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Environmental Assessment of Groundwater Quality for Irrigation Purposes: A Case Study Of Hillah City In Iraq

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ABSTRACT

This study was conducted to evaluate the groundwater quality of wells located around the Hillah city of Iraq, for the purposes of determining its suitability as water for agricultural irrigation, according to the Irrigation Water Quality Index (IWQI). The number of wells that are being investigated was 24. The spatial distribution of water quality parameters was investigated using ArcGIS software. Ten parameters were established for the dry and wet seasons of 2018 and 2019, which include pH, electric conductivity (EC), total dissolved solids (TDS), calcium, potassium, magnesium, bicarbonate, sodium, chloride and sulfuric. The results showed that all pH and sodium absorption ratio values were within the allowable limits. About 69%, and 75% electric conductivity, total dissolved solids, values respectively were higher than the allowable limits. Most values of positive and negative ions were higher than the allowable limits. In 2018, the water quality of (4%) of wells number was classified as moderate restriction and approximately 96% was poor quality in dry season, while the IWQI was enhanced in the wet season. In 2019, the quality of water was dropped as most of the water quality was classified as severe restriction and few in the high restriction for the dry season. These values were increased in the wet season due to the freshwater dilution effect. Water quality index show that a large percentage of the wells have poor water quality leads to severe restriction for irrigation requirements and need relatively high permeability soils and salt-resistant plants.

Keywords: Groundwater, irrigation, spatial distribution, water quality index, wells

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INTRODUCTION

Water is an important source of life for human societies and other living creatures (Al-Ridah et al., 2020). Geographically, Iraq is one of the Middle Eastern countries that suffer from a semi-arid climate. The main source of water in Iraq is the Tigris and Euphrates rivers, whose water sources are from Turkey. Recently, and specifically since 1990, Turkey started construction of the GAP "Southeastern Anatolia Project "project, which consists of 24 dams and led to a significant decrease in the water supply to Iraq (Al-Mohammed & Mutasher, 2013). Therefore, it is necessary to search for an additional source that reduces the lack of water revenues for the country. Groundwater is one of the most important other alternative water sources that are used for various purposes, including irrigation, drinking, and industry (Abdullah et al., 2015). When groundwater gets polluted, it becomes difficult to get rid of pollution even when it is stopped from its source. Therefore, assessing groundwater quality for different purposes is necessary. The Water Quality Index (WQI) is used in terms of numbers to assess the quality of water to be used for any purpose (Mahmood et al., 2013). The Water Quality Index (WQI) is an effective way to classify, manage, and define groundwater quality as a single parameter. It measures water quality for multiple purposes (drinking, irrigation, and industries) by converting a set of water quality variables into a single value to determine the water quality in general (Boateng et al., 2016). WQI is a mathematical model used to convert water quality variables into a single value that represents the water quality level for a specific place and time (Gidey, 2018). The city of Hilla is characterized as an agricultural city with a high density, which requires large quantities of irrigation water. These quantities are mostly prepared from the Euphrates river and its branches in the city. Also, due to the low water imports, as mentioned above, groundwater is used in different places of the region to supply water to plants for agricultural lands around the city or for public and private gardens within the city. Therefore, the objective of current study is to investigate the suitability of groundwater in the region for the purpose of irrigation requirements using the irrigation water quality index (IWQI) and to make a spatial distribution of water quality elements to obtain a map of the quality of groundwater in the Hilla city.

MATERIALS AND METHOD

Area of the Study

The city of Hillah is in the center of Iraq. The main source of irrigation and drinking water is the Euphrates River and its multiple branches. About 24 shallow wells in the area were dug in unconfined aquifer as shown in detail in Table 1 and as shown by its spatial distribution according to Figure 1. The studied area covers about 80 by 40 Km and its climate is characterized by being hot, dry in summer, cool and less rainy in winter (Al-Dabbas & Al-Ali, 2016). Its soil is alluvial clay, sandy soils and containing on organic matter with

Table 1
Depth and location of wells

No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Depth (m)	12	9	10	12	9	7	14	10	12	10	12	9
X	44.432	44.420	44.400	44.396	44.393	44.541	44.571	44.469	44.464	44.577	44.395	44.377
Y	32.483	32.462	32.406	32.398	32.449	32.546	32.657	32.627	32.621	32.577	32.645	32.640
No.	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Depth (m)	12	10.5	12	12	10	9	11	9	9	9	9	7.5
X	44.430	44.465	44.372	44.428	44.381	44.364	44.343	44.668	44.873	44.950	44.990	44.905
Y	32.673	32.302	32.209	32.251	32.349	32.380	32.467	32.399	32.448	32.488	32.533	32.321

