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GROUNDWATER QUALITY ASSESSMENT FOR IRRIGATION PURPOSE USING WATER QUALITY INDEX IN GREEN BELT PROJECT IN KARBALA CITY- IRAQ

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Abstract

The term water quality index is a method for combining multiple water quality data with a single numerical value. This value is indicative of the potential for water use in different consumer sectors such as the irrigation sector.The aim of the current study is to assess the groundwater of Green-Belt project which is a part of Dibdibba quarter within the boarder of Karbala governorate/Iraq for irrigation purposes. Groundwater samples were taken from (20) wells selected in study area in April 2019. The required measurements were conducted for each of these samples and the values of the following parameters were found; (pH), (EC), (K^{+1}), (Ca^{+2}), (Mg^{+2}), ($Na^{+1,}$ (Cl^{-1}), (SO_4^{-2}) and (HCO_3^{-1}). The Canadian Water Quality Index Model for Irrigation (CIWQI) and The Irrigation Water Quality Index Model (IWQI) presented by Meireles were applied to groundwater sampling test data. The results showed that the (CIWQI) values ranged from (20-38) and the groundwater quality for all wells were classified under "Poor water categories". The (IWQI) values ranged between (25 -51) and the assessment of ground water quality showed that there were (50%) of the wells lies in "Severe Restrictions (SR) category" while 50% of the wells lies in "High Restriction (HR)category". This means avoiding the cultivation of plants sensitive to salts in the study area and turning to cultivation of plants with moderate to high tolerance of salts.

Keywords: Canadian water quality index, Groundwater quality, Green belt project, Karbala city.

1. Introduction

Groundwater has gained great global importance due to the need it of use in various purposes like agricultural, industrial and domestic. Many reports indicate that more than 33% of human water needs and more than 50% of drinking water needs in villages around the world are provided by groundwater and the world's food that produced by irrigation depends on groundwater by 40% [1]. Surface water that enters to Iraqi borders from neighbouring countries has been decreased in quality and /or deteriorating quality in recent years. As a result, specialists have begun to develop a new strategy to provide alternatives to increase the country's freshwater resources.

The middle region of Iraq contains large reservoirs of good quality groundwater. The cost of extracting this water is low because its levels are near to the ground surface. Therefore, adopting the trend towards the use of groundwater, especially in the agricultural sector, can be considered one of the successful solutions to compensate for the shortage of surface water in Iraq and provide the necessary water requirements [2].

The quality and quantity of water entering to the Iraqi borders in the past years have been greatly affected for several reasons including; large dams implemented in neighbouring countries (Turkey, Syria, and Iran) on the source of the Tigris and Euphrates, large agricultural projects implemented and planned in the Eastern Anatolian Turkey, reduced annual local rainfall, and poor management of water use for various purposes in Iraq [3]. The agricultural sector in Iraq appears to be the most affected sector in the dry seasons because the amount of water consumed by this sector is 75% of the total water resources. This is evident in 2008 and 2009, when the drought has damaged nearly 40% of Iraq's agricultural land [4].

Poor groundwater quality has major impacts on soil and crop yields. Therefore, it is necessary to provide great care in managing the quality of this water in order to reduce or eliminate these effects significantly ,The risk of increasing salinity of groundwater when used for irrigation is a constant threat to irrigated agriculture. The different chemical composition of this water may be related to its toxicity and thus affect plant growth [5].

Groundwater quality varies depending on many factors such as; nature and components of water that feed aquifers entering from nearby water bodies, the type and composition of some salts and rocks that come into contact with groundwater during its movement in the unsaturated soil profile zone, and the quality of the chemical pollutants resulting from the leakage of wastewater to the soil surface and then to the groundwater reservoirs [6].

The application of groundwater quality standards is adopted to demonstrate the suitability of groundwater quality according to its purpose. The Water Quality Index (WQI) is a fast, effective and verifiable tool for the suitability of groundwater quality for irrigation. This index is obtained through a number of mathematical processes that can convert a large amount of water quality data to a single number to enable the decision-maker to make an appropriate judgment on water quality and appropriate uses [7].

Meireles et al. [8] developed the model of Irrigation Water Quality Index (IWQI), which was used to classify groundwater quality for irrigation in the Acarão Basin city located in the northern state of Carrara, Brazil.

This model was created based on a number of parameters, such as EC, Na^{+1}, Cl^{-1} and HCO_3^{-1}. These parameters have a significant impact on the water quality of irrigation and can reflect the risk of soil salinity and water toxicity in plants. Hari Siswoyo et al. [9] produced a study to assess the groundwater quality for irrigation in Jombang Regency, East Java, Indonesia, this study was based on the IWQI techniques, and the groundwater quality was classified and found to range between moderate restriction and low resection for irrigation.

Asante et al. [10] conducted a study to assess the suitability of groundwater for irrigation in the Lambussie-Karni region of Ghana by using a new model (IWQI), this model is derived from the linear combination of the problems of salinity. These problems are the infiltration and permeability, the specific ion toxicity; the toxicity to trace elements, and the problem of various effects on sensitive crops.

Abbasnia et al. [11] presented a study to assess the quality of groundwater in three villages in Iran; a set of groundwater quality distribution maps for irrigation in these villages was prepared by using the combination of IWQI concepts and GIS technology.

In Iraq, several studies were conducted to assess the quality of groundwater and demonstrate its suitability according to the purpose of its use. Al-Hadithi [12] presented a study based on the combination of (IWQI) concepts and ArcGIS technology in order to assess the suitability of groundwater quality for irrigation, the study concluded to provide a distribution of (IWQI) values in different locations in the western region of Iraq.

Al-Kubaisi et al. [13] presented a study to Mapping groundwater quality Index for irrigation in the Dibdibba aquiferat Karbala - Najaf plateau, central of Iraq. This spatial distribution indicated that groundwater when classify according to irrigation purpose is generally of moderate quality in the Dibdibba aquifer.

