As for the wet season, the results were different, and it was found that there were three classes for different purposes was evaluated and compared. Through a detailed study of the variation in groundwater characteristics in different areas in Tuz Khurmatu district by determining the irrigation water quality index with eight criteria, the drinking water quality index with twelve criteria, and the water quality index for livestock and poultry with eight criteria, it was found that the wells of the study area with respect to For the indicators of water quality for drinking, irrigation, livestock and poultry in the dry season, the categories were (excellent, good and poor), (excellent, good, poor and very poor), (excellent, good and poor) for each of them respectively. In the wet season, the water quality for drinking, irrigation, livestock and poultry was (excellent, good and poor), (excellent, good and poor), (excellent, good and poor).

***Keywords*:** Groundwater, Water Quality Index, IWQI, WQI, GIS, Kirkuk, Iraq.

INTRODUCTION

Water is an essential factor for all living organisms on Earth [1]. Groundwater is one of the most important water resources, representing 17.7% of the world's drinking water. It originates primarily from rainwater and irrigation water that seeps into the ground and is stored underground in non-porous layers to form the aquifer [2]. Groundwater is essential for daily, agricultural, and industrial use, this faces numerous environmental pollution problems due to the increasing demand for it due to population growth [3][4] Limited natural resources in arid regions are accompanied by a decline in agricultural production, making it difficult to find alternative sources to meet growing food needs [5]. The Water Quality Index is a measure for determining the quality of groundwater and its characteristics based on its physical, chemical, and biological properties to reduce the hazard caused by water pollution. Many countries and international organizations have developed acceptable and approved standards for determining water quality to ensure consumer safety [6]. Assessing the suitability of well water is a fundamental step, as it helps determine the suitability of this water for various uses, particularly irrigation and drinking [7]. Contamination of water resources with urban waste and agricultural and industrial processes leads to the deterioration of water properties, making it unsuitable for irrigation and drinking. Therefore, element concentrations in water must be within limits and comply with the standard conditions recommended by health authorities [8]. The water quality index for drinking, and water for livestock, and poultry is a fundamental criterion for their safety and productivity [9]. Given the geographical location of these wells, which are unique to the Tuz Khurmatu region, with the prevalence of dissolved ions and salts at varying concentrations in the water of the widespread wells, and the increase in industrial and agricultural activity, the district has witnessed a development in industrial and agricultural activities, leading to the infiltration of chemical pollutants such as pesticides, fertilizers, and industrial waste into groundwater layers, in addition Urban expansion and the absence of advanced sewage systems lead to the discharge of untreated wastewater, which causes organic and bacterial pollutants to seep into groundwater, posing a threat to the health of the population. Furthermore, the effects of climate change and drought lead to lower rainfall rates and increased pumping rates affecting the quality of groundwater, which increases the concentration of harmful elements such as salts and heavy metals. Due to the lack of studies related to groundwater in this region, this study was conducted to assess the extent of Livestock suitability of well water in the studied area for irrigation, human consumption, and animal drinking.

MATERIALS AND METHODS

The study was conducted groundwater wells spread across the district of Tuz and the sub-districts of Sulayman Bek and Amerli, within the administrative borders of Salah al-Din Governorate. the study area extends between latitudes (34° 53 - 59 = -34° 52 - 46 =) north and longitudes (44° 44 - 32 = -44° 36 - 41 =) east, with a total area of 191,801.65 hectares. (Figure 1) Twenty-five wells were selected (Table 1) spread across the study area, Samples were taken for each well after operating the well water pump for 10 minutes during the dry season in September 2024 and the wet season in March 2025. Water samples were then taken to the Soil Sciences and Water Resources Laboratories at the College of Agriculture at the University of Kirkuk in clean polyethylene plastic bottles, washed several times with sample water before filling them. To conduct physical and chemical analyses.

