Assessment of Groundwater in Al-Hawija (Kirkuk Governorate) for Irrigation Purposes.

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Abstract
The study area is located in Kirkuk governorate - northern Iraq, It covers an area of 630 km^2.Twenty eight groundwater samples were collected from the study area during October 2012. pH, electrical conductivity(EC) and total dissolved solids (TDS) and chemical analysis of major ions (Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, SO_4^{2-} and HCO_3^-) were determined. Sodium adsorption ratio (SAR), residual sodium carbonate (RSC), sodium percent (Na%) and electrical conductivity were used to evaluate the suitability of groundwater for irrigation purpose. The groundwater samples mostly have no harmful effects and no hazard in terms of SAR and RSC respectively, and permissible in terms ofNa%, but they are poor, very poor and marginal as irrigation water.
Key words: Al-Hawija, irrigation, groundwater**.**

تقدير صلاحية المياه الجوفية في الحويجة (محافظة كركوك) لاغراض الري

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الخلاصة
تقع منطقة الدراسة في محافظة كركوك– شمال العراق. وتغطي مساحة 630 كم2. ثمانية وعشرون نموذج مياه جوفية جمعت من منطقة الدراسة اثناء تشرين الثاني 2012. تم حساب دالة الحامضية, التوصيل الكهربائي ومجموع الاجسام الصلبة المذابة والتحاليل الكيميائية للايونات الرئيسية (Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-,SO_4^{2-} and HCO_3). تم استخدام نسبة امتزاز الصوديوم(SAR), كاربونات الصوديوم المتبقية (RSC),النسبة المئوية للصوديوم والتوصيل الكهربائي في تحديد صلاحية المياه الجوفيةلاغراض الري. لايوجد اي ضرر او خطورة من استخدام المياه الجوفية في منطقة الدراسة استنادا" الىقيم نسبة امتزاز الصوديوم(SAR) وكاربونات الصوديوم المتبقية(RSC)على التوالي وهي مقبولة استنادا" الى قيم النسبة المئويةللصوديوم (Na%)ولكنهافقيرة, فقيرةجدا"لاغراض الري.

Introduction

Irrigation water quality directly affects soils and crops, and their management. It is possible to produce high quality crops only by using high-quality irrigation water when other inputs are kept optimal. Characteristics of irrigation water can vary with the source of the water. Regional differences in water characteristics will result from variation of geology and climate and climatic parameters' are the most important factors related to irrigation [1]. Moreover, there may also be great differences in the quality of water available on a local level depending on whether the source is from surface water

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bodies (e.g., rivers and ponds) or from aquifers with varying geology, and whether the water has been chemically treated.

The chemical constituents of irrigation water can affect plant growth directly through toxicity or deficiency, or indirectly by altering plant availability of nutrients [2,3].In recent decades the groundwater became one of the most important natural resources as a result of increasing water demand and decreasing rainfall amount and surface water supplies. The study area is one of an important agricultural areas in Iraq, because it provides many areas in country with vegetables and grains. The agriculture in this area depends on groundwater drawn from wells as well as the surface water from the Kirkuk Irrigation Project and Al-Hawija Irrigation Project.

There are many researchers studied this area. Parsons (1955) [4] studied a hydrogeological conditions of the area. Thereafter a comprehensive survey has been made through dug and pipe wells scattered in the area. AL-Jawad et al. (1997) [5] studied the groundwater levels and topographic features, the extents of the geologic water-bearing layers and the groundwater suitability for the multi purposes. AL-Jumaily (2007) [6] studied major ions and some heavy metals in Al-Hawija Irrigation Project. Al-Nakash et al. (2003) [7] evaluate and develop an operational program for the wells drilled in Kirkuk governorate of the period 2001-2003 by the General Company for Water Well Drilling. Hassan (2007) [8] studied heavy metals concentrations in surface soils in Al-Hawija area. Al-Kazwini et al. (2007) [9] studied the sediment transport and how to compute their amount in the Kirkuk Irrigation Project. Al-Hamdani (2009) [10] studied the relationship between groundwater, irrigation and drainage projects in Tawuq sub-basin south of Kirkuk, also the pollutant sources, their amounts, their changes in high water season.