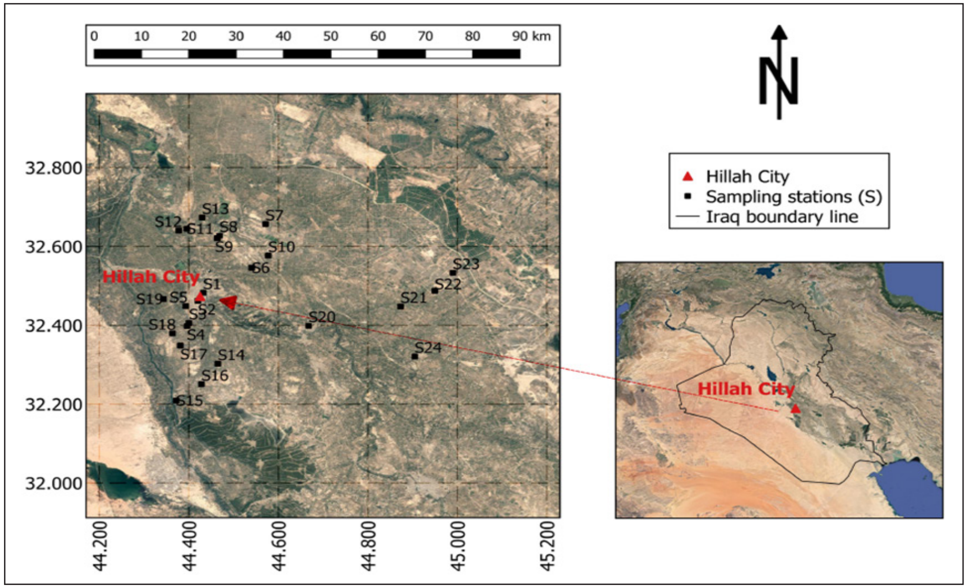

Figure 1. The area of the study

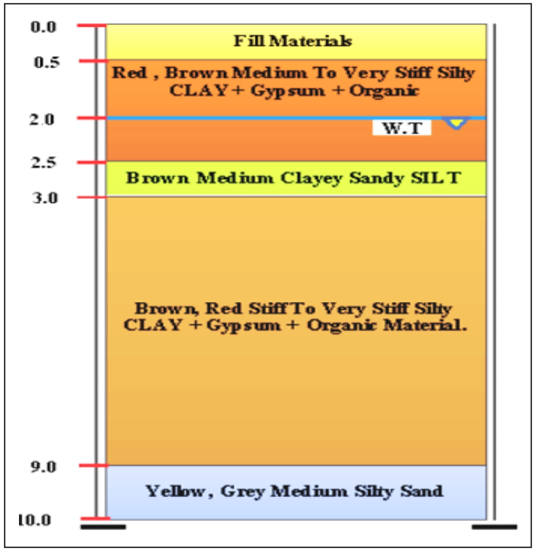

Figure 2. Soil profile of the study area adopted from Chabuk et al. (2017)

soft and weak cohesion properties due to relatively high levels of groundwater in most of its regions as shown in Figure 2 (Al-Khaqani, 2006; Al-Zubaydi et al., 2016; Chabuk et al., 2017). Tests were conducted for the water produced from it for the dry seasons (July) and wet seasons (January) and for two consecutive years (2018-2019). The study includes ten water quality parameters which are pH, Total Dissolved Solids (TDS), Electric Conductivity (EC), Calcium (Ca^{2+}), Potassium (K^+), Magnesium (Mg^{2+}), Bicarbonate (HCO_3^-), Sodium (Na^+), Chloride (Cl^-), Sulfuric (SO_4^-). The standard methods are used in the laboratory to test water quality parameters and to calculate the water quality index for the region.

Irrigation Water Quality Index (IWQI)

To assess the quality of groundwater in Hillah city to determine their suitability for irrigation purposes, IWQI was used (Meireles et al., 2010). In this method and for the purpose of calculating the relative weight, the estimated values for each parameter (which should be used) must be from the irrigation water quality data according to the University of California Consultation Committee (UCCC), Ayers and Westcot (1999), and Abbasnia et al. (2018).