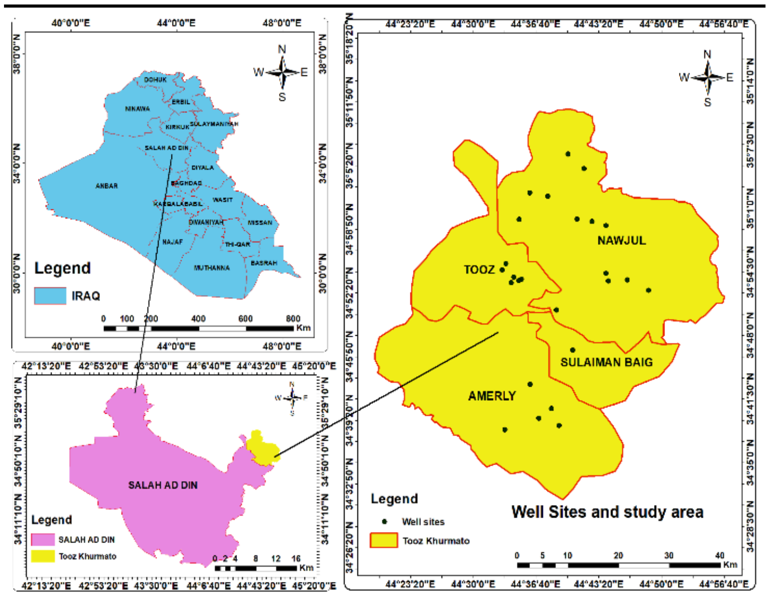

Figure:(1) Map of the study area and wells locations.

1- Assessment of drinking Water Quality index(WQI)

To calculate the water quality index, three steps are required as mentioned [10].

Step 1: A weight (Wi) is assigned to each of the chemical parameters, namely pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^{+}), potassium (K^{+}), sulfate ($SO_4^{-)}$, bicarbonate (HCO_3^{-}), nitrate (NO_3^{-}), and chloride (Cl^{-}). This is based on their perceived health effects and relative importance to the overall quality of water for drinking purposes. A weight of 5 is assigned to parameters that have significant impacts on water quality and are important to quality, and a minimum of 1 is assigned to parameters considered harmless.

Step 2: Calculate the relative weight (Wi) of each parameter using Equation (1).

Step 3: The quality classification scale (qi) is calculated for each parameter by dividing its concentration in each water sample by the standard for each of them according to the standard specifications, then multiplying the result by 100 using Equation (2).

Step Four: Calculate the Water Quality Index (WQI) for each sample using Equation (3) Table (1).

$$Wi = \frac{\mathrm{Wi}}{\sum_{i=1}^{n} Wi} \qquad \ldots\ldots\ldots(1)$$

$$qi = \left(\frac{\mathrm{ci}}{\mathrm{si}}\right) * 100 \qquad \ldots\ldots\ldots(2)$$

$$\mathrm{WQI}=\sum_{i=1}^{n}(Wi * Qi) \qquad \ldots\ldots\ldots(3)$$

Which:

Wi: Relative weight.

wi: weight of each parameter.

n: number of transactions.

Qi: Quality rating.

Ci: Concentration of each chemical parameter in each water sample.

Si: Standard value according to [11] mgl^{-1}

The WQI index was classified according to the classification [10] Table (4).

Table (1): Water quality standard, assigned and relative weight value.

Number	Chemical properties	Unite	Standard drinking limits (WHO‹2011)mg.l^{-1}	Custom weight (Wi)	Relative weight (Wi)
1	pH	-	8.5	4	0.10811
2	EC	dSm^{-1}	1.5	4	0.10811
3	TDS	mg l^{-1}	1	5	0.13514
4	TH	mg l^{-1}	500	2	0.05405
5	Ca	mg l^{-1}	200	2	0.05405
6	Mg	mg l^{-1}	150	2	0.05405
7	Na	mg l^{-1}	400	2	0.05405
8	K	mg l^{-1}	12	1	0.02703
9	SO_4	mg l^{-1}	400	4	0.10811
10	HCO_3	mg l^{-1}	500	3	0.08108
11	NO_3	mg l^{-1}	45	5	0.13514
12	Cl	mg l^{-1}	600	3	0.08108
				∑37	0.999≈1