This study aims to evaluate the groundwater quality in the study area for irrigation purpose.

Study Area

The study area is a part of Kirkuk governorate. It is located between latitudes (35° 16′ 20" - 35° 32′ 33"), and longitudes (43° 45′ 50" - 44° 10′ 12"), which covers an area ofabout630km². This area is delimited by The Lesser Zab River in the northwest,the Btewa anticline in the east and northeast, Kirkuk -Beji motorway in the south and southeast,whilst Al-Hawija Irrigation Project in the west and southwest. AL-Hawija plain is located at the southwestern part of Kirkuk governorate, within the Hammrin-Makhul tectonic sub zone, the area is of simple topography with an average elevation of 270 m.a.s.l., having a semi-arid climate [11]. Geologically the largest part of the study area is covered by quaternary deposits represented by river terraces, polygenic deposits, slope deposits, residual gravels, flood plain, valley fill deposits and fixed sand dunes. Tertiary deposits were exposed in the Btewa anticline represented from the oldest to the youngest by Fatha Formation (M. Miocene), Injana Formation (U.Miocene), Mukdadyia Formation (L. Pliocene) and Bai-Hassan Formation (U. Pliocene) figure-1.

Materials and Methods

From different locations in the study area, 28 groundwater samples were collected during October, 2012 figure-2. The groundwater samples were collected after 10 minutes of pumping to ensure collecting representative samples. The depth of the wells varied from 30 to 150 m. The coordinates for each sample (Longitude, Latitude and elevation) are accurately determined using a GPS (Global Positioning System) instrument (Type-GPS72). The temperature (T °C), electrical conductivity (EC) and total dissolved solids (TDS) are measured immediately after sampling in the field using a portable conductivity meter WTW (LF330). The pH, electrical conductivity (EC) and total dissolved solids (TDS) and the chemical analysis of major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-} and HCO_3^{-}) are carried out in the laboratory of General Commission for Groundwater using a standard procedure of APHA (2005) [12].

