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EVALUATION OF IRRIGATION WATER QUALITY INDEX (IWQI) FOR AL-DAMMAM CONFINED AQUIFER IN THE WEST AND SOUTHWEST OF KARBALA CITY, IRAQ

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ABSTRACT

The main purposes of establishment of the modern village in Karbala desert, Iraq is to developing the agriculture plan in this desert of Karbala governorate. Thus, the main usage of the drilled wells in the study area is the irrigation. In order to assessment the groundwater quality for irrigation purposes in a way of high accuracy, the irrigation water quality index (IWQI) will be considered and developed in this research to classify groundwater of the Dammam confined aquifer within Karbala desert area. For this purpose, 30 wells distribution within study area were chosen to take water samples during March 2012.

Based on the results of the irrigation water quality index(IWQI) map, above 56% of the study area falls within the "Severe restriction'' category, which is the dominant in the central and southeast parts of the study area. The rest of the study area, which is the 44% and below falls within the ''High restriction'' category, and it is dominant in the western parts the study area. These categories of groundwater should be used only with the soil having high permeability with some constraints imposed on types of plant for specified tolerance of salts..

KEYWORDS: Irrigation Water Quality Index, GIS, Dammam Aquifer, Karbala Desert, Iraq

INTRODUCTION

The irrigation water quality and the associated hazards to soil characteristics and crop yield is often a complex phenomenon that involves the combined effect of many parameters. A water quality index provides a single number that expresses overall water quality at a certain location and time based on several water quality parameters. The objective of an index is to turn complex water quality data into information that is understandable and useable by the public.

A single number cannot tell the whole story of water quality; there are many other water quality parameters that are not included in the index. However, a water quality index based on some very important parameters can provide a simple indicator of water quality (Yogendra and Puttaiah, 2008).

Although Water Quality Index (WQI) is usually orientated to qualify urban water supply, it has been widely used by environmental planning decision makers. The quality of the irrigation water has to be evaluated to avoid or, at least, to minimize impacts on agriculture (Mohammed,2011).

The utilization of degraded quality waters in irrigation has been the main cause for the deterioration of the quality of soils and the agricultural crops grown on such soils (Ayers and Westcot, 1985). The concept of indices to represent gradations in water quality was first proposed by (Horton, 1965). The need for such readily understood evaluation tool was ultimately realized, and several researchers (e.g. Brown et al., 1970; Prati et al., 1971; Landwehr, 1979; Bhargava, 1985; Dinius, 1987 and Smith, 1990) have developed their own rating schemes (Mohammed, 2011).

So far, many researches and projects have been conducted to measure water quality index. Rokbani et al. (2011), Jerome1 and Pius (2010) and Simsek & Gunduz (2007) used irrigation water quality index (IWQI) as a management tool for groundwater quality. Meireles et al., (2010) classify water quality in the Acarau Basin, in the North of the state of Ceara, Brazil for irrigation use.

THE STUDY AREA

The study area is located in western south of Karbala province center under the south coast of Al-Razzaza lake in Iraq. It located between latitudes (32˚ 26′ 54″N - 32˚ 33′ 16″N), and longitudes (43˚ 47′ 58″E - 43˚ 59′ 45″E), it forms about (134.6) km^2 as shown in Figure (1).

The main soil types of the study area are sedimentations of sand, gravel and gravelly sand with the existence of clayey lenses which are generally take the form of compacted clayey balls interfered with small amount of sand and gypsum working as agent material.

The study area could be described as of smooth and easy topographic features, having a general elevation ranging between 50m-95m above sea level (m.a.s.l).

Geology of the Area

Whole the study area is within the desert plain, a part of unstable shelf. It is with plain-like to slightly expressed hilly character. Generally, it is considered as a part of Karbala –Najaf plateau, which belongs to the Mesopotamia zone, and located in the central part of Iraq.

All the studied area is covered by Gypcrete deposits. The lithology was obtained from 40 wells drilled by the General Commission of groundwater (Some of which is shown in Figure.2) and the information obtained from coring well.

The stratigraphic column in the study area consists of the following formations (in sequence from oldest to newest): Tayarat formation (Cretaceous), Umm Er Radhuma formation (Upper Paleocene), Dammam Formation (Eocene), Euphrates Formation (Early Miocene), Nfayil Formation (Middle Miocene), Fatha (Lower Fars) Formation (Middle Miocene), Injana (upper fares) Formation (Late Miocene) and Dibdibba Formation (Pliocene – Pleistocene).

Groundwater Aquifer in Study Area

The geological formations, which contain groundwater and can be considered as water bearing formations within the basin in Karbala desert, are Tayarat, Umm Er-Radhuma, Dammam, Euphrates and Dibdibba formations.

The geological investigations of the geological sections through deep boreholes showed the presence of rather complicated multi-aquifer system with impermeable sediments (mainly marl) being in lenses form, which locally separate the aquifers, (Al-Jiburi and Al-Basrawi, 2007).

Among the above mentioned water bearing formations the most producing units within the study area are represented by the combination of two formations: Umm Er Radhuma and Dammam Formations, which represent the main reservoir of water produced in the region of study area, (Al-Jawad et al., 2002).

Figure (3); show the extension of the Dammam formation and the stratigraphical position with other formations within study area.