The first step to build a model is to determine the influencing and controlling elements of the water quality used for irrigation. The elements (EC, Na+, Cl, and HCO_3), as well as the sodium absorption ratio SAR, were considered because they had the greatest influence on IWQI, as stated in Meireles et al. (2010). The second step is to determine the measurement values for the water quality (q_i) based on Table 2 according to Ayers and Westcot (1985), the values of (qi) are calculated from Equation 1:

$$q_i = q_{max} - \left[\frac{(x_{ij} - x_{inf})}{x_{amp}} \times q_{imap}\right] \qquad (1)$$

Where:
qi:limiting values parameter for quality measurement.
q_{imax}: maximum value of qi for the class.
x_{ij}: observed parameter value.
x_{inf}: equivalent value to the lower limit of the class to which the parameter belongs.
q_{iamp}: class amplitude.
x_{amp}: class amplitude to which the parameter belongs.

For calculating the value (x_{amp}) of the last class in Table 2 for each element, the upper limit was considered equal to the highest value calculated in the analysis of water quality data. The cumulative weight (w_i) is calculated according to Majeed et al. (2016) from Table 3 where the values of (w_i) are normalized and therefore when combined they are equal to 1.

The water quality index is calculated from the following Equation 2:

$$IWQI = \sum_{i=1}^{n} q_i\, w_i \qquad (2)$$

Where (IWQI) is the irrigation water quality index and it is a non-dimensional value between 0 and 100. For any sample, the higher value of (IWQI) gives the best quality of water according to Table 4 (Bernardo, 1995; Holanda & Amorim, 1997).

Table 2

Water quality measurement (qi) parameter limiting value adopted from Ayers & Westcot (1985)

q_i	**EC (µs/cm)**	**SAR $(meq/L)^{0.5}$**	**Na^+ (meq/L)**	**Cl^- (meq/l)**	**HCO_3^- (meq/l)**
85-100	$200 \le EC < 750$	$SAR < 3$	$2 \le Na < 3$	$Cl < 4$	$1 \le HCO3 < 1.5$
60-85	$750 \le EC < 1500$	$3 \le SAR < 6$	$3 \le Na < 6$	$4 \le Cl < 7$	$1.5 \le HCO3 < 4.5$
35-60	$1500 \le EC < 3000$	$6 \le SAR < 12$	$6 \le Na < 9$	$7 \le Cl < 10$	$4.5 \le HCO3 < 8.5$
0-35	$EC < 200$ or $EC \ge 3000$	$SAR \ge 12$	$Na < 2$ or $Na \ge 9$	$Cl \ge 10$	$HCO3 < 1$ or $HCO3 \ge 8.5$

Table 3

IWQI parameters weights (w_i) adopted from Majeed et al. (2010)

Parameters	**w_i**
EC	0.211
Na^+	0.204
HCO_3^-	0.202
Cl^-	0.194
SAR	0.189
Total	1

Table 4

Irrigation water quality index features adopted from Bernardo (1995) and Holanda and Amorim (1997).

WQI	Water use restrictions	Recommendation	
		Soil	Plant
85-100	No restriction (NR)	It can be used for most soils with a low potential to cause salinity and sodium problems, and filtration is recommended within irrigation practices, except for soils with very low permeability.	There are no toxic risks for most plants
70-85	Low restriction (LR)	It is recommended for use on irrigated soils with light texture or moderate permeability, and salt filtering is recommended. Soil sodium may occur in soils with heavy texture, and it is recommended to avoid their use on soils with high clay levels of 2: 1.	Avoid plants that are sensitive to salt
55-70	Moderate restriction (MR)	It can be used on soils with medium to high permeability values, while suggesting moderate salt leaching.	Plants with moderate salt tolerance can be grown.

Table 4 *(continue)*

WQI	Water use restrictions	Recommendation	
		Soil	Plant
40-55	High restriction (HR)	It can be used on soils with high permeability without compact layers. A high frequency irrigation schedule should be adopted for water with an EC higher than 2.000 dS m-1 and SAR above 7.0.	It should be used to irrigate plants with medium to high salt tolerance with special salinity control practices, with the exception of water with low values of sodium, chloride, and HCO3.
0-40	Severe restriction (SR)	Its use for irrigation should be avoided under normal conditions. In special cases, they may be used occasionally. Water with low levels of salt and a high specific absorption rate requires the application of gypsum. In soils with high salt content, the soil should be of high permeability, and excess water should be used to avoid salt accumulation.	Only plants with high salt tolerance, except for water with very low values of Na, Cl and HCO3

Note: SR – severe restriction; HR – high restriction; MR – moderate restriction; LR – no restriction.