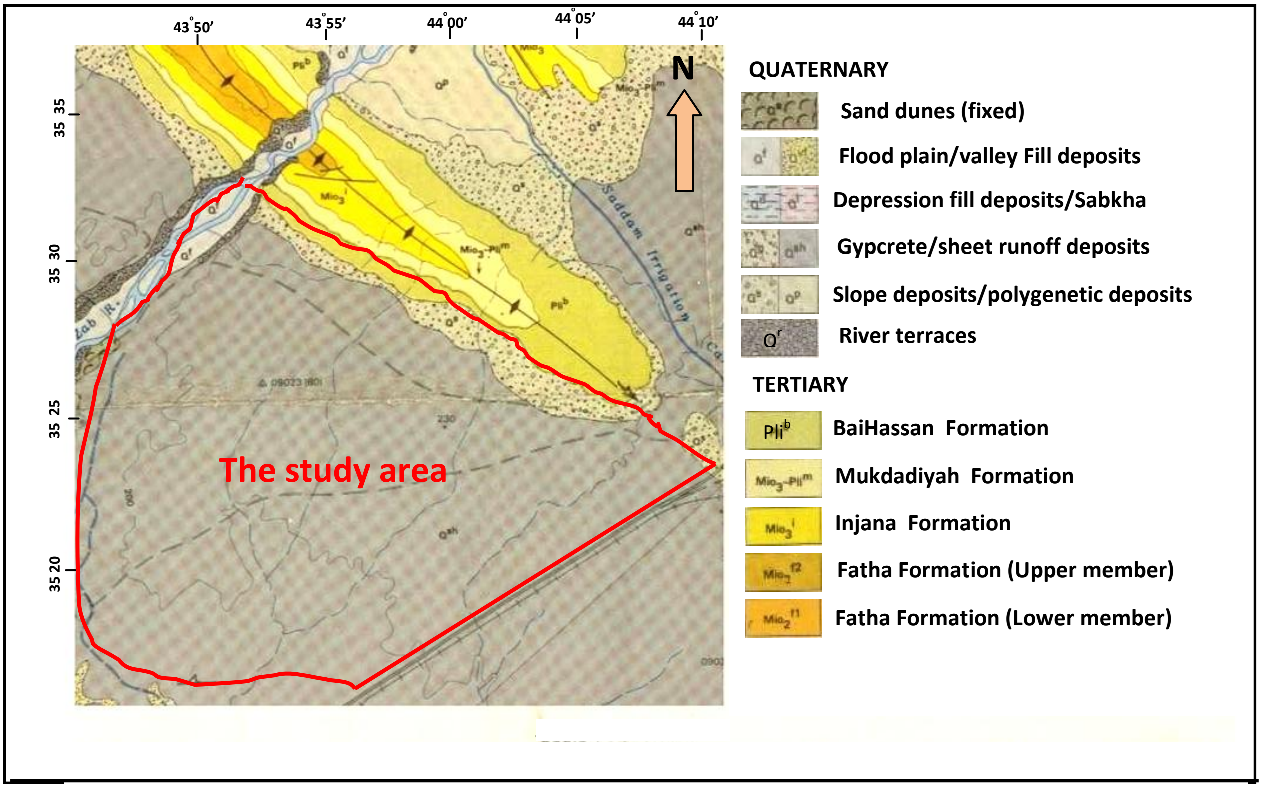

Figure 1- Geological map of the study area

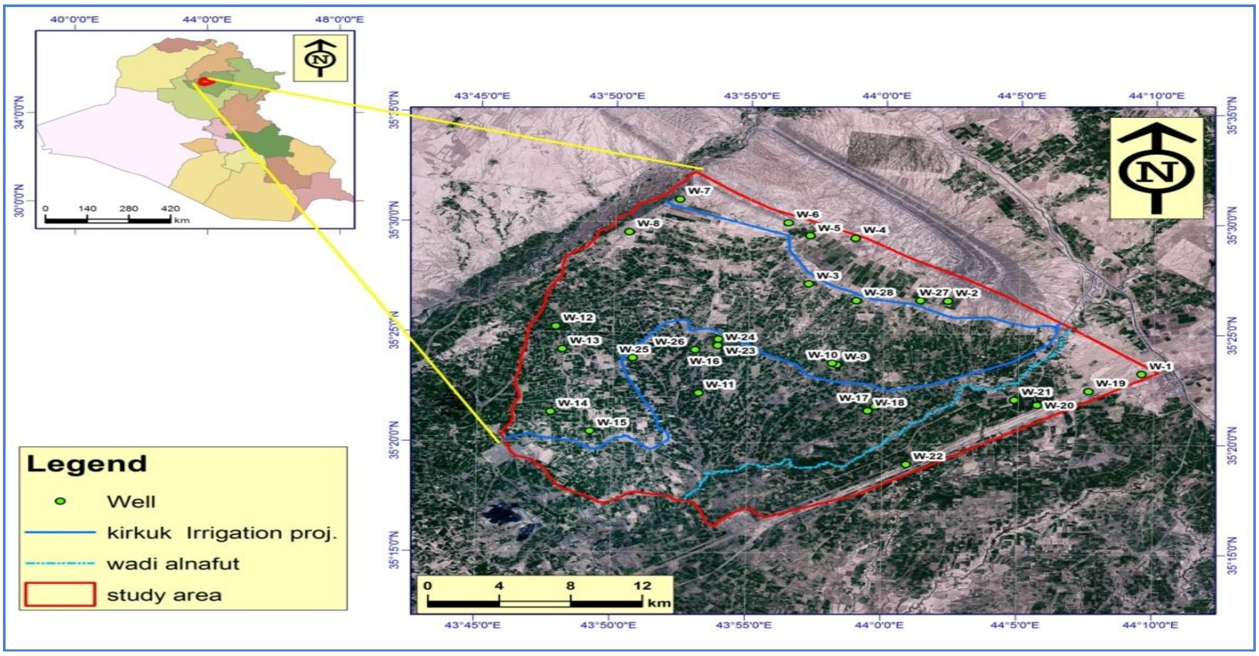

Figure 2- distribution of groundwater samples in the study area.