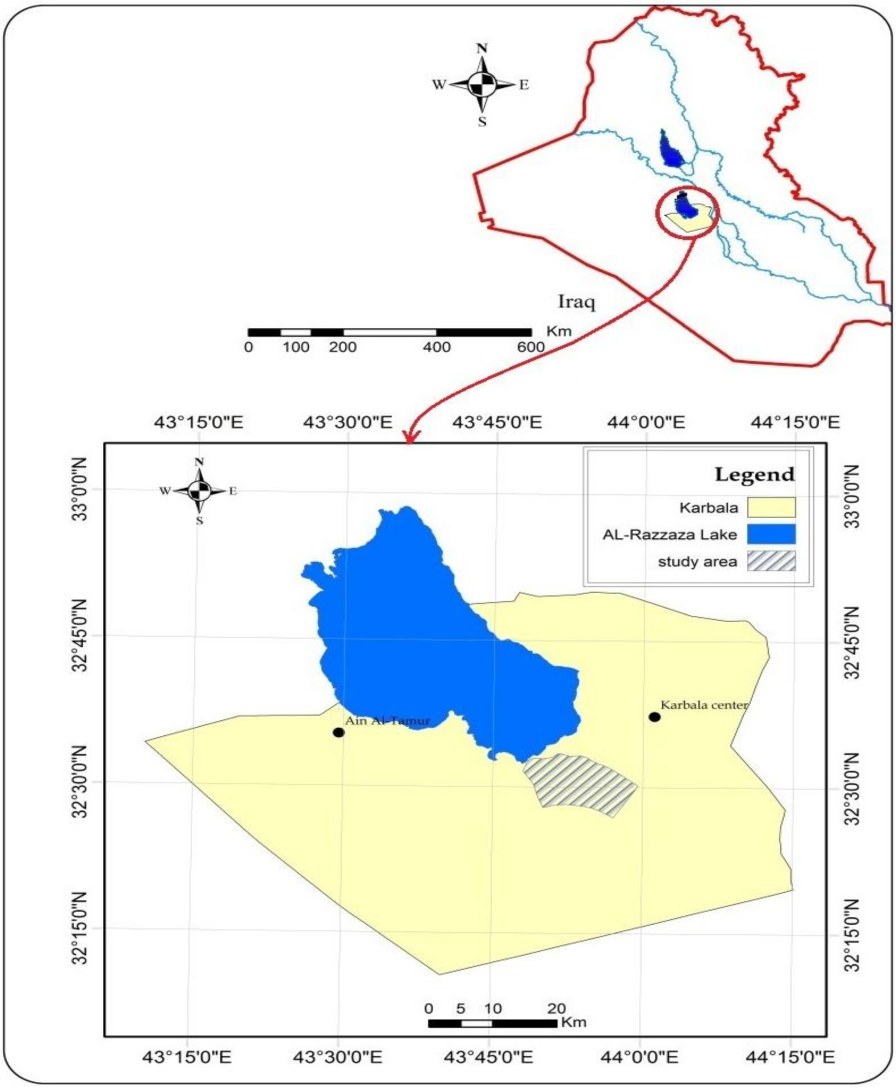

Figure 1: Geographical Location of the Study Area Relative to Iraqi Map

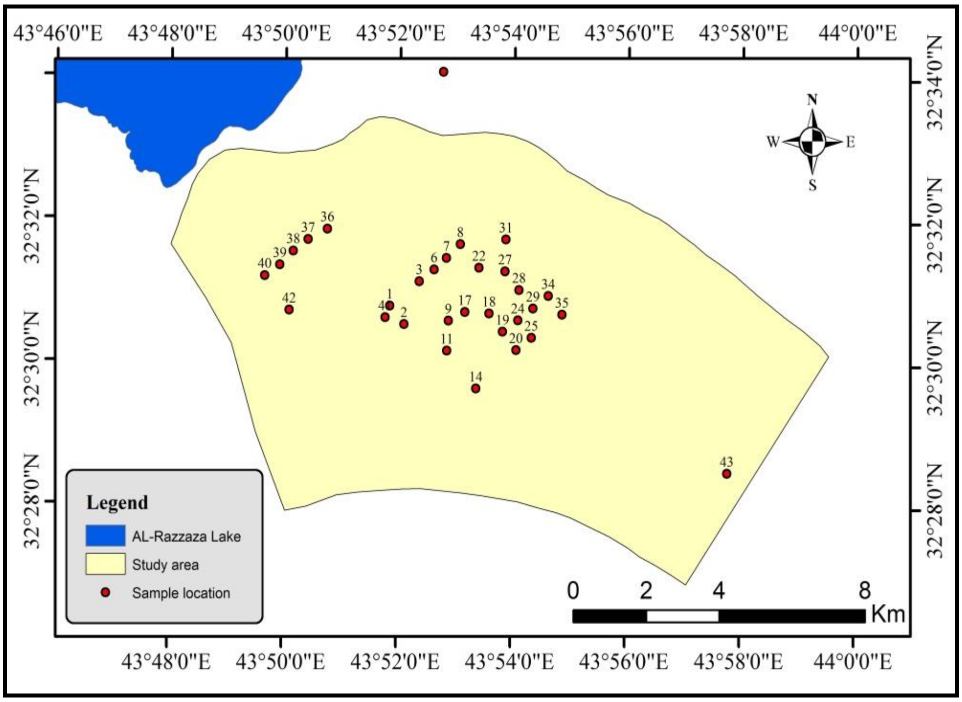

Figure 2: Locations of the Water Samples of the Well in the Study Area

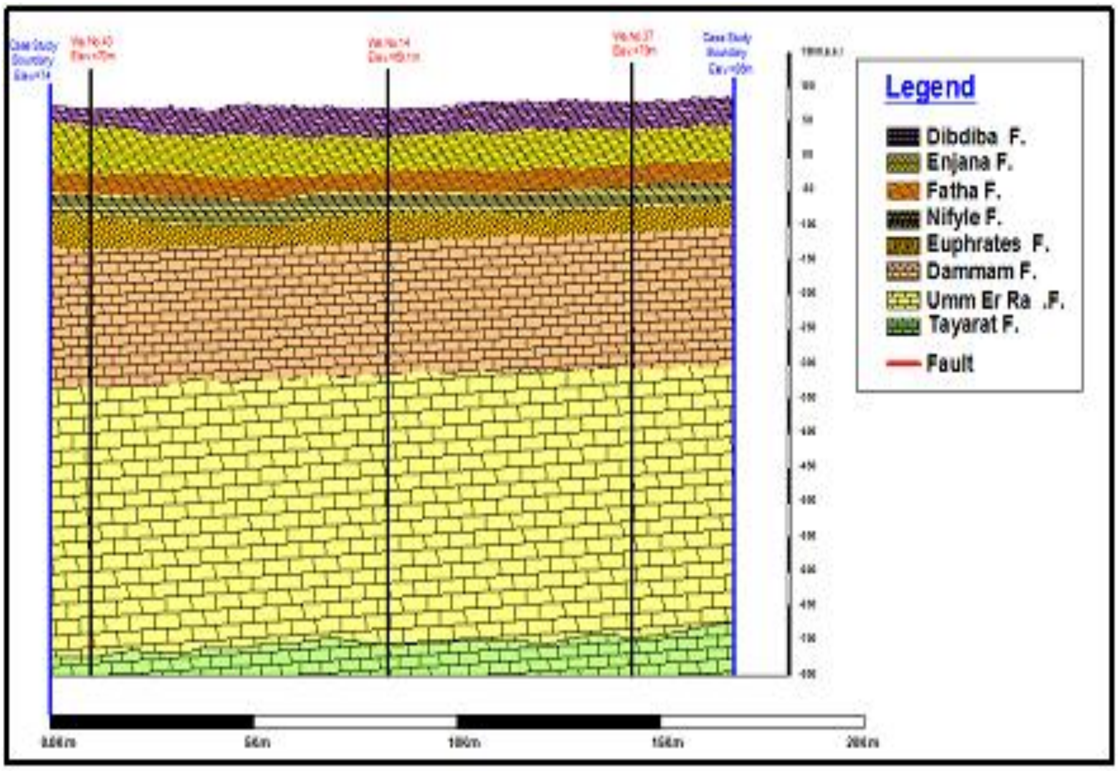

Figure 3: The Stratigraphic Correlation between the Wells in the Study Area Developed from (Consortium, 1977; Sissakian, 1995)

MATERIAL AND METHODOLOGY

The quality of deep groundwater in the Karbala desert (represented by the study area) was determined by taking samples from 30 of the wells within the study area, Figure 2.

The purposes of this investigation were (1) to provide an overview of present groundwater quality and (2) to determine spatial distribution of groundwater quality parameters such as electrical conductivity EC, Chloride Cl^-, Sodium Na, Bicarbonates HCO_3, and Sodium Adsorption Ratio SAR concentrations, and (3) to map irrigation water quality index(IWQI) in the study area in order to identify places with the best quality for irrigation within the study area by using Geographical Information System GIS and Geostatistics techniques.

ArcGIS 9.3 was used for generation of various thematic maps and ArcGIS Spatial Analyst to produce the final irrigation water quality index (IWQI) map. An interpolation technique, ordinary Kriging, was used to obtain the spatial distribution of groundwater quality parameters.

Groundwater samples were taken directly from 30 wells in March 2012. The location of groundwater samples are displayed on Figure (2). The wells were pumped until the temperature, conductivity, and pH stabilized. Clean polyethylene bottles containers were used for the collection of water samples for the analysis and delivered to the General Commission of Groundwater laboratory.

In situ, measurements included electrical conductivity (EC), TDS, pH and temperature. Laboratory tests were carried out to find the ion concentrations of (Ca^{+2}, Mg^{+2}, Na^+, K^+, Cl^-,SO_4^{-2} ,No_3^-,HCO_3^-) in (mg/l). Physical and chemical parameters including statistical measures, such as minimum, maximum, mean and standard deviation, are reported in Table (1).