2- Assessment of Irrigation Water Quality Index The irrigation water quality index was calculated using the equation indicated by [12]. It is calculated in three steps:

Step 1: Eight attributes were used to calculate the Irrigation Water Quality Index (IWQI): electrical conductivity (EC), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), sodium percentage (Na%), magnesium adsorption ratio (MAR), permeability index (PI), Kelly index (KI), and potential salinity (PS). To calculate each of these attributes, the relative weight (Wi) and water quality value (Qi) were used.

Step 2: Calculate the relative weight values as shown in Table (2).

Step 3: Calculate the Irrigation Water Quality Index (IWQI). The IWQI was calculated using the following equation:

IWQI= $\sum_1^n qiwi$ ………. (4)

Which:

IWQI: Irrigation Water Quality Index

Its value ranges between (0-300) and is unitless. The IWQI values were evaluated and calculated as indicated by [12] into eight characteristics, as in (4).

Table (2): Reference values (si), weight of attributes (wi), and relative weight (RWi) for the attributes used in classifying water quality for irrigation (IWQI).

adjective	si	wi	RWi
EC	2.25	5	0.17241
SAR	18	5	0.17241
RSC	2.5	1	0.03448
Na%	60	3	0.10344
MAR	50	3	0.10344
IP	85	4	0.13793
KI	1	3	0.10344
PS	5	5	0.17241
The total		$\sum wi = 29$	0.99996

3- Assessment Water Quality Index for Livestock(WQI)

The WQI values for livestock and poultry irrigation were calculated according to the steps mentioned in [13] [14].

Step 1: The values of eight chemical properties of well water were calculated, including acidity (PH), electrical conductivity (EC), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^{+}), chloride (Cl^{-}), sulfate (SO_4^{-}), and nitrate (NO_3^{-}), as shown in Table (3).

Step 2: The relative weight (Wi) values were calculated according to [15] using the following equation (5).

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \qquad \dots\dots\dots (5)$$

Which:

Wi: Relative weight.

wi: weight of each parameter.

n: number of transactions.

Step 3: The quality rating (qi) values were calculated according to the following equation:

$$qi = \left(\frac{ci}{si}\right) * 100 \qquad \dots\dots\dots (6)$$

qi: Quality classification.

CI: Concentration of each chemical parameter in each water sample.

SI: Standard value.

Table (3): Reference values (si), weight of traits (wi), and relative weight (Rwi) for the traits used in classifying water quality for livestock and poultry (WQI)

adjective	si	Wi	RWi
pH	8.5	4	0.16
EC	1.6	4	0.16
Ca^{+2}	1000	2	0.08
Mg^{+2}	500	2	0.08
Na^{+}	300	3	0.12
Cl^{-}	300	1	0.04
SO_4^{-2}	500	4	0.16
NO_3^{-}	133	5	0.2
The total	$\sum \mathrm{wi} = 25$		1

Step 4: The values of the sub-index (Sli) and the water quality index (WQI) were calculated according to the following equation:

Sli=Wi*qi ………. (7)

WQI=$\sum Sli$ ……….. (8)

The WQI was classified into five sections as mentioned by [13]. As in Table (4)

Table (4): Classification of Water Quality Index (WQI) values for drinking, irrigation, livestock and poultry.

Class	WQI Value	Water quality
I	50 <	Excellent
II	50-100	Good
III	100-200	Poor
IV	200-300	Very Poor
V	300 >	Unsuitable

Results and discussion

1- Drinking water quality index(WQI)

Tables 5 and 7 reveal that, for the dry season, there are three WQI categories for the study area's well water for drinking. The first category, "Excellent for drinking," accounted for 16% of the total wells in the study area, the second category, "Good for drinking," accounted for 44%, and the third category, "Poor and unsuitable for drinking," accounted for 40%. For the wet season, the first category, "Excellent for drinking," accounted for 8%, the second category, "Good for drinking," accounted for 56%, and the third category, "Poor and unsuitable for drinking," accounted for 36%. Figure 2 shows that 25% of the study area's wells in the wet season had an increase in their Water Quality Index (WQI) compared to the dry season, while 75% of them had a decrease in this value. This is due to rainwater, which causes microbial and physical contamination.