Assessment parameters of irrigation water

Use of poor water quality can create four types of problems, namely toxicity, water infiltration, salinity and miscellaneous [2]. To assess water quality for irrigation, there are four most popular criteria: TDS or EC, sodium adsorption ratio (SAR), chemical concentration of elements like Na+, Cl- and residual sodium carbonate (RSC) [13,14].

The suitability of water for irrigation is determined by its mineral constituents and the type of the plant and soil to be irrigated [15]. There are many classifications to know the suitability of water for irrigation purposes. They depend on several variables including the cations , anions ,EC, TDS, pH, sodium adsorption ratio (SAR), soluble sodium percentage (Na%) and residual sodium carbonate (RSC).

Salinity Hazard

The total concentration of salts in an irrigation water is measured by the electrical current conducted by the ions in solution. This measurement is expressed as electrical conductivity is an estimate of the quantity of salts in solution. The higher the salt concentration, the higher the EC [16]. Turgeon (2000) classified an irrigation water according to the total concentrations of soluble salts to low (C1), medium (C2), high (C3) and very high (C4) salinity zones based on the EC values table-1.

Sodium Adsorption Ratio (SAR)

The sodium alkali hazard is typically expressed as a sodium adsorption ratio (SAR). The index quantifies the proportion of sodium to calcium and to magnesium ions in a sample. High values of SAR imply a hazard of sodium replacing absorbed calcium and magnesium, a situation ultimately damaging to soil structure [17].

(SAR) values are calculated according to the following equation [18]:

$$SAR = \frac{rNa}{\sqrt{r(Ca + Mg)/2}}$$

Where:

SAR= sodium adsorption ratio

rNa^{+} , rCa^{2+} and rMg^{2+} : Concentration of Ions by (epm) units.

Turgeon (2000) were classified irrigation water according to SAR values table-2.

Table 1-Classification of irrigation water based on salinity EC values (Turgeon, 2000).

Level	EC (µS/cm)	Hazard and limitations
C1	< 250	Low hazard; no detrimental effects on plants, and no soel buildup expected.
C2	250 - 750	Sensitive plants may show stress; moderate leaching prevents salt accumulation in soil.
C3	750 - 2250	Salinity will adversely affect most plants; requires selection of salt-tolerant plants, careful irrigation, good drainage, and leaching.
C4	> 2250	Generally unacceptable for irrigation, except for very salt-tolerant plants, excellent drainage, frequent leaching, and intensive management.

Table 2- Classification of irrigation water based on SAR values [20].

Level	SAR	Hazard
S1	<10	No harmful effects of sodium.
S2	10-18	An appreciable sodium hazard in fine-textured soils of high CEC but could be used on sandy soils with good permeability.
S3	18-26	Harmful effects could be anticipated in most soils and amendments such as gypsum would be necessary to exchange sodium ions.
S4	>26	Generally unsatisfactory for irrigation.

Soluble Sodium Percentage (Na%)

The sodium in irrigation waters is usually denoted as percent sodium and can be determined using the following formula:

$$\mathrm{Na\%} = \frac{\mathrm{rNa + rK}}{\mathrm{rCa + rMg + rNa + rK}} \times 100$$

Where:

rNa^{+} , rCa^{2+}, rMg^{2+} ,and rK^{+}: Concentration of Ions by (epm) units.

Don(1995) [21] classified the quality of irrigation water according to Na% values table-3.

Table 3-Classification of irrigation water based on Na% values.

Na%	20	20-40	40-60	60-80	>80
Water quality	Excellent	Good	Permissible	Doubtful	unsuitable

Residual Sodium Carbonate (RSC)

The high concentration of bicarbonate in irrigation water leads to precipitation of calcium and magnesium in the soil, Thus the sodium concentration will increase [19]. RSC is calculated using the following equation:

$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$

Where the ionic concentrations in meq/l units.

A negative RSC indicates that sodium buildup is unlikely since sufficient calcium and magnesium are in excess of what can be precipitated as carbonates. A positive RSC indicates that sodium buildup