Table 1: The Results of Water Quality Analysis for the Aquifer in the Study Area

No.	Well No.	Parameter										
		EC µs/cm	TDS mg/l	PH	Ca^{+2} mg/l	Mg^{+2} mg/l	Na^{+} mg/l	K^{+} mg/l	Cl^{-} mg/l	NO_3^{-} mg/l	SO_4^{-2} mg/l	HCO_3^{-}
1.	1	2450	1900	7.18	90	42	220	8	373	3.6	488	287
2.	2	2590	1867	7.13	71	34	425	13.5	361	3	512	270
3.	3	3650	2895	7.21	214	117	340	6	529	3.4	860	451
4.	6	2680	1930	7.03	197	108	216	3.9	471	6	420	391
5.	7	2630	1903	7.11	196	110	213	4.8	468	5.1	419	396
6.	8	2810	2048	7.14	69	41	427	17.1	360	4.1	509	270
7.	9	2760	2011	7.15	195	112	213	7.6	478	6.5	416	385
8.	11	2540	1860	7.07	175	103	207	8	481	5	395	270
9.	14	4170	2953	7.09	211	113	334	11	520	7.1	611	412
10.	17	2810	2048	7.14	74	32	428	10.9	361	4.8	511	271
11.	18	2740	1990	7.22	175	121	188	12	446	4.1	529	176
12.	19	2960	2144	7.06	137	97	374	2.4	467	3	680	358
13.	20	2870	2066	7.31	70	40	426	16.6	359	3.8	510	269
14.	22	2915	2118	7.18	184	90	302	4.1	463	6.1	537	394
15.	24	2960	2150	7.17	217	93	331	4	445	5.1	779	240
16.	25	3290	1680	7.3	220	97	327	4.1	452	5.2	663	238
17.	27	3180	2335	7.07	209	115	318	4.9	517	7.2	550	438
18.	28	3240	2393	7.22	225	105	371	3	530	6.8	771	311
19.	29	3100	2233	7.21	214	114	330	11	522	8.5	612	410
20.	31	3050	2100	7.18	74	52	320	15.2	364	4	501	263
21.	34	3010	2156	7.06	134	96	371	3.5	465	2.5	680	361
22.	35	2900	2210	7.05	76	54	302	17	373	4	548	286
23.	36	3310	1690	7.2	106	51	215	2	533	3.3	380	250
24.	37	2780	1380	7.18	97	62	220	2.6	512	3.5	410	258
25.	38	2800	1400	7.16	98	60	240	3.13	488	3.8	422	274
26.	39	2990	1480	7.14	95	55	232	3.8	522	4.8	397	263
27.	40	2750	1450	7.2	96	61	251	4.2	389	3.6	461	278
28.	41	2259	1645	7.21	81	45	218	6.6	382	3.9	504	301
29.	42	2300	1600	7.14	86	47	210	6.1	405	4.2	479	286
30.	43	3500	2500	7.12	210	110	390	20	530	7.1	900	430
Maximum		**4170**	**2953**	**7.31**	**225**	**121**	**428**	**20**	**533**	**8.5**	**900**	**451**
Minimum		**2259**	**1380**	**7.03**	**69**	**32**	**188**	**2**	**359**	**2.5**	**380**	**176**
Mean		**2933**	**2004**	**7.15**	**143**	**79.2**	**298**	**7.9**	**452**	**4.7**	**548**	**316**
Std.Dev.		**395.5**	**384.5**	**0.07**	**59.8**	**30.8**	**79.3**	**5.2**	**63.2**	**1.5**	**139.7**	**72.2**