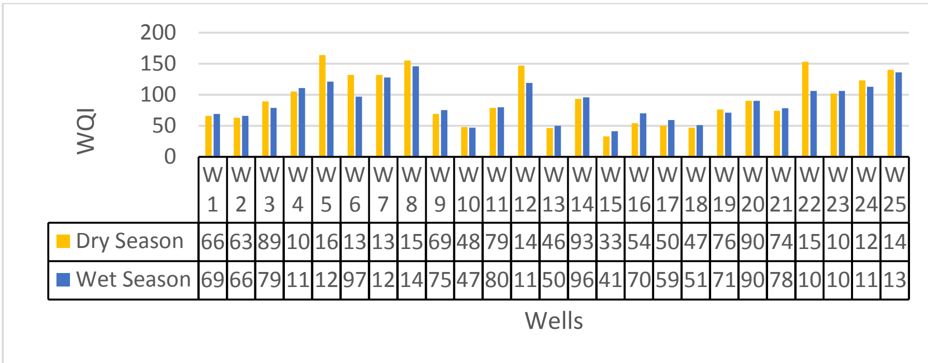

Figure 2: Water Quality Index (WQI) for drinking of the wells of study area.

Table (5): Water Quality Index (WQI) for drinking in study area wells for the dry and wet seasons.

NO Well	WQI(Dry Season)	WQI(Wet Season)
W1	66	69
W2	63	66
W3	89	79
W4	105	111
W5	164	121
W6	132	97
W7	132	128
W8	155	146
W9	69	75
W10	48	47
W11	79	80
W12	147	119
W13	46	50
W14	93	96
W15	33	41
W16	54	70
W17	50	59
W18	47	51
W19	76	71
W20	90	90
W21	74	78
W22	153	106
W23	102	106
W24	123	113
W25	140	136
Min	33	41
Max	164	146
Range	131	105

Average	93	88
SD	40	29
CV	43	33

2- Irrigation water quality index(IWQI)

Tables 6 and 7 show that for the dry season, there are four WQI categories for the study area's well water for irrigation. The first class is "excellent for irrigation," accounting for 28% of the total wells in the study area. The second class is "good for irrigation," accounting for 28%. The third category is "poor for irrigation," accounting for 32%. The fourth category is "very poor for irrigation," accounting for 12%. For the wet season, there are three IWQI classes for the study area's well water. The first category is "excellent for irrigation," accounting for 20%. The second category is "good for irrigation," accounting for 40%. Figure 3 shows that 44% of the study area's wells in the wet season had higher Irrigation Water Quality Index scores compared to the dry season. This is due to increased rainfall, which reduces the concentration of salts and pollutants in groundwater sources, making them more suitable for irrigation.

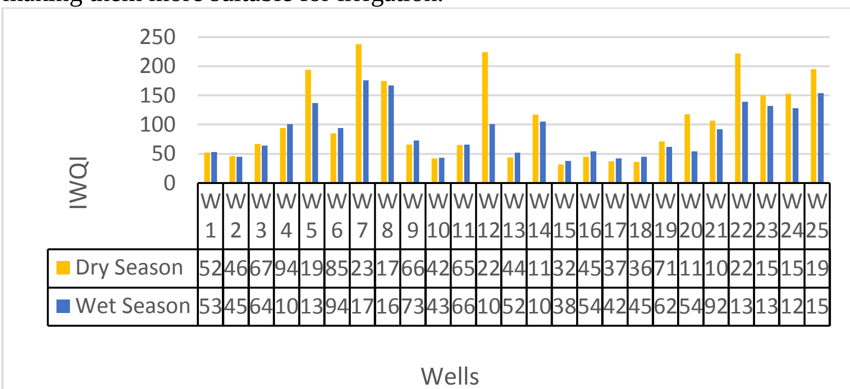

Figure 3: Irrigation Water Quality Index (IWQI) for the wells of study area.