RESULTS AND DISCUSSION

Water Quality Parameters and Spatial Distribution

The statistical parameters represented by the mean and standard deviation (SD) of the ten water quality parameters are presented in Table 5. It is noted that the mean rate in the dry season of the concentration of most water quality data exceeds the mean in the wet season for the same year due to the dilution process during high levels of water in the wet season (Hassan et al., 2017). Using the program (ArcGIS) and by taking advantage of interpolation and drawing the spatial distribution on the map of the region under study for the average concentration of the ten water quality parameters, which includes the locations of wells numbered from 1 to 24 as shown in Figures 3 and 4.

pH Effect. pH is affected by dissolved salts in groundwater such as carbonates, bicarbonate, silicates, fluorides, and other salts in the dissociated form. High values (pH) indicate the presence of sodium and low values reflect the presence of free acids in water (Kushwah et al., 2012). The spatial distribution shows that the values of the (pH) are closely related and rise in the southern part (well 14 and 20) and the northwestern (well 11, 12, and 19). It decreases in the eastern part (well 20, 22 and 24) and the northern (well 10 and 7) on the map. The amount of the value of (pH) ranges from 7.01 to 7.93 with an average value of 7.32. These values are all within the parameters of the Food and Agriculture Organization (FAO) (6.5-8.5) (Ayers & Westcot, 1999).

Electrical Conductivity (EC) Effect. EC is a good indicator for measuring the amount of dissolved solids in groundwater; therefore, it is used to detect pollutants in water. Through

Table 5

Statistical parameters of water quality data.

Year & season	Parameter	pH	EC (µs/cm)	TDS (mg/L)	K (mg/L)	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	Cl (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	SAR
2018 Dry	Min.	7.11	1518	1220	0.975	208.84	20.16	43.4	157.85	113	106.3	2.32
	Max.	7.77	10190	8021	124.8	736	133	250	1200	866	955	8.82
	Mean	7.28	5158.17	3746.33	42.60	421.94	63.51	128.74	662.65	545.88	527.90	5.57
	SD	0.17	2796.21	1995.23	43.84	145.15	35.33	57.68	239.48	235.23	226.49	1.67
	No. of samples	24	24	24	24	24	24	24	24	24	24	24
2018 Wet	Min.	7.01	900	621	1	68	20	39	159	96	90	1.15
	Max.	7.71	8310	6956	91	502	125	195	856	655	704	7.04
	Mean	7.34	3323.58	2702.04	26.51	294.92	57.00	103.55	422.88	353.94	329.54	4.10
	SD	0.21	2193.36	1670.43	30.33	137.73	31.24	40.47	196.77	164.38	167.90	1.67
	No. of samples	24	24	24	24	24	24	24	24	24	24	24
2019 Dry	Min.	7.07	1688	1430	2.2	208.84	50	111	302	520	208	1.76
	Max.	7.93	6570	5300	80	575	188	366	800	1412	676	5.32
	Mean	7.32	4025.58	3062.88	44.51	416.63	130.88	245.67	571.06	987.08	458.72	3.81
	SD	0.21	1421.23	1068.83	25.73	103.93	41.14	74.21	121.19	257.64	124.15	0.81
	No. of samples	24	24	24	24	24	24	24	24	24	24	24
2019 Wet	Min.	7.09	1628	1723	2	128	5.16	17.6	181	295.68	181	1.49
	Max.	7.91	6120	4116	66	580	159	360	781	1290	551	18.15
	Mean	7.34	3839.88	2656.67	22.93	357.71	65.81	138.72	452.08	719.07	342.96	5.23
	SD	0.24	1219.53	681.90	19.59	135.49	44.72	87.82	189.73	285.10	114.41	3.17
	No. of samples	24	24	24	24	24	24	24	24	24	24	24

measuring electrical conductivity, one can gain the concentration of salts and mineral substances in groundwater (Deshmukh, 2013). Noting the spatial distribution of (EC), their values are high in the eastern parts (wells 20, 21, 22, and 24), the far west (wells 12, 16 and 19) and low in the central western part (wells 1, 6, 7, 8, 9, and 10) of the map. It is noted that the values of electrical conductivity were confined between 1518 µs / cm) and 10190 µs / cm) for the dry season of the year 2018. According to the specifications of FAO, (31%) of all groundwater samples are moderate salinity (700– 3000 µs/cm) and the rest are very salty (above 3000 µs/cm).