The Suitability of Groundwater for Irrigation Purposes

The quality of irrigation water is highly variable depending upon both the type and the quantity of the salts dissolved in it. These salts originate from natural (i.e., weathering of rocks and soil) and anthropological (i.e., domestic and industrial discharges) sources and once introduced, they follow the flow path of the water. It is commonly accepted that the problems originating from irrigation water quality vary in type and severity as a function of numerous factors including the type of the soil and the crop, the climate of the area as well as the farmer who utilizes the water. Nevertheless, there is now a common understanding that these problems can be categorized into the following major groups: (a) salinity hazard, (b) infiltration and permeability problems, (c) Specific ion toxicity and (d) miscellaneous problems (Simsek and Gunduz, 2007).

Salinity Hazard

Salinity hazard occurs when salts start to accumulate in the crop root zone reducing the amount of water available to the roots. This reduced water availability sometimes reaches to such levels that the crop yield is adversely affected.

These salts often originate from dissolved minerals in the applied irrigation water or from a high saline water table. The reductions in crop yield occur when the salt content of the root zone reaches to the extent that the crop is no longer able to extract sufficient water from the salty soil. When this water stress is prolonged, plant slows its growth and drought-like symptoms start to develop (Ayers & Westcot, 1985). Unless the soil is leached with low salt content water, the salinization of the soil is an irreversible process that makes agricultural lands unusable.

Being the most influential water quality guideline on crop productivity, the extent of salinity hazard could be measured by the ability of water to conduct an electric current. Since conductance is a strong function of the total dissolved ionic solids, either an electrical conductivity (EC) measurement or a total dissolved solids (TDS) analysis could be used in measuring the salinity of water. In general, the amount of water available to the crop gets lower when the electrical conductivity is higher. Under such circumstances, the soil appears to be wet but the crop experiences the so-called physiological drought. Since plants can only transpire ‘pure’ water, the usable portion of water by plants decreases dramatically as conductivity increases. Usually, waters with EC values of below 700 µS/cm are considered to be good quality irrigation waters (Ayers & Westcot, 1999).

Permeability and Infiltration Hazard

Although the infiltration rate of water into soil is a function of many parameters including the quality of the irrigation water and the soil factors such as structure, compaction and the organic content, the permeability and infiltration hazard typically occurs when high sodium ions decrease the rate at which irrigation water enters the soils lower layers. The reduced infiltration rate starts to show negative impacts when water cannot infiltrate to the roots of the crop to the extent that the crop requires. Hence, these salts start to accumulate at the soil surface. When the crop is not able to extract the required amount of water from the soil, it is not possible to maintain an acceptable yield and the agricultural production is reduced (Simsek& Gunduz, 2007). The most common water quality factor that influence the normal rate of infiltration of water is the relative concentrations of sodium, magnesium and calcium ions in water that is also known as the sodium adsorption ratio (SAR). The SAR value of irrigation water quantifies the relative proportions of sodium (Na^{+1}) to calcium (Ca^{+2}) and magnesium (Mg^{+2}) and is computed as (Ayers &Westcot, 1985)

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

Where:

SAR: Sodium Adsorption Ratio (meq/l) $^{1/2}$

Na^{+}, Ca^{+2}, and Mg^{+2}: Concentration of Ions by milliequivalents per liter (meq/l) units.

Specific Ion Toxicity

Sodium

The detection of sodium toxicity is relatively difficult compared to the toxicity of other ions. Typical toxicity symptoms on the plant are leaf burn, scorch and dead tissue along the outside edges of leafs in contrast to symptoms of chloride toxicity which normally occur initially at the extreme leaf tip (Simsek and Gunduz, 2007).

Chloride

Chloride is another ion commonly found in irrigation waters. Its toxic effects are immediately seen as leaf burns or leaf tissue deaths.

Miscellaneous Effects

Bicarbonate

Alkalinity is a measure of the capacity of water to neutralize an added acid. Being the major component of alkalinity, carbonate and bicarbonate ions are generally responsible for high pH values (i.e., above 8.5) of water. Elevated levels of carbonates cause calcium and magnesium ions to form insoluble minerals leaving sodium as the dominant ion in solution (Simsek and Gunduz, 2007).

The Model of Irrigation Water Quality Index (IWQI)

The requirements for irrigation water quality could differ from one field to the other depending on the cultivated crop pattern as well as the regional soil and climatologic conditions (Babiker et al. 2007). In this regard, irrigation water quality mapping is considered to be a valuable instrument for the spatially distributed assessments of individual quality parameters. Accordingly, GIS provides an important platform for visualizing such maps and making comparative evaluations. However, in addition to individual assessments, a critical phase of the quality management procedure is to collectively evaluate all parameters mentioned in the previous section. These last years, the Water Quality Index (WQI) was very used to determine the suitability of the groundwater for drinking and irrigation purposes (Rokbani et.al, 2011).

IWQI model was applied on the data. This model developed by (Meireles et al., 2010). In the **first step**, identified the parameters were considered more relevant to the irrigation use. In the **second step**, a definition of quality measurement values (qi) and aggregation weights (w_i) was established. Values of (qi) were estimated based on each parameter value, according to irrigation water quality parameters proposed by the University Of California Committee Of Consultants - UCCC and by the criteria established by Ayers and Westcot (1999) as shown in Table (2). Water quality parameters were represented by a non-dimensional number; the higher the value is the better water quality.