Table (6): Irrigation Water Quality Index (IWQI) for the wells of the study area for the dry and wet seasons.

NO Well	WQI(Dry Season)	WQI(Wet Season)
W1	52	53
W2	46	45
W3	67	64
W4	94	101
W5	194	137
W6	85	94
W7	238	176
W8	175	167
W9	66	73
W10	42	43
W11	65	66
W12	224	101
W13	44	52
W14	117	105
W15	32	38
W16	45	54
W17	37	42
W18	36	45
W19	71	62
W20	118	54
W21	107	92
W22	222	139
W23	150	132
W24	153	128

W25	195	154
Min	32	38
Max	238	176
Range	206	137
Average	107	89
SD	67	43
CV	63	49

3- **Livestock and Poultry water quality index(WQI)**

Figure 4 shows that 24% of the study area's wells during the wet season had higher WQI scores compared to the dry season. This may be due to the rainwater in the wet season, which dilutes salts from water sources, reducing levels of pollutants such as nitrates, phosphates, and sulfates. Tables 7 and 8 show that for the dry season, there are three WQI categories for the study area's well water for livestock and poultry. The first Class, "Excellent for livestock and poultry," accounted for 28% of the total wells in the study area. The second, Class "Good for livestock and poultry," accounted for 48% of the total. The third, Class "Poor for livestock and poultry," accounted for 24% of the total. For the wet season, the first, Class "Excellent for livestock and poultry," accounted for 32% of the total, the second, Class "Good for livestock and poultry," accounted for 52%, and the third, Class "Poor for livestock and poultry," accounted for 16%.

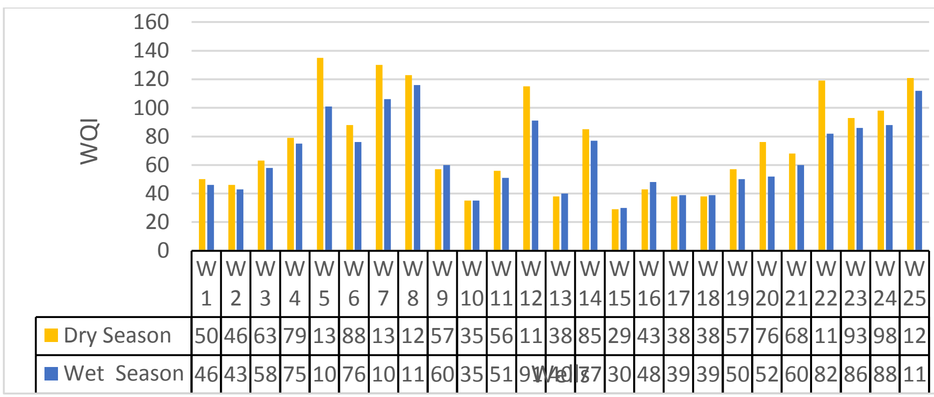

Figure 4: Water Quality Index for Livestock and Poultry (WQI) of study area.

Table (7): Water Quality Index (WQI) for watering livestock and poultry for the study area wells for the dry and wet seasons.

NO Well	WQI(Dry Season)	WQI(Wet Season)
W1	50	46
W2	46	43
W3	63	58
W4	79	75
W5	135	101
W6	88	76
W7	130	106
W8	123	116
W9	57	60
W10	35	35
W11	56	51
W12	115	91
W13	38	40
W14	85	77

W15	29	30
W16	43	48
W17	38	39
W18	38	39
W19	57	50
W20	76	52
W21	68	60
W22	119	82
W23	93	86
W24	98	88
W25	121	112
Min	29	30
Max	135	116
Range	106	86
Average	75	66
SD	34	26
CV	45	39

Table (8): Water Quality Index (IWQI) categories for drinking, irrigation, livestock and poultry (Mireles et al., 2010).