Total Dissolved Solids (TDS) Effect. Dissolved solids consist of water leaching through the soil, dissolved limestone, gypsum, rocks exposed to erosion and other salts. The flow of water through the subsurface and geological formations carries with it many salts and dissolved ions, thus changing the quality of the groundwater (Jain et al., 1997). Increasing concentrations of dissolved salts such as sodium, magnesium, chlorides, sulfates, and calcium carbonate in addition to human activities will contribute to increase the amount of salinity in the groundwater and thus increasing the amount of TDS (Salama et al., 1999). Through the spatial distribution of (TDS), it is noted that its values are high in the eastern parts (wells 20, 21, 22, and 24), the far west (wells 12, 16, and 19). Yet, it is low in the central western part (wells 1, 6, 7, 8, 9, and 10). The lowest value for (TDS) is (1220 mg /L) at the highest value (8021 mg /L) in the dry season of 2018. The food and agriculture organization has determined the values of (TDS) as causing a slight to moderate restriction in the use of irrigation water (Slight to Moderate of Restriction on use if its value is between (450-2000 mg/L) and severe restriction if it increases above this limit. It was noted that 25% of the measured samples with TDS values were described as slight to moderate restriction and the rest were highly restricted water in use.

Cation (K^{2+}, Na^+, Mg^{2+} and Ca^{2+}) Effect. The most important sources of cation in groundwater are weathering processes of soil and rocks, whether sedimentary or igneous, and human activities. They reach groundwater by filtering water through the soil (Sravanthi & Sudarshan, 1998; Basha et al., 2010; Lateef, 2011). Mostly, the spatial distribution shows that the values of cations on the map are high in the southeast and northwestern part and decrease in the eastern and northern part on the map. Through Table 5, the lowest values were (K= 0.975 mg/L in the dry season of 2018, Na^+= 68 mg/L for the wet season of the same year, Mg^{2+} = 5.16 mg/L for the wet season of 2019 and Ca^{2+} = 17.6 mg/L for the wet season of 2019). The highest values were (K^{2+} =124.8 mg/L is in the dry season of 2018, Na^+ = 736 mg/L, for the wet season for the same year, Mg^{2+} = 159 mg/L for the wet season for 2019 and Ca^{2+} = 366 mg/L for the dry season of the same year). The acceptable limitations for positive elements are (K^{2+} <10 mg/L, Na^+ <50 mg/L, Mg $^{2+}$ <24 mg/L, Ca^2

$^{+}$ <120 mg/L). For four seasons, the results of the groundwater analysis showed that 65%, 100%, 90% and 60% of the observed values for K^{2+}, Na^{+}, Mg^{2+} and Ca^{2+} respectively, are higher than the desired limits.

Anion (Cl^{-}, SO_4^{2-}, HCO^{3-}) Effect. The important source of chloride salts (Cl^{-}) in groundwater is weathering processes for rocks and soil and are transported to groundwater by filtration. While sulfates (SO_4^{2-}), groundwater reaches it through weathering processes of (sulphide-bearing) or soil can be another source for sulfates. Further, evaporation deposits can also be a source for sulfates. Another important source is airborne pollutants containing sulfur oxides and converts them to sulfuric acid during rain fall to filter into the soil (Singh et al., 2012; Mallick, 2017). Having bicarbonate ions (HCO_3^{-}) in groundwater is associated with the presence of magnesium and calcium ions or is released from rocks, soil and the disintegration of the gypsum or the presence of carbon dioxide and calcium carbonate water that interact in the presence of water to produce (HCO_3^{-}) (Ravikumar & Somashekar, 2015; Al-Qawati et al., 2018). In general, the spatial distribution of anions values on the map shows that they are high in the southern part and somewhat western part and low in the northern part excepting the wells 12 and 13 on the map. The lowest value was (Cl^{-}=157.85 mg/L in the dry season, SO_4^{2-} = 96 mg/L, for the wet season, and HCO_3^{-} = 90 mg/L for the wet season) for the year 2018. As for the highest value of Cl^{-} =1200 mg/L in the dry season of 2018, SO_4^{2-} = 1412 mg/L, for the dry season of 2019, and HCO_3^{-} = 955 mg/L for the season dry for the year 2018. Allowed values for negative elements are (Cl^{-} <140 mg/L, $SO4^{2-}$ <400 mg/L, HCO_3^{-} <120 mg/L). For four seasons, the results of the groundwater analysis showed that 100%, 75% and 97% of the values of Cl^{-}, SO_4^{2-} and HCO_3^{-}, respectively, were higher than the permissible values.