Table 2: Parameter Limiting Values for Quality Measurement (q_i) Calculation (Ayers and Westcot, 1999)

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

Values of qi were calculated using the equation (2), based on the tolerance limits shown in Table (2) and water quality results determined in laboratory:

$$q_i = q_{imax} - \left\{ \frac{\left[(x_{ij} - x_{inf}) \times q_{iamp} \right]}{x_{amp}} \right\} \tag{2}$$

Where q_{imax} is the maximum value of qi for the class; x_{ij} is the observed value for the parameter; x_{inf} is the corresponding value to the lower limit of the class to which the parameter belongs; q_{iamp} is class amplitude; x_{amp} is class amplitude to which the parameter belongs.

In order to evaluate x_{amp}, of the last class of each parameter, the upper limit was considered to be the highest value determined in the physical-chemical and chemical analysis of the water samples. Each parameter weight used in the IWQI was obtained by (Meireles et al., 2010) as shown in Table (3). The w_i values were normalized such that their sum equals one.

The irrigation water quality index (IWQI) was calculated as:

$$IWQI = \sum_{i=1}^{n} q_i w_i \qquad (3)$$

IWQI is dimensionless parameter ranging from 0 to 100; qi is the quality of the i^{th} parameter, a number from 0 to 100, function of its concentration or measurement; w_i is the normalized weight of the i^{th} parameter, function of its relative importance to groundwater quality. Division in classes based on the proposed water quality index was based on existent water quality indexes, and classes were defined considering the risk of salinity problems, soil water infiltration reduction, as well as toxicity to plants as observed in the classifications presented by Bernardo (1995) and Holanda and Amorim(1997). Restrictions to water use classes were characterized as shown in Table (4).

Table 3: Weights for the IWQI Parameters (Meireles et al., 2010)

Parameter	Weight (w_i)
EC	0.211
Na	0.204
HCO_3	0.202
Cl	0.194
SAR	0.189
Total	**1.0**

RESULTS AND DISCUSSIONS

Assessment of Individual Hazard Groups

Salinity Hazard

The values, medians and stander deviation of Electrical conductivity in collected samples from 30 wells are presented in Table (1). Spatial distribution of EC concentrations in the studied area are shown in Figure (4). The EC in the study region is varied from 2259 to 4170 µS/cm with a mean of 2933 µS/cm [Table (1)]. As shown in Figure (4), the EC value increases to the east as well as the south eastern part of the studied area.

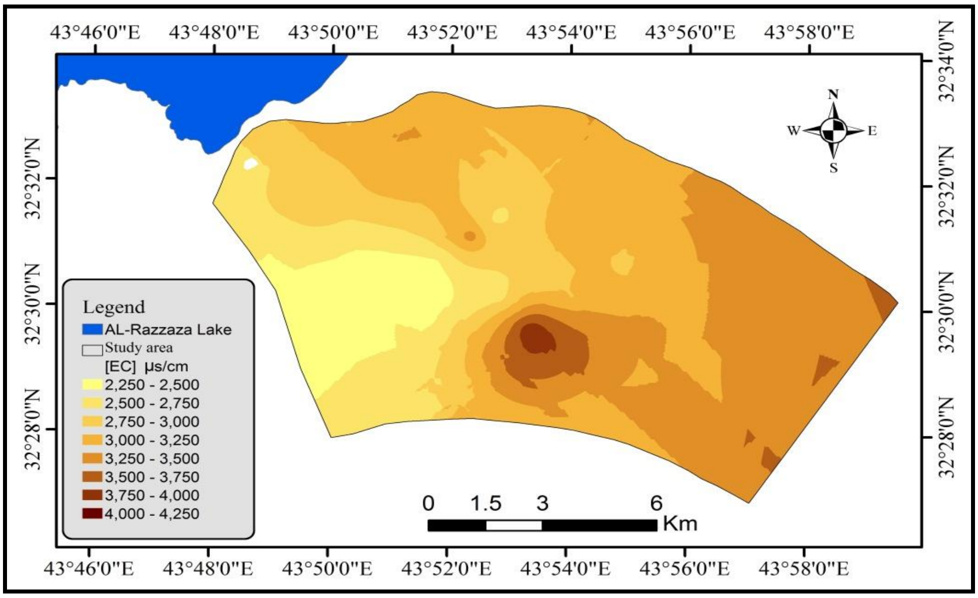

Figure 4: Spatial Distribution of Electrical Conductivity (EC), (µs/cm) in Study Area

Infiltration Hazard

The spatial distribution of SAR for the study area is presented in Figure (5). It can be seen from the figure that the SAR values increases from the south-west to the north-east following the general trend of the aquifer flow direction.

Specific Ion Toxicity

The sodium ion (Na^+) concentration of water samples ranged between (188ppm) to (428ppm) with mean (298 ppm). Spatial distributions of sodium ion (Na^+) concentration in the studied area are shown in Figure (6). Chloride concentrations are presented as the other parameter defining the specific ion toxicity. The chemical analysis of water samples showed that the average chloride ion concentrations in the study area (452ppm) and the maximum and minimum values (533 ppm), (359 ppm) respectively (Table 1).Spatial distributions of chloride ion concentrations are shown in Figure (7) in meq/l unit. It is shown that the chloride ion concentrations relatively very high values in all water sampling as compared to the value of good quality irrigation water (4 meq/l).

Miscellaneous Effects

The bicarbonates ion (HCO_3^-) concentration of water samples ranged between (176ppm) to (451ppm) with mean (316 ppm) (Table 1). In general, the bicarbonate concentrations values of below 90 mg/l (1.5 meq/l) are considered to be ideal for irrigation (Ayers &Westcot, 1985). Spatial distributions of bicarbonate ion concentrations are shown in Figure (8) in meq/l unit. In the study area the high salinity together with high concentrations of Bicarbonates indicates a probable hydraulic connection with relatively unmineralised surface (pluvial) water, (Jassim and Goff, 2006). It's important to mentions that; As a result of the fact of the aquifer is confined and deeply large (200 m depth) from the ground level in addition to the recharge area relatively far from studied area, it is expected that no significantly change in chemical-physical properties of groundwater with short time. So, there is no need to take other samples for different time periods.

Discussion of Irrigation Water Quality Index

Figure (9) shows the steps to found the final irrigation water quality index (IWQI) map that was produced by overlapping of the thematic maps (EC, SAR, Na, Cl and HCO_3) as a result of geostatistical analysis. The spatial integration for groundwater quality mapping was carried out using ArcGIS Spatial Analyst extension according to Eq. (3). This integration gives the IWQ index map shown in Figure (10). This figure represents the spatial distribution of the IWQ index within the domain of interest and could be considered as a general suitability map for providing irrigation water from the aquifer. Since the map shows the spatial distribution of groundwater quality in the plain as index values, it is now much easier for a decision maker to assess the quality of groundwater for irrigation purposes and further locate the most suitable site for drilling wells to extract irrigation waters.

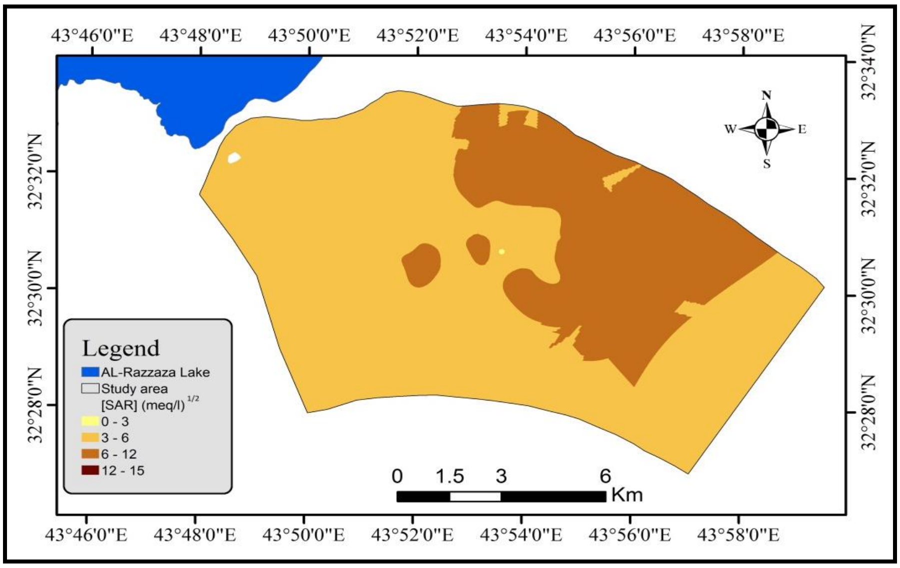

Figure 5: Spatial Distribution of SAR Concentration in the Study Area

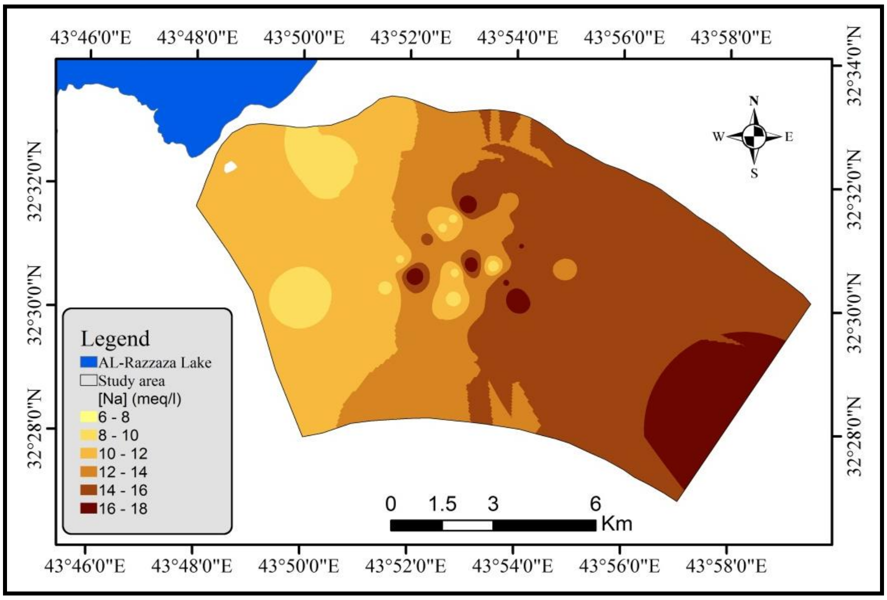

Figure 6: Spatial Distribution of Sodium ion Concentration in the Study Area

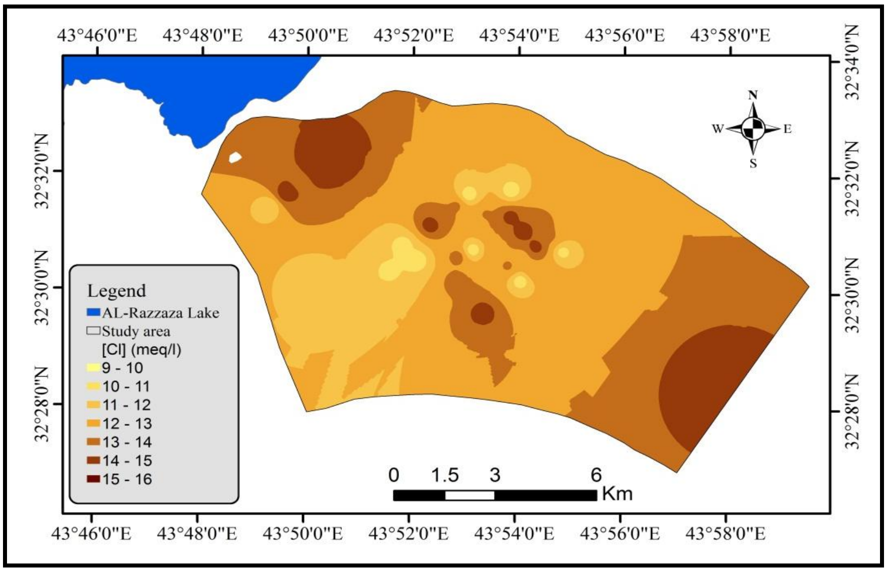

Figure 7: Spatial Distribution of Chloride ion (Cl) Concentration in the Study Area

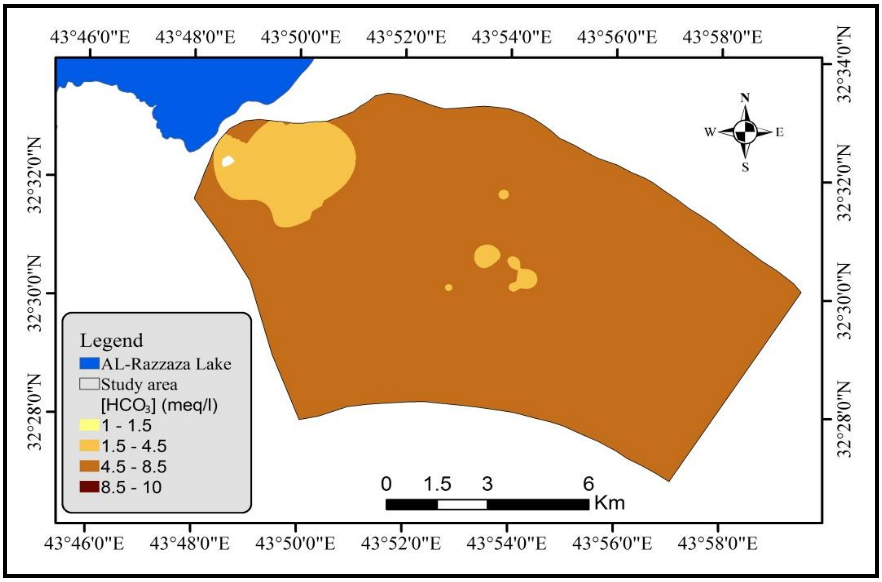

Figure 8: Spatial Distribution of Bicarbonates Ion (HCO_3) Concentration in the Study Area

Table 4: Water Quality Index Characteristics (Meireles et al., 2010)

IWQI	**Water Use Restrictions**	**Recommendation**	
		Soil	**Plant**
85-100	No restriction (NR)	May be used for the majority of soils with low probability of causing salinity and sodicity problems, being recommended leaching within irrigation practices, except for in soils with extremely low permeability.	No toxicity risk for most plants
70-85	Low restriction (LR)	Recommended for use in irrigated soils with light texture or moderate permeability, being recommended salt leaching. Soil sodicity in heavy texture soils may occur, being recommended to avoid its use in soils with high clay	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 may be 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 µS cm-1 and SAR above 7.0.	Should be used for irrigation of plants with moderate to high tolerance to salts with special salinity control practices, except water with low Na, Cl and HCO_3 values
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 HCO_3.

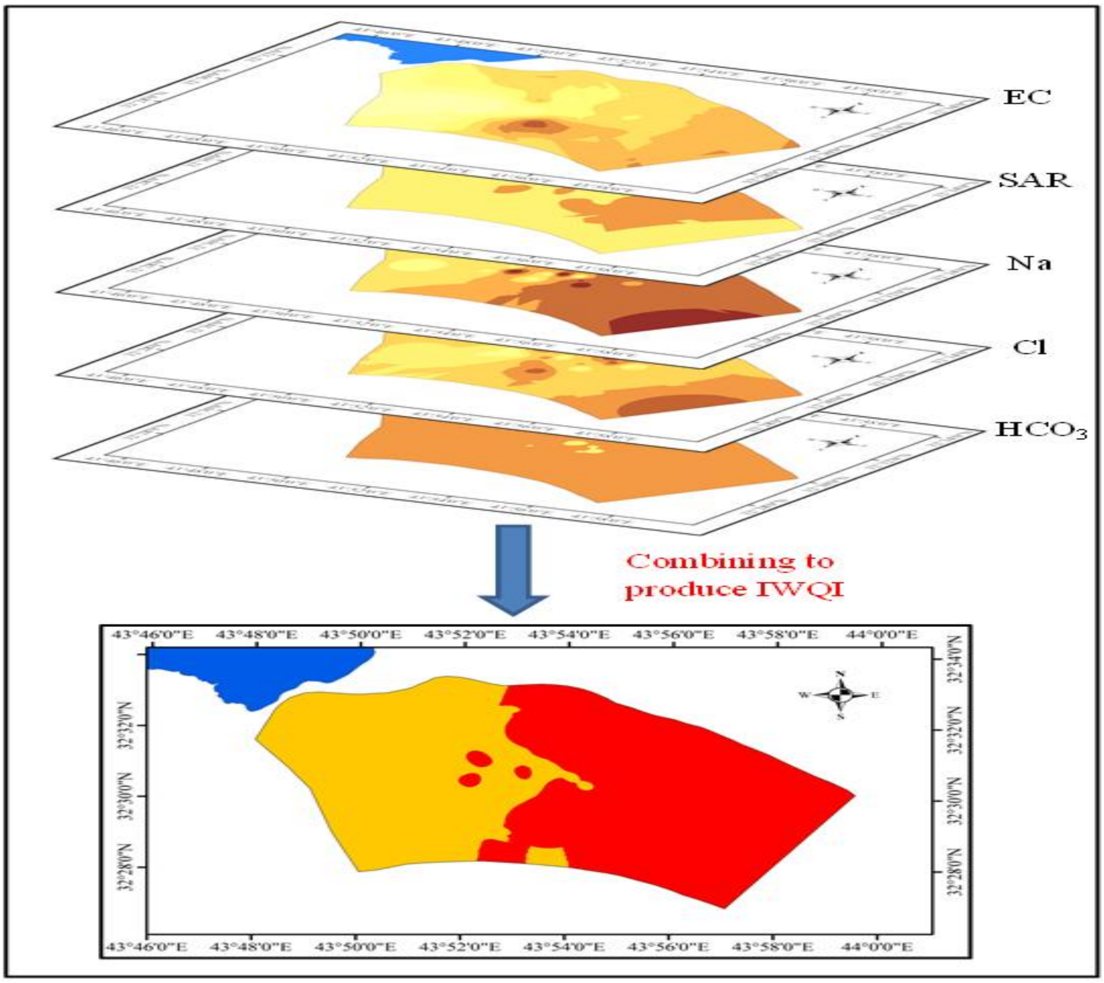

Figure 9: Steps for Creating Irrigation Water Quality Index

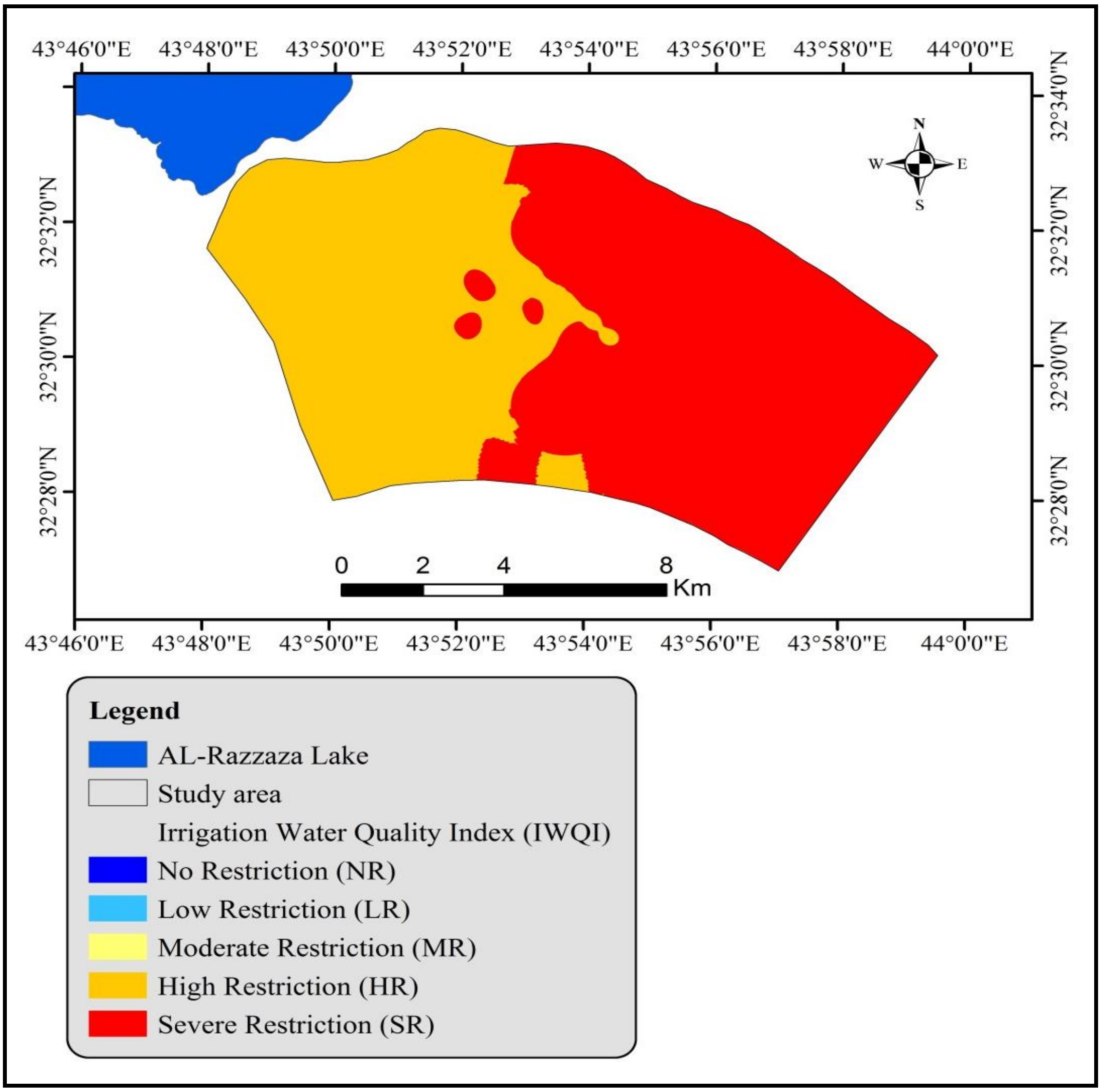

Figure 10: Irrigation Water Quality Index (IWQI) Map for the Study Area

Figure (10) shows spatial distribution of IWQI in the study area and it is varying from severe restriction (SR) to high restriction (HR) according to verify it with Table (4). The area for (Severe restriction) water quality could be found on a large area at the southeast and small areas at the center of the study area. These areas for (Severe restriction) water quality cover 56.1% (about 75.45 km^2) of total study area. The rest of the study area, which is about 43.9% (59.15 km^2), has water classified as (High restriction) quality levels (Table 5). In addition, The IWQI was decrease from west to east, because of increase the electrical conductivity, SAR, Sodium ion, Chloride ion in this direction as shown in figures (4,5,6 and 7) respectively. According to the recommendation in Table (4) these types of water should be used only with the soil have high permeability. Fortunately; all the study area located in Karbala desert which have very high permeability soil (sand).So, the groundwater could be used in irrigation with some constrains in type of plant with tolerance to salt as mentioned in table (4).

Table 5: Irrigation Water Quality Index Classes of the Study Area

IWQI	Water Use Restrictions	Area (Km^2)	Percent from Total Case Study Area
40-55	High restriction (HR)	59.15	43.9%
0-40	Severe restriction (SR)	75.45	56.1%
Total		**134.6**	**100%**

CONCLUSIONS

The use of GIS and water quality index (WQI) methods could provide a very useful and an efficient tool to summarize and to report on the monitoring data to the decision makers in order to be able to understand the status of the groundwater quality; and to have the opportunity for better use in future as well. Based on the results of the irrigation water quality index(IWQI) map, over 56% of the study area fall within the ‘‘Severe restriction’’ category, which is the dominant in the central and southeast parts of the study area. The rest of the study area, which is about 44% fall within the ‘‘High restriction’’ category, its dominant in the western parts the study area. These categories of groundwater should be used only with the soil have high permeability with some constrains in type of plant for tolerance of salts.

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