Class	WQI Value	Water quality
I	50 <	Excellent
II	50-100	Good
III	100-200	Poor
IV	200-300	Very Poor
V	300 >	Unsuitable

Conclusion:

Through a detailed study of the variation in groundwater characteristics in different areas in Tuz Khurmatu district by determining the irrigation water quality index with eight criteria, the drinking water quality index with twelve criteria, and the water quality index for livestock and poultry with eight criteria, it was found that the first class is excellent for drinking, amounting to 16%, the second class is good for drinking, amounting to 44%, and the third category is poor and unsuitable for drinking, amounting to 40%. As for the wet season, the results were different, and it was found that there are three categories: the first class is excellent for drinking, amounting to 8%, the second class is good for drinking, amounting to 56%, and the third class is poor and unsuitable for drinking, amounting to 36%. There are four WQI classes of well water in the study area for irrigation. For the dry season, the first class is excellent for irrigation, reaching 28%, the second class is good for irrigation, reaching 28%, the third class is poor for irrigation, with a percentage of 32%, and the fourth class is very poor for irrigation, reaching 12%. For the wet season, there are three IWQI classes of well water in the study area. The first class is excellent for irrigation, reaching 20%, the second class is good for irrigation, reaching 40%, and the third class is poor for irrigation, reaching 40%. For the dry season, there are three WQI classes of well water in the study area for livestock and poultry. The first class is excellent for livestock and poultry, reaching 28%, the second class is good for livestock and poultry, reaching 48%, and the third category is poor for livestock and poultry, reaching 24%. For the wet season, three classes appeared. The first category is excellent for livestock and poultry, reaching 32%, the second class is good for livestock and poultry, reaching 52%, and the third class is poor for livestock and poultry, reaching 16%.

References

[1]. Ahmed, A. (2023). Assessing Sirwan River Water Quality based on a single-factor assessment and comprehensive pollution index methods. Kirkuk University Journal for Agricultural Sciences, 14(4), 153-164. doi: 10.58928/ku23.14414

[2]. Muhammed, S. (2018). Study of some Physical and chemical Properties of some Wells, Springs and Aaw Spee river’s water of Qadr Karam district and their Suitability for drinking and Irrigation purposes. Kirkuk University Journal for Agricultural Sciences, 9(4), 126-136. doi: 10.58928/ku18.09416

[3]. Ali, D. (2023). Groundwater and its detection by geophysical methods (Review). Kirkuk University Journal for Agricultural Sciences, 14(4), 243-253. doi: 10.58928/ku23.14422

[4]. Hameed, A. (2019). Modification properties Groundwater for Irrigation Use By Magnetic Technique Of Some Wells Kirkuk city. Kirkuk University Journal for Agricultural Sciences, 10(3), 63-69. doi: 10.58928/ku19.10308

[5]. BAWAY, A., & Azeez, D. (2024). Groundwater Quality Assessment for Irrigation in Kirkuk Governorate. Kirkuk