Sodium Absorption Ratio (SAR). SAR is an important component for assessing the validity of irrigation water. The higher the sodium concentration in irrigation water is the more sodium absorption will increase. This reduces the validity of irrigation water. The effect of irrigation water on soil permeability to water depends on the interference between the flocculating effects of specific conductance and the diffusion effect of sodium. If the specific conductance is high, this increases the soil's tolerance to water with a high SAR (Bhat et al., 2018). The distribution of the value of (SAR) spatially distributed scattered over the directions of the map may seem high for wells (4, 10, 12, 16, and 22), and low for other wells (7, 14, 17, 18, and 21). The FAO organization has defined different ranges of the value of (SAR). The higher the electrical conductivity is the greater the negative impact of the (SAR) on the water viability for irrigation purposes. The maximum value was in the dry season of the year 2018 and was (SAR = 5.27). The lowest value (SAR = 1.49) was in the wet season of 2019 and is somewhat close to the corresponding value in the year 2018 (SAR = 1.51). For SAR values between (0-3 and 3-6), the values of (EC) were (<700,700-2000 and > 2000 µs / cm) leading to problems ranging from zero-effect, medium to high-impact, respectively.

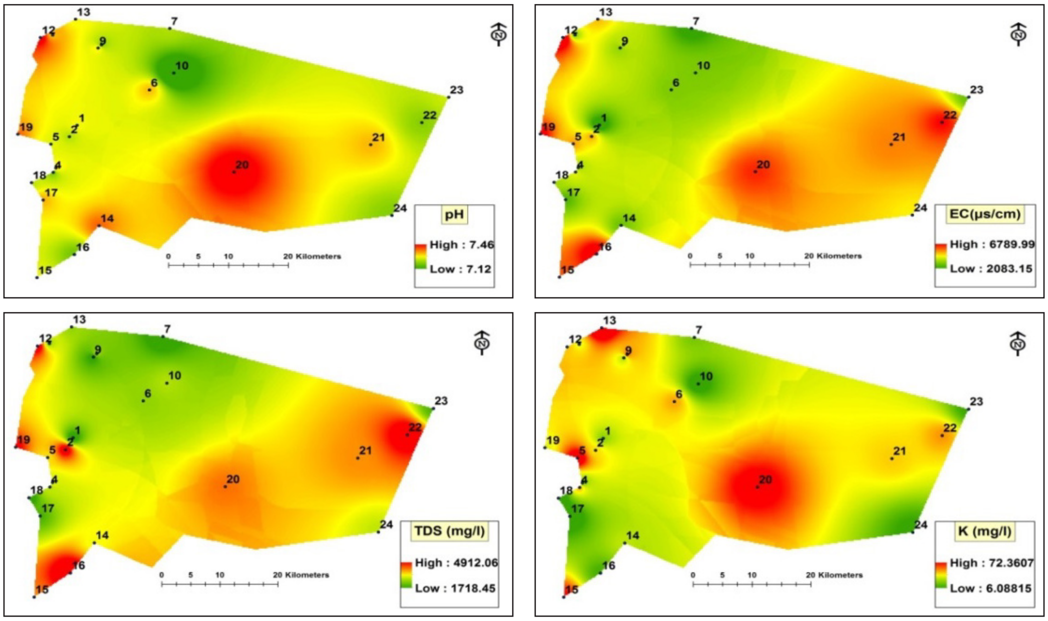

Figure 3. Spatial distribution of average of pH, EC, TDS and K$^+$ in the studied area

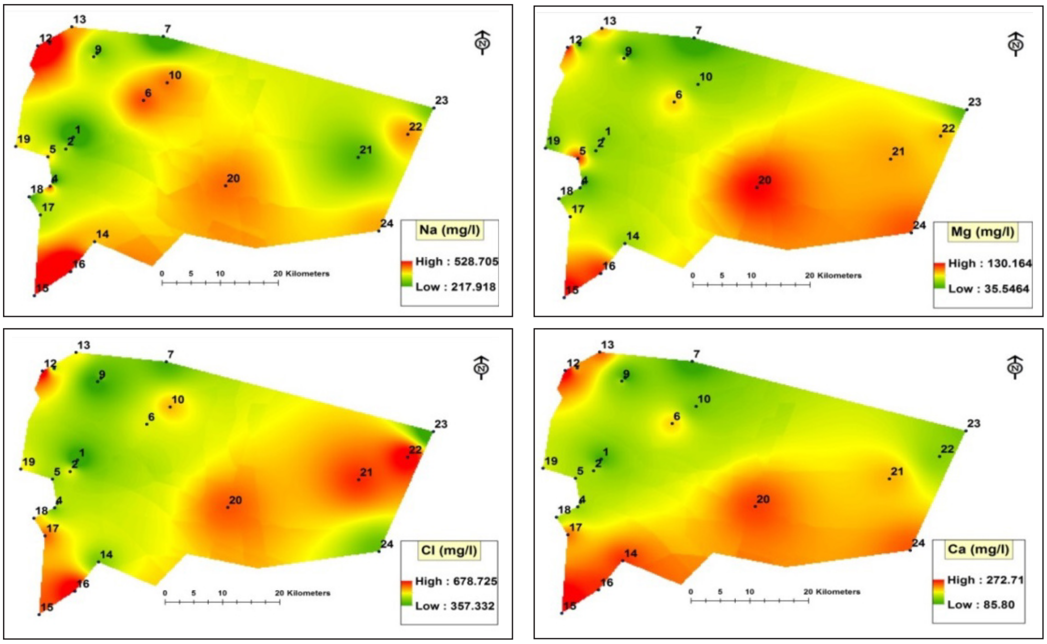

Figure 4. Spatial distribution of average Na$^+$, Mg^{2+}, Ca^{2+}, Cl$^-$, SO4$^-$, HCO$_3^-$ and SAR in the studied area

Irrigation Water Quality Index (IWQI)

Based on Equations 1 and 2 as well as Table 2 and 3, the Water Quality Index (IWQI) for the dry and wet seasons of 2018 and 2019 for all wells was calculated. The values of (IWQI) are shown in Figure 5. Figure 5 shows the changes in the values of (IWQI) over the four seasons of most wells where the highest values of (IWQI) were in the wet season of 2018 and the lowest values in the dry season for the same year. The annual rate of (IWQI) values were calculated for each season separately and as in Table 6. Table 6 shows that the water quality in the wet season is of higher value (IWQI) than most of the dry season for most wells. In general, the high-water levels in the wet season in the Hilla River and the branching irrigation canals raise the water level (Al-Amar, 2015). Consequently, this reduces the concentrations of water quality elements due to dilution which leads to high values of (IWQI) and improvement of groundwater quality accordingly. By comparing the values of (IWQI) with the determinants in Table 4, the quality of the well water can be classified into several classes, as shown in Table 7. For example, (67%) of the wells in the dry season of 2018 can be classified under the category (SR) and (29%) and (4%) of the

Table 6
Wells IWQI of each season and year

Well No.	Mean of IWQI		Overall mean of IWQI	Well No.	Mean of IWQI		Overall mean of IWQI
	Dry	Wet			Dry	Wet	
1	43.08	58.81	50.95	13	31.25	53.20	42.22
2	32.58	51.89	42.24	14	45.93	44.66	45.29
3	39.55	56.23	47.89	15	29.60	42.31	35.95
4	30.58	46.52	38.55	16	26.77	34.86	30.81
5	35.46	39.79	37.62	17	46.68	43.45	45.07
6	40.16	41.05	40.60	18	51.87	48.93	50.40
7	41.96	66.72	54.34	19	34.28	44.15	39.21
8	36.32	49.27	42.80	20	26.94	48.63	37.78
9	47.66	56.97	52.31	21	32.17	47.82	40.00
10	35.49	45.69	40.59	22	26.18	43.21	34.70
11	40.45	40.53	40.49	23	37.38	63.16	50.27
12	25.50	36.53	31.01	24	35.29	39.08	37.19

Table 7
IWQI classification of groundwater quality

IWQI	Water Use Restrictions	2018		2019	
		Dry	Wet	Dry	Wet
0-40	SR	67%	37.5%	62.5%	41.7%
40-55	HR	29%	33.3%	37.5%	45.8%
55-70	MR	4%	8.3%	....	12.5%
70-85	LR	......	20.8%	.....	......

wells under the category (HR) and (MR), respectively, and so on. Through the schedule, we can say that these wells in the best conditions suffer from restrictions in use for irrigation purposes and the problem is more than that in the dry season.

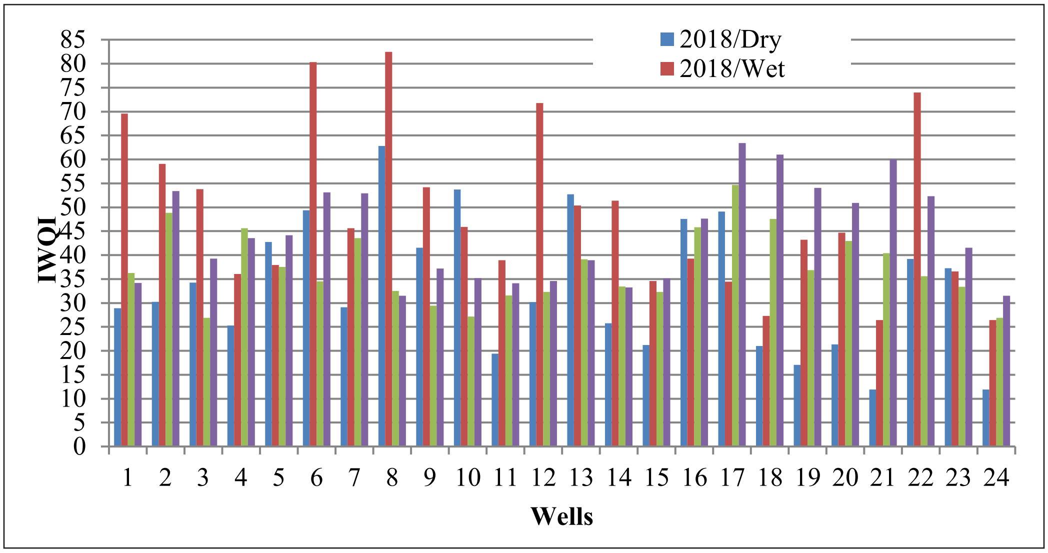

Figure 5. The four seasonal variation at each well is shown starting with 2018 (dry), 2018 (wet) followed by 2019 (dry) and lastly 2019 (wet).

CONCLUSION

The main conclusions of this study can be summarised as:

1. The values of (IWQI) were higher in the wet season than in the dry season, since the dry season results in a decline in the discharge of the Hilla River and its branches, which provides fresh water to the region's wells.
2. The spatial distribution shows that there is a slight variation of pH values with an irregular change in the values of (SAR) for all wells and for the years of study in its dry and wet seasons.
3. High (EC) and (TDS) levels in groundwater suggest high salinity, which is caused by soil leaching. It is hard to use for direct irrigation. The spatial distribution of EC and TDS is high in the eastern and western parts of the area map, but low in the central western parts.
4. For the positive ions, 65%, 100%, 90%, and 60% of observed values K^{2+}, Na^+, Mg^{2+} and Ca^{2+}, respectively, were higher than the permissible limits. The spatial distribution on the map is high in the southeastern and northwestern part and low in the eastern and northern part. As for the negative ions, 100%, 75%, and 97% of the values for Cl^-, SO_4^{2-}, and HCO_3^-, respectively, were also higher than the

permissible limits. The spatial distribution on the map is high in the southern part as well as the part Western and low in the northern part.

5. The SAR values do not cause significant problems in filtering the main components into the soil. (85%) of (SAR) values between (3-6) and (EC) values greater than (1200 µs / cm). 15% of the SAR values between (0-3) where EC are greater than (700 µs/cm). The spatial distribution of SAR values is random on the map, depending on the change in sodium concentrations.
6. For dry and wet seasons, a large percentage of wells have poor water quality and need relatively high permeability soils and salt-resistant plants.

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