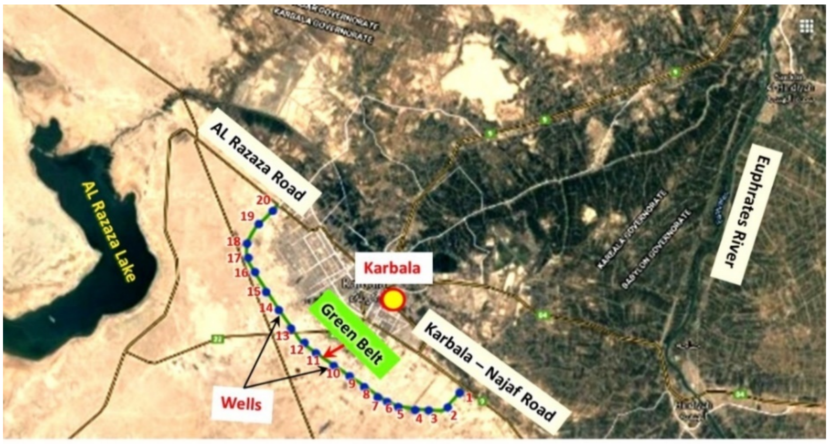
Al Maliki et al. [7] conducted a study to assess the suitability of groundwater for irrigation in an agricultural area near the city of Kufa, in the north of Najaf, Iraq. Final WQI values were linked with the ArcMap environment to produce final WQI maps for the study area. The results of this study showed that all groundwater samples in the study area are suitable for cultivation.

Other researchers have studied many projects in the same city of study area; Abd et al. [14] conducted a study in Karbala/Iraq to assess the groundwater of the Debdaba formation and the possibility of using it for irrigation purposes using the Water Quality Index. The IWQI values were mapped using the IDW method and other studies conducted to assess the quality of groundwater in the Green Belt and Dibdibba aquifer for irrigation purposes. All of these studies were based on the combination of IWQI and ArcGIS techniques, for mapping that shown the distribution of IWQI for the study area [14-18].

The aim of the current study is to assess the quality of groundwater in the southwestern green- belt of Karbala and to determine its suitability for irrigation purposes. To achieve this goal, two models were used: the first is the Canadian Irrigation Water Quality Index (CIWQI) model and the second is the Irrigation Water Quality Index (IWQI) model. Based on the results, the necessary measures are recommended to provide a good groundwater quality management that can contribute to increasing the productivity of plants and crops grown in the area.

2. Study Area

Karbala city is located geographically in the central region of Iraq, about 100 km south of the Iraqi capital (Baghdad). This city has an important religious character, with an area of about 5,000 km^2 and a population of about 1.5 million people [16]. The study area was selected in the Green Belt project ,which are located between latitudes (32° 31′ 33″N - 32° 39′ 31″N), and longitudes (44°03′ 07″E -43° 55′ 53″E), and it has an area about (100) km^2. The Green Belt surrounds Karbala city from the southwest in the desert region and begins from Karbala-Razaza road to Karbala-Najaf road. The Euphrates River is located to the east of study area, while Al-Razazah Lake is located to its west as shown in Fig. 1. The Iraqi government began implementing the Green Belt project for Karbala city in 2006 and it was completed in 2010. This project gets great attention from the researchers and directorates of environment, agriculture and irrigation in the city, because it achieves several objectives including; improving the environment, treating desertification and planting fast growing eucalyptus trees, which serves as windbreaks coming to the city as well as growing a large number of olive and palm trees. The drip irrigation system is used to irrigate the project trees by using groundwater that is pumped from wells that have been drilled for this purpose. It is noting that the groundwater represents the main source of irrigation in all farms that cover large areas behind this project [15-17].



The climate of the study area is characterized by hot, dry summer accompanied by a high rate of evaporation and cold winter with a decrease in the rate of precipitation. For these reasons, it should be directed towards assessing the quality of groundwater and its suitability for agricultural use as a successful alternative in times of water scarcity [15]. Al-Sudani [6] described the Dibdibba aquifer that forms the rocky foundation of the desert extending between the two cities Karbala and Najaf. Geologically the study area is part of the Dibdibba formation within the boundaries of Karbala governorate, Dibdibba formation is unconfined aquifer, it consists of Sandstone with fine gravel, clay siltstone, and silty clay stone and it was covered with gypsum and sandy soil layers. The actual utilization of groundwater of the study area began in the mid of 1980s for irrigation purpose .The total number of wells operated and exploited in the Dibdibba aquifer exceeded 3,000 water wells

[13]. In this project, more than 100 wells were drilled at depths ranging from 36-50 m. Groundwater is withdrawn in large quantities daily from these wells to provide irrigation requirements for the project. All these wells penetrated the regional unconfined aquifer, 18 basins of different size were built along the project in order to addresses low water production, where ponds are filled with water and then pumped [16].

In the current study, twenty groundwater wells were chosen in the Green Belt region in order to assess the suitability of their water for irrigation. Table 1 shows the coordinates of these wells.

Table 1. The coordinates of the wells in the study area.

Well No.	Coordinates				Well No.	Coordinates			
1	N	32°	32'	17.617"	11	N	32°	33'	38.088"
	E	44°	03'	58.165"		E	44°	00'	22.324"
2	N	32°	32'	19.834"	12	N	32°	33'	46.9872"
	E	44°	03'	42.116"		E	44°	00'	6.08"
3	N	32°	32'	23.082"	13	N	32°	34'	15.402"
	E	44°	03'	24.448"		E	43°	59'	17.639"
4	N	32°	32'	26.0484"	14	N	32°	34'	26.742"
	E	44°	03'	4.748"		E	43°	58'	58.336"
5	N	32°	32'	26.5488"	15	N	32°	34'	33.1752"
	E	44°	02'	40.589"		E	43°	58'	50.592"
6	N	32°	32'	54.96"	16	N	32°	34'	46.2072"
	E	44°	01'	36.797"		E	43°	58'	39.626"
7	N	32°	33'	6.5952"	17	N	32°	35'	43.008"
	E	44°	01'	17.155"		E	43°	57'	56.862"
8	N	32°	33'	15.7536"	18	N	32°	35'	50.568"
	E	44°	01'	0.566"		E	43°	57'	48.258"
9	N	32°	33'	24.4944"	19	N	32°	38'	3.7824"
	E	44°	00'	44.597"		E	43°	57'	6.16"
10	N	32°	33'	30.9996"	20	N	32°	38'	17.2896"
	E	44°	00'	33.714"		E	43°	57'	6.001"

3. Materials and Methods

This paragraph includes the method of selecting groundwater samples and determining the variables affecting the determination of well water quality. This paragraph also addresses how to calculate the water quality index value by using more than one model.

3.1. Sampling of groundwater

Twenty wells were selected in the Green Belt project of study area in Karbala city, the coordinates of these wells were determined by using the (GPS), and then recorded in Table 1. Satellite image of the study area and the location of these wells are shown in Fig. 1, Groundwater samples were collected from these wells in April 2019 by using dry and clean 3-liter plastic containers. Each water sample was analysed for the following parameters; Acidity/Passivity (pH), Electrical conductivity (EC), Potassium (K^{+1}), Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Sodium (Na^{+1}), Sulphate (SO_4^{-2}), Chloride (Cl^{-1}) and Bicarbonate (HCO_3^{-1}). It should be noted that measurements were carried out in the Central Water Laboratory of the Karbala Agriculture Directorate, according to the standard specification adapted from APHA [19]. Table 2 shows the parameters and their units, type of analysis and specification number that was adopted in each test.

Table 2. Water quality parameters, units, and standard test methods techniques [19].

Parameters	Nomenclatures	Type of analysis	APHA reference method
Acidity/Passivity	pH	Electrometric Method	4500-H^+ B
Conductivity	EC	Laboratory Method	2510- B
Potassium	K^{+1} (mg/l)	Flame Photometric Method	3500-K D
Calcium	Ca^{+2}(mg/l)	EDTA Titrimetric Method	3500-Ca B
Magnesium	Mg^{+2} (mg/l)	EDTA Titrimetric Method +Calculation Method	3500-Mg B
Sodium	Na^{+1}(mg/l)	Flame Photometric Method	3500-Na B
Chloride	CL^{-1} (mg/l)	Argentometric Method	4500-Cl B
Sulphate	$SO4^{-2}$ (mg/l)	Gravimetric Method	4500-$SO4^{-2}$ C
Bicarbonate	HCO_3^{-1}(mg/l)	Titration Method	2320 B

3.2. Canadian irrigation water quality index (CIWQI) model

The (CIWQI) model consists of three factors (scope, frequency amplitude). By feeding the expressions and sub expressions of these three factors; Eqs. (1) to (7) [20], with the required water quality data, a single value is obtained that represents the(CIWQI).The range of the value of this index is between 0 -100 . Within this range, the quality of irrigation water can be classified into five categories, shown in Table 3.

Table 3. Canadian irrigation water quality index (CIWQI) categorization schema [20].

CIWQI	Rank	Description
95–100	**Excellent**	Water quality is protected with a virtual absence of threat or pristine levels. These index values can only be obtained if all measurements are within objectives virtually all of the time.
80–94	**Good**	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
65–79	**Fair**	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
45–64	**Marginal**	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
0–44	**Poor**	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

The following factors are used to determine the (CIWQI) for current study; F_1 (Scope); the percentage of parameters that deviates from their standard values; No. of failed parameters, divided by the total number of parameters selected

$$F_1 = \left[\frac{(NFP)}{(TNP)}\right] \times 100 \tag{1}$$

in which; NFP = No. of failed parameters and TNP = total No. of parameters.

F_2 (Frequency); the percentage of individual measurements that deviates from their standard values; No. of failed measurements", divided by the total number of measurements

$$F_2 = \left[\frac{(NFM)}{(TNM)}\right] \times 100 \tag{2}$$

in which; NFM= No. of failed measurements and TNM = total No. of measurements

F_3 represents the amount by which failed measurements values that deviate from their standard values, F_3 called also; (amplitude) and can be calculated by the following steps [20]:

Step 1: Finding the value of term; (Excursion); which represents the number of times by which the measurement value is exceeding the standard value, (or the measurement value is less than the standard value if the standard value is the minimum value). There are two cases in calculating Excursion:

a) When the measurement value must not be greater than the standard value

$$EX_i = \left[\frac{(FMV_i)}{(S.V.)}\right] - 1) \quad (3)$$

in which EX_i: :excursion i, FMV_i: failed measurement value i and S.V.: standard value

b) When the measurement value must not be less than the standard value

$$EX_i = \left[\frac{(S.V.)}{(FMV_i)}\right] - 1 \quad (4)$$

Step 2: Normalized sum of Excursions can be calculating by the dividing the summation of excursions on the total number of measurements as follows

$$NSE = \left[\frac{\{\sum_{i=1}^{n}(EX_i)\}}{(TNM)}\right] \quad (5)$$

in which; NSE = normalized sum of excursions and TNM = total No. of measurement

Step 3: F_3 can then be determined by the following expression

$$F_3 = \left[\frac{(NSE)}{(0.01\ NSE+0.01)}\right] \quad (6)$$

Finally, the value of CIWQI can be obtained according to Eq. (7) [20] as, follows;

$$CIWQI = 100 - \left[\frac{\sqrt{(F_1{}^2+F_2{}^2+F_3{}^2)}}{1.732}\right] \quad (7)$$

3.3. Irrigation water quality index (IWQI) model

In order to operate the (IWQI) model presented by Meireles et al. [8] on the observed irrigation groundwater quality data, a clear path was adopted according to the following steps:

I. Identify and select the parameters that are closely related to irrigation uses; EC Na^{+1}, HCO_3^{-1}, Cl^{-1}, and SAR°
II. The quality measurement Qi values for each parameter were calculated using Eq. (8) [8], based on the measured water quality data and the criteria of limits of tolerance shown in Table 4

$$Qi = Qi_{max.} - \left[\frac{(Xij - X_{inf}) * Qi_{ampl.})}{X_{ampl.}}\right] \quad (8)$$

where Qi_{max} represents the maximum value of (Qi) in Table 4 for the category in which the parameter is located.

x_{ij} is the measured value for the parameter; x_{inf} is the value that represent the lower limit of the category to which the parameter is located.

Qi_{ampl} represents category ampleness; $x_{ampl.}$, is a category ampleness in which the parameter is located. It should be noted that the highest measured value is taken into consideration as the highest limit when finding ($x_{ampl.}$), for the last category of each parameter.

III. The weight for each parameter (w_i) is listed as in Table 5. Weight is given to each parameter based on the ratio of the influence of that parameter on the quality of the groundwater for irrigation.

IV. From what is found in steps 2 and 3 above, the IWQI can be determined according to formula in Eq. (9) [8], as follows

$$IWQI = \sum_{i=1}^{n}(Qi \times wi \quad (9)$$

IWQI values range from 0 to 100; (Qi) is the Quality rating measurements of the i^{th} parameter; w_i is the weight of the i^{th} parameter

V. Based on the calculated values of IWQI, the groundwater is classified into categories according to the classification in Table 6. The divisions in categories for this classification show the restrictions imposed on the use of irrigation water in terms of soil and plant problems. In other words, this division takes into consideration both ; soil salinity risks , problems of decreasing soil water infiltration rate , the problems of toxicity in plants and other various effects on sensitive crops [8].

Table 4. Limiting values for the quality measurement; Qi calculation [8].

Q_i	EC dS /m	SAR° $(meq/l)^{1/2}$	Na^{+1}	Cl^{-1}	HCO_3^{-1}
			meq/l		
85-100	0.20 ≤ CE< 0.75	2 ≤ SAR° < 3	2 ≤ Na < 3	1 ≤ Cl < 4	1 ≤ HCO_3<1.5
60-85	0.75 ≤ CE < 1.50	3 ≤ SAR° < 6	3 ≤ Na < 6	4 ≤ Cl < 7	1.5 ≤HCO_3<4.5
35-60	1.50 ≤ CE< 3.00	6 ≤ SAR° <12	6 ≤ Na < 9	7 ≤ Cl <10	4.5 ≤HCO_3<8.5
0-35	EC < 0.20 or EC ≥ 3.00	SAR° < 2 or SAR° ≥ 12	Na < 2 or Na ≥ 9	Cl < 1 or Cl ≥10	HCO_3< 1 or HCO_3 ≥ 8.5

Table 5. Weights for the parameters that considered in irrigation water quality index (IWQI) model [8].

Parameter	EC	Na^{+1}	HCO_3^{-1}	Cl^{-1}	SAR°	Total
Weight (Wi)	0.211	0.204	0.202	0.194	0.189	$\sum = 1$

3.4. Adjusted sodium adsorption ratio

The water adsorption ratio (SAR) affects the normal rate of soil water infiltration, and therefore it can be considered one of the most important factors in assessing water quality for irrigation. This ratio can be found according to Eq. (10) [21]:

$$\mathrm{SAR} = \frac{\mathrm{Na}^{+1}}{\sqrt{\frac{\{(\mathrm{Mg}^{+2})+(\mathrm{Ca}^{+2})\}}{2}}} \tag{10}$$

All ion concentrations in Eq. (10) are expressed as (meq/l). The concentrations of Ca^{+2}, Mg^{+2}, and Na^{+1} ions were measured according to the APHA specification sections; 3500-Ca B, 3500-Mg B, and 3500-Na B respectively [19], which were indicated in Table 2.

It should be mentioned to fact that there are changes in the calcium concentration in soil water caused by the dissolution of calcium in the soil due to rainfall or melting of this variable during or after irrigation periods. These changes were not taking in consideration in Eq. (10), so this equation can be rewritten by entering the equilibrated calcium concentration (Ca_{eq}^{+2}) to get the Eq. (11). A new term in Eq. (11) is $adj\ R_{Na}$ (adjusted sodium adsorption ratio); or (SAR°) (corrected sodium adsorption ratio) [21]. In the current study (SAR°) was calculated according to the procedure and a series of equations that details described by Lesch et al. [22] and the final equation is

$$\mathrm{adj}\ \mathrm{R_{Na}} = \mathrm{SAR}^{\circ} = \frac{\mathrm{Na}^{+1}}{\sqrt{\frac{\{(\mathrm{Mg}^{+2})+(\mathrm{Ca_{eq}}^{+2})\}}{2}}} \tag{11}$$

Table 6. Irrigation water quality index characteristics [8].

IWQI	Water use restriction	Recommendation: Soil	Recommendation: Plant
85-100	No restriction	Used for the majority of soils with low probability of causing salinity and sodicity	No toxicity risk for most plants
70-85	Low restriction (LR)	Used in irrigated soils with light texture or moderate permeability, recommended salt leaching. Soil sodicity in heavy texture soils	Avoid salt sensitive plants
55-70	Moderate restriction (MR)	May be used in soils with moderate to high permeability values, being suggested moderate leaching of salts.	Plants with moderate tolerance to salts grown.
40-55	High restriction (HR)	May be used in soils with high Permeability without compact layers. High frequency irrigation schedule should be adopted for water with EC above 2000 dS m-1 and SAR above 7.0	Irrigation with moderate- high tolerance to salts, salinity practices
0-40	Severe restriction (SR)	Should be avoided its use for irrigation under normal conditions. In special cases, may be used occasionally. Water with low salt levels and high SAR require gypsum application. In high saline content water soils must have high permeability, and excess water should be applied to avoid salt accumulation.	Only plants with high salt tolerance, except for waters with extremely low values of Na, Cl and HCO3

4. Results and Discussions

Calculation results for this site study according to CIWQI and IWQI models are presented in the next sections.

4.1. Canadian irrigation water quality index (CIWQI) model

The (CIWQI) model was operated by using the observed data that shown in Table 7. This data represents the groundwater tests of 20 selected wells in the Green Belt region. The best useful way to understand how the (CIWQI) model works is by demonstrating the following detailed example which uses the set data for the well (No.1). The parameters that will be taken when calculating this index model are; pH, electric conductivity (EC), Potassium (K^{+1}), Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Sodium (Na^{+1}), Chloride (Cl^{-1}), Sulfate (SO_4^{-2}), Bicarbonate (HCO_3^{-1}), and sodium adsorption ratio (SAR). It should be mentioned that the bolded values in the Table 7 do not meet the standard value. On this basis and for the well (No.1) the total number of parameters that do not meet the standard values is seven. Therefore and by using Eq. (1):

$$\therefore F_1 = \frac{7}{10} \times 100 = 70$$

There are seven tests that do not meeting the standard values and the total number of tests is ten. Therefore by using Eq. (2), the value of F_2 can be calculated;

$$\therefore\ F_2 = \frac{7}{10} \times 100 = 70$$

By using Eq. (3) can be calculate the excursions of the failed tests;

$$\sum_{i=1}^{n} EX_i = EX_{(EC)} + EX_{(K^{+1})} + EX_{(Ca^{+1})} + EX_{(Mg^{+1})} + EX_{(Na^{+1})} + EX_{(Cl^{-1})} + EX_{(SO_4^{-2})}$$

$$\therefore \sum_{i=1}^{n} EX_i = \left[\left\{\left(\frac{5.2}{3}\right) - 1\right\} + \left\{\left(\frac{57}{2}\right) - 1\right\} + \left\{\left(\frac{30.94}{20}\right) - 1\right\} + \left\{\left(\frac{7.65}{5}\right) - 1\right\} + \left\{\left(\frac{25.86}{9}\right) - 1\right\} + \left\{\left(\frac{27.56}{10}\right) - 1\right\} + \left\{\left(\frac{42.45}{20}\right) - 1\right\}\right] = 34.1$$

The (NSE) can be calculating by using Eq. (5). Therefore;

$$\therefore NSE = \left[\frac{34.1}{10}\right] = 3.41$$

By using Eq. (6), the value of (F_3) can be calculated;

$$F_3 = \left[\frac{(3.41)}{(0.01\ (3.41) + 0.01\ )}\right] = 77.32$$

Then by using the Eq. (7) the CIWQI can be calculated as

$$CIWQI = 100 - \left[\frac{\sqrt{\{(70)^2 + (70)^2 + (77.32)^2\}}}{1.732}\right] = 27.48 \cong 27.5$$

Table 8 has explained the calculated values of CIWQI for the remaining 19 wells in the study area which were calculated in the same way. It was found that the values of the CIWQI ranged pt. 20-38 and the water of all wells was classified under poor water categories as shown in Fig. 2. This classification means that the validity of this water is poor for irrigation purposes and as its use leads to damage to plants and soil [23].

Table 7. Physical and chemical characteristics of the groundwater of the study project.

	pH	EC	K^{+1}	Ca^{+2}	Mg^{+2}	Na^{+1}	CL^{-1}	$SO4^{-2}$	HCO_3^{-1}	SAR
S.V.[21]	6-8.5	3	2	20	5	9	10	20	8.5	12
Well No.	-	ds/m	meq/l							$(meq/l)^{1/2}$
1	7.3	5.2	57	30.9	7.65	25.8	27.5	42.4	1.1	5.9
2	7.1	6	74	31.4	7.57	36.4	34.5	31.5	1.0	8.2
3	7.2	5.5	69	31.7	4.56	28.5	29.5	41.1	0.9	6.7
4	7.3	6	75	30.4	6.19	30.2	55.9	45.3	1.3	7.0
5	7.3	5	69	32.0	3.91	21.6	23.9	40.7	0.9	5.1
6	7.4	5.5	64	29.6	4.96	20.5	21.9	40.9	0.8	4.9
7	7.4	4.5	65	32.8	2.2	19.4	16.9	38.3	0.6	4.6
8	7.3	4.5	57	23.5	6.1	19.2	17.5	44.0	0.9	5.0
9	7.4	4.3	53	35.2	2.03	18.6	16.5	29.2	1.1	4.3
10	7.2	4.4	60	36.8	1.38	20.1	23.9	41.8	1.0	4.6
11	7.3	4.5	52	32.8	5.41	15.7	19.3	38.1	0.7	3.6
12	7.1	3.7	63	23.7	6.02	14.6	17.1	36.8	1.1	3.8
13	7.3	4.5	53	23.7	7.41	16.5	21.5	39.3	0.7	4.2
14	7.2	4	39	26.1	5.62	14.8	18.9	35.0	0.9	3.7
15	7.2	4	45	26.4	5.21	12.8	17.5	35.8	0.7	3.2
16	7.2	3.6	50	24.0	7.33	9.82	14.9	35.4	0.6	2.4
17	7.2	4.2	72	20.0	1.67	9.55	23.9	36.8	0.7	2.9
18	7.3	4.5	79	17.4	3.97	11.6	20.1	38.5	1.0	3.5
19	7.3	6	119	22.8	6.74	29.0	32.2	45.4	1.3	7.5
20	7.4	4.9	107	20.1	6.67	15.9	24.8	41.8	0.0	4.3

The results for all the twenty wells showed that the number of failed parameters was between of 6-7. These variables exceeded the allowed values for irrigation purposes specified by the World Food Organization [21]. This has made groundwater quality poor in most wells when used for irrigation. Specifically, the values of (EC, Na^{+1}, Cl^{-1}) were very high, which led to a deviation of the water quality index calculated significantly from the natural values. That makes the groundwater of wells poorness for the cultivation of most of the agricultural crops in this region.

Table 8. CIWQI values and irrigation groundwater quality.

Well No	F1 Scope	F2 Freq.	ΣExcursion	*NSE*	F3Amplitue	CIWQI	Water quality categories
1	70	70	34.06	3.06	77.32	28	Poor
2	80	80	44.42	4.44	81.62	20	Poor
3	60	60	40.3	4.03	80.12	33	Poor
4	70	70	47.3	4.73	82.55	26	Poor
5	60	60	39.0	3.90	79.6	33	Poor
6	60	60	36.3	3.63	78.4	33	Poor
7	60	60	35.62	3.56	78.1	33	Poor
8	70	70	31.8	3.18	76.1	28	Poor
9	60	60	28.9	2.89	74.3	35	Poor
10	60	60	38.1	3.81	79.21	33	Poor
11	70	70	29.27	2.92	74.55	29	Poor
12	70	70	33.67	3.36	77.1	28	Poor
13	70	70	29.64	2.96	74.8	28	Poor
14	70	70	21.91	2.19	68.66	30	Poor
15	70	70	24.33	2.43	70.87	30	Poor
16	70	70	26.23	2.62	72.4	29	Poor
17	60	60	37.92	3.79	79.13	33	Poor
18	50	50	41.62	4.16	80.7	38	Poor
19	70	70	66.1	6.61	86.86	24	Poor
20	70	70	57.0	5.7	85.1	25	Poor

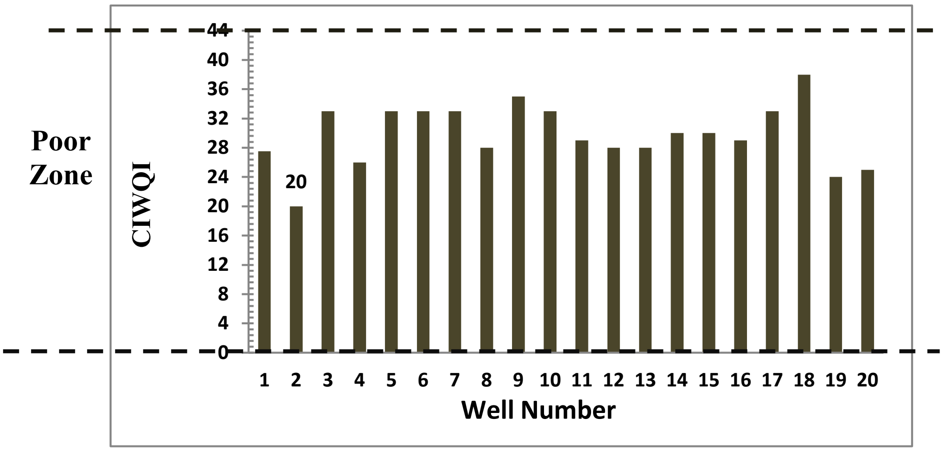


Fig. 2. The Canadian irrigation water quality index (CIWQI) value.

4.2. Irrigation water quality index (IWQI) model

The model of IWQI was applied on the irrigation groundwater tests data that shown in Table 9 for 20 wells in the study area. In order to provide a clear working mechanism for the operation of the IWQI model, the following detailed example illustrates the steps for applying this model on the set data of the groundwater tests for well No. 1;

I. Identify and selected of five parameters will be considered in the IWQI index calculations: (EC, Na^{+1}, HCO_3^{-1}, Cl^{-1}, SAR°).

II. From Table 9, the observed values (X_{ij}) of the (EC, Na^{+1}, HCO_3^{-1}, Cl^{-1}, and SAR°) are 5.2, 25.86,1.105,27.56 and 6.48 respectively.

III. Based on the observed values (X_{ij}) in the step (2) above and by using Table 4, the categories are of the (EC, Na^{+1}, HCO_3^{-1}, Cl^{-1}, SAR°) are determined as follows; 0-35, 0-35, 85-100,0-35 and 35-60 respectively. Then the Q_{imax} and Q_{ampl} for these parameters can be determined.

IV. Depending on the values of the (X_{ij}), the lower limit of each category (X_{inf}) and the upper limit were specified, then the values of ($X_{ampl.}$) for each of the (EC, Na^{+1}, HCO_3^{-1}, Cl^{-1}, SAR°) were determined. In the same context and in order to find the upper limit of the parameter in the last category, the highest values of the measured values of the parameter were adopted.

V. Based on the results of the above steps ,the quality measurement (Qi) values for each parameter were calculated by using Eq. (8)

$$Q_{EC} = 35 - \left[\frac{(5.2 - 3) * 35}{(6 - 3)}\right] = 9.33,$$

$$Q_{(Na^{+1})} = 35 - \left[\frac{(25.86 - 9) * 35}{(36.47 - 9)}\right] = 13.52$$

$$Q_{(HCO3^{-1})} = 100 - \left[\frac{(1.105 - 1) * 15}{(1.5 - 1)}\right] = 96.85$$

$$Q(cl^{-1}) = 35 - \left[\frac{(27.56 - 10) * 35}{(55.92 - 10)}\right] = 21.61$$

$$Q_{(SAR^{\circ})} = 60 - \left[\frac{(6.48-6)*25}{(12-6)}\right] = 58$$

VI. By using Table 5, the weights Wi of the EC , Na^{+1}, $HCO3^{-1}$, Cl^{-1} , SAR° can be selected as follows; 0.211, 0.204 ,0.202 , 0.194 and 0.189 respectively

VII. Finally, the value of IWQI; was determined according to Eq. (9)

$$\therefore \mathrm{IWQI} = \{Q_{EC} \times w_{EC}\} + \left\{ Q_{(Na^{+1})} \times w_{(Na^{+1})}\right\} + \{Q_{(HCO3^{-1})} \times w_{(HCO3^{-1})}\} + \left\{ Q_{(Cl^{-1})} \times w_{(Cl^{-1})}\right\} + \{Q_{(SAR^{\circ})} \times w_{(SAR^{\circ})}\}$$

$$= \{9.33 \times (0.211)\} + \{ 13.51 \times 0.204\} + \{96.85 \times 0.202\} + \{21.61 \times 0.194\} + \{58 \times 0.189\}$$

$$= \{1.97\} + \{ 12.76\} + \{19.54\} + \{4.193\} + \{10.962\} = 39.5$$

The IWQI values for the remaining wells were calculated in the same manner and the results were recorded in Table 9. It was noted that the values of IWQI calculated in this way ranged from 25.2-50.9 for all wells, see Fig. 3, from the result the concentrations of the parameters; EC, Na^{+1} and Cl^{-1}exceeding the irrigation standard values. These cases can significantly reduce the value of irrigation water quality index. When performing the classification of groundwater quality for wells for irrigation in the study area according to the categories in Table 6 and based on calculated IWQI values, it was found there are 50% of the wells lies in Severe Restrictions (SR) category while 50% of the wells lies in High Restriction (HR) category. Therefore, it can be said that the quality of groundwater wells ranged between *HR-SR*, see Fig. 3. The dependence on the average value (39.3) of IWQI in assessing the groundwater quality of all wells was found to fall within the SR category. Highly tolerant (plants and crops) of salt can be irrigated using well water that falls within the category SR. While the water of wells within the category HR can be used for irrigation of plants and crops with moderate to high tolerance to salts, with continuous special measures that can reduce the salinity problem, see Table 6 [8] and Table 10 [23]. Fortunately, the soil in the study area is sandy and has a high permeability [15], and due to high salinity levels in irrigation groundwater, therefore, it requires constant washing of the soil to prevent the accumulation of salts due to the continuous use of water, which leads to a negative impact on the soil and the productivity of agricultural crops [23].

Table 9. Values of IWQI and the Irrigation groundwater quality classification in study project.

Well No.	EC	Ca^{+2}	Mg^{+2}	Na^{+1}	CL^{-1}	$HCO3^{-1}$	Ca^{+2}		IWQI	Water quality categories
1	5.2	30.9	7.6	25.8	27.5	1.1	24.1	6.4	39.4	SR
2	6	31.4	7.5	36.4	34.5	1.0	26.0	8.8	32.0	SR
3	5.5	31.7	4.5	28.5	29.5	0.9	26.8	7.2	25.2	SR
4	6	30.4	6.1	30.2	55.9	1.3	21.6	8.1	29.7	SR
5	5	32.0	3.9	21.6	23.9	0.9	26.5	5.5	30.6	SR
6	5.5	29.6	4.9	20.5	21.9	0.8	27.5	5.1	32.1	SR
7	4.5	32.8	2.2	19.4	16.9	0.6	35	4.5	41.4	HR
8	4.5	23.5	6.1	19.2	17.5	0.9	21.1	5.2	34.0	SR
9	4.3	35.2	2.0	18.6	16.5	1.1	24.9	5.0	46.4	HR
10	4.4	36.8	1.3	20.1	23.9	1.0	27.9	4.9	44.6	HR

11	4.5	32.8	5.4	15.7	19.3	0.7	30.7	3.7	40.8	HR
12	3.7	23.7	6.0	14.6	17.1	1.1	19.2	4.1	50.9	HR
13	4.5	23.7	7.4	16.5	21.5	0.7	20	4.4	40.3	HR
14	4.0	26.1	5.6	14.8	18.9	0.9	23.5	3.8	39.5	SR
15	4.0	26.4	5.2	12.8	17.5	0.7	26.1	3.2	43.7	HR
16	3.6	24.0	7.3	9.8	14.9	0.6	27.4	2.3	43.6	HR
17	4.2	20.0	1.6	9.5	23.9	0.7	20.6	2.8	43.6	SR
18	4.57	17.4	3.9	11.6	20.1	1.0	15.1	3.7	50.2	HR
19	6.0	22.8	6.7	29.0	32.2	1.3	16.9	8.4	30.1	SR
20	4.9	20.1	6.6	15.9	24.8	1.1	17.1	4.6	47.7	HR

Note: The Units for all parameters are in (meq/l) except (Ec) in (ds/m), (SAR) in $(meq/l)^{1/2}$ and(IWQI) which has no units.

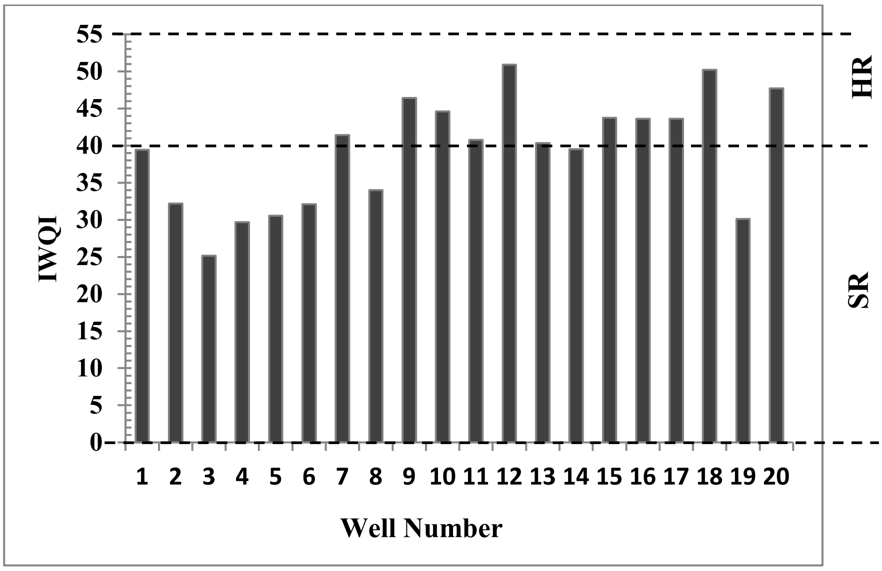


Fig. 3. IWQI values for selected wells.

Table 10. Classification of crops and plants according to their tolerance to salts [23].

Highly tolerant	Date palm	Barley	Sugar beet	Cotton	Asparagus	Spinach
Moderately tolerant	Wheat Tomato	Oats Alfalfa	Rice Maize	Flax Pomegranate	Potatoes Olive	Carrot, Onion Grape, Fig
Sensitive	Red clover Plum	Peas Almond	Beans Apricot	Sugarcane Peach	Pear Prune	Apple Orange

4.3. Groundwater quality assessment

In the present study, the quality of groundwater wells in the Green Belt project of Karbala city-Iraq was evaluated for irrigation using two models: the first is CIWQI model and the second is IWQI model. By observing the assessment results of this water, it was classified as "poor water category" according to the first model, and it was classified under the category of "water with severe to high restriction"; (*SR-HR*), according to the second model. As a result of both methods of assessment; there are significant restrictions on most crops that irrigated with groundwater of these wells. It can be said that this groundwater is suitable in most cases for irrigation of high-tolerance plants such as ; palm, olive and eucalyptus, which are already cultivated in the study area (the Green Belt Project). Based on the above results, the quality of the groundwater was determined for the wells in the study area, and it was decided that good management of this water is required when it is used to irrigate other types of crops other than those cultivated in the study area. This management will contribute to the rapid growth and health of the cultivated plants and thus increase their productivity [24].It has become necessary to highlight the parameters that contributed to poor water quality in these wells and discuss the problems resulting from their increasing concentration and exceeding the standard values allowed for irrigation.

Accordingly, it is required to develop effective solutions and procedures to develop plans that provide good quality management of the groundwater uses of these wells for irrigation. The salinity values of EC in the water of these wells ranged between 3-6dS/m; as shown in Table 7, and significantly exceeded the permissible limits for irrigation, thus the problem of salinity clearly occurred [21].To reduce the effect of this problem on plant growth and increase its productivity, a number of procedures are required, such as; selecting a high tolerance plants, leaching the soil before planting, increasing the Irrigation frequency to ensure that salts are not collected in the root zone of the plant and changing the irrigation method. The use of the drip irrigation method ; which help to expels salts from area around the roots due to the continuous pumping of water from the emitters of the system and finally reduce the salinity in groundwater by dilution it with fresh water if available from nearby surface water sources. A new degree of groundwater salinity can take a wide range to irrigate other types of crops. The most inexpensive way to reduce the concentration of salts in irrigation water is the dilution [24-25].

Observing the results in Table 7 shows that chloride concentrations in the groundwater wells ranged from 14.98-55.92 meq/l and all values were outside the standard limits for irrigation uses. These results led to the occurrence of "Chloride Toxicity problem" [21].To reduce the effect of this problem, it is recommended to use this water for irrigation in the cold climate of low-speed wind because high temperature with the presence of chloride will damage the leaves of plants, and also advised to rinse the leaves of the plant by clean water after the end of irrigation [24-25].The results did not indicate to a problem of sodicity (Permeability Hazarded), because the maximum values of EC-SAR are pt. 3 to 6 as shown in Table 7 and are within the limits allowed for irrigation according to Ayers and Westcott [21]. This range does not cause the occurrence of this problem in the soil. It should be noted that according to the analysis of soil texture, the soil in the study area is mostly sandy soil [15].The natural of this soil helps to remove the salts easily and expelled away from the area around the roots of plant with irrigation water and the continuous leaching of the soil with additional water. The results also showed in Table 6 that the pH and bicarbonate (HCO_3^{-1}) concentrations for the groundwater of wells did not exceed the allowed standard values specified by the specifications for irrigation uses. On this basis, the concentrations of these two variables, would not have any effect on the growth of plants already cultivated in the study area, which are; (Palm, olive, and eucalyptus).

When comparing the results of the current study with the results of Abd et al. (2018) [14], for assessing groundwater quality when using (IWQI) model for wells in the same study area, it was found that they are very close. As 50% of the wells for the current study and 66% of the wells for the study conducted by [14], were classified as severely restricted water (SR) when used for irrigation. This also corresponds to the results of evaluating this groundwater by using the (CWQI) model, as it was found to be within a (poor category), when classified for irrigation purposes. This means that there are severe restrictions when using groundwater for irrigation in the Green Belt area. It also requires many necessary measures and good management of groundwater quality to preserve plants and soil and increase the productivity of plants irrigated with this water.

5. Conclusions

The use of groundwater can be considered as one of the strategic solutions in arid and semi-arid regions such as the Western desert in Iraq, where the surface water quantities decrease significantly, especially in times of water scarcity. In the current study, a qualitative assessment of groundwater quality in the Green Belt project in the western desert part of Karbala was conducted. For the purpose of assessment of this groundwater for irrigation purposes, two models were applied on the groundwater testing data for 20 selected wells in the study area; the first is CIWQI model and the second is IWQI model. The following conclusion can be reported from this study:

- The Canadian Water Quality Index values ranged between 20-38 for all wells and fall into the "poor water category", which is not suitable for irrigation in normal cases. The significant increase in the values of salinity, EC, sodium (Na^{+1} and chlorine (Cl^{-1} contributed to increased deviations from the permissible limits for irrigation.
- The values of the IWQI ranged between 25-51 for all wells , and the classification of groundwater quality according to their suitability for irrigation; showed that there are 50% of the wells lies in "Severe Restrictions; (SR) category", while50% of the wells lies in "High Restriction; (HR) category".
- The groundwater for wells was classified as "Severe Restrictions; (SR) category" is suitable for irrigation (plants and crops) that are highly tolerant of salts such as Cotton, Sugar beets, Date palm, and Spinach. While the groundwater for wells that was classified as "High Restriction (HR) category is suitable for irrigation (plants and crops) of medium to high tolerance to salts such as Wheat, Maize, Rice, Alfalfa, Tomato and Olive.
- The results showed that the "Salinity Problem" will occur, when used the groundwater in the Karbala Green-Belt project for irrigation. And to increase the productivity of cultivated plants and reduces costs; a good management and great care are required for the quality of groundwater in this region. In order to mitigate the impact of the salinity problem and increase the productivity of plants requires other measures such as; cultivation of high tolerance crops, increasing irrigation frequency, leaching the soil with fresh water before planting , changing irrigation method and dilution the groundwater with fresh water. It is possible to use the fresh water of the

Husseinieh River, which branches off the Euphrates River and which serves the areas adjacent to the project area.

- The results did not record a "Soil Sodicity Problem”. And the soil in the Green-Belt project is "sandy soil" with high permeability, therefore, excess water can be used to dissolve salts and prevent their accumulation in the soil, which contributes to increase plant growth.
- This study showed that concentrations of pH and HCO_3^{-1} in the groundwater of wells will not cause any effects on the growth of already cultivated plants in the project , which are palm, olive and eucalyptus.

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Nomenclatures

adj RNa	Adjusted sodium adsorption ratio, (meq/l)1/2
EXi	Excursion
*F*1	Scope`
*F*2	Frequency
*F*3	Amplitude
FMVi	Failed measurement value
NFM	No. of failed measurements
NFP	No. of failed parameters
NSE	Normalized sum of Excursions
Qi	Quality measurement
Qi max	Maximum value of the quality measurements
Qiampl	Represents category ampleness
S.V.	Standard value
SAR°	Corrected sodium adsorption ratio (meq/l)1/2
TNM	Total No. of measurements
TNP	Total No. of parameters
xampl.,	Category ampleness in which the parameter is located
xij	Measured value for the parameter
xinf	Lower limit value of the category to which the parameter is located

Abbreviations

APHA	American Public Health Association
ArcGIS	Geographic information system working with maps ,3D
ArcMap	ArcGIS Desktop ,2D
CIWQI	Canadian Irrigation water quality index
E	East
EC	Conductivity, dS/m
EDTA	Ethylene diaminetetra acetic acid
GPS	Global Positioning System
HR	High restriction
IDW	Inverse distance weighted interpolation method
IWQI	Irrigation water quality index

LR	Low restriction
MR	Moderate restriction
N	North
SAR	Sodium adsorption ratio, (meq/l)1/2
SR	Severe restriction
WQI	Water quality index

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