University Journal for Agricultural Sciences, 15(3), 119-125. doi: 10.58928/ku24.15314
[6]. APHA, AWWA and WCPE (2017). "Stand Method for Examination of water and wastewater American public Health Association, 23RD ed., Washington DC, USA.
[7]. Sarkar, M., & Pal, S. C. (2021). Human health hazard assessment for high groundwater arsenic and fluoride intact in Malda district, Eastern India. Groundwater for Sustainable Development, 13, 100565.
[8]. Khatri, N., Tyagi, S., Rawtani, D., Tharmavaram, M., & Kamboj, R. D. (2020). Analysis and assessment of ground water quality in Satlasana Taluka, Mehsana district, Gujarat, India through application of water quality indices. Groundwater for Sustainable Development, 10, 100321.
[9]. Qablan, Abdul Bari Younis Hussein and Al-Hamdani, Ibrahim Omar Saeed and Al-Safawi, Abdul Aziz Younis Tali'a. (2018). Application of the Canadian Model CCMEWQI to Evaluate Well Water for Irrigation and Livestock Watering, Case Study: Well Water of Al-Siddiq and Al-Hadbaa Neighborhoods in Mosul City, Proceedings of the First International and Third Scientific Conference of the College of Science, Tikrit University 27(4): 193-202
[10]. Saleh, S. M., Al-Alaiy, S. G., & Abdul-Razzak, B. (2017). Application of water quality index to assessment of groundwater quality. University of Aden Journal of Natural and Applied Sciences, 21(1), 125-134.
[11]. WHO . (2011). Guideline of drinking water quality . 3d.ed.Incorporating first and Second addenda , vol ,1:210-220.Recomendatior.(WSH).Geneva .
[12]. Meireles, A. C. M., Andrade, E. M. D., Chaves, L. C. G., Frischkorn, H., & Crisostomo, L. A. (2010). A new proposal of the classification of irrigation water. Revista Ciência Agronômica, 41, 349-357.
[13]. Boateng, A., Cai, H., Borgia, D., Gang Bi, X., & Ngwu, F. N. (2017). The influence of internal corporate governance mechanisms on capital structure decisions of Chinese listed firms. Review of Accounting and Finance, 16(4), 444-461.
[14]. Kesharwani, P., Gothwal, A., Iyer, A. K., Jain, K., Chourasia, M. K., & Gupta, U. (2018). Dendrimer nanohybrid carrier systems: an expanding horizon for targeted drug and gene delivery. Drug discovery today, 23(2), 300-314.
[15]. Rahman, M. M., Howladar, M. F., & Faruque, M. O. (2017). Assessment of soil quality for agricultural purposes around the Barapukuria coal mining industrial area, Bangladesh: insights from chemical and multivariate statistical analysis. Environmental Systems Research, 6, 1-13.

تقييم جودة مياه بعض آبار المياه الجوفية المنتشرة في محافظة صلاح الدين.

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الخلاصة
تهدف الدراسة الى تقييم جودة المياه الجوفية لآبار منتشرة في محافظة صلاح الدين/ طوزخورماتو لأغراض الشرب والري والماشية والدواجن تقع منطقة الدراسة بين دائرتي العرض (34 ***(=46 -52 º34=-59 -53*** ºشمالاً وخطي الطول (44 ***(=41 -36 º44=-32 -44*** ºشرقاً وبمساحة إجمالية بلغت (191801.65) هكتاراً، تم اختيار 25 بئراً بصورة عشوائية في منطقة الدراسة خلال الموسم الجفاف(أيلول2024) والموسم الرطب(آذار2025) بعدها أخذت العينات المائية إلى المختبر لأجراء التحاليل الفيزيائية والكيميائية تم تقييم جودة المياه للأغراض المختلفة ومقارنتها، ومن خلال الدراسة التفصيلية لتباين خصائص المياه الجوفية في مناطق مختلفة في قضاء طوزخورماتو من خلال تحديد مؤشر جودة مياه الري بثمان معايير ومؤشر جودة مياه الشرب بثنى عشر معياراً ومؤشر جودة المياه للماشية والدواجن بثمان معايير، وجد أن آبار منطقة الدراسة بالنسبة لمؤشرات جودة المياه للشرب، والري، والماشية والدواجن في الموسم الجاف، كانت أصناف (ممتاز، وجيد وفقير)، (ممتاز وجيد وفقير وفقير جداً)، (ممتاز وجيد وفقير) لكل منهم على التوالي. ما في الموسم الرطب فأن جودة المياه للشرب والري والماشية والدواجن، كانت أصناف (ممتاز وجيد وفقير)، (ممتاز وجيد وفقير)، (ممتاز وجيد وفقير).

الكلمات المفتاحية: مياه جوفية، دليل جودة المياه، IWQI، WQI، GIS، كركوك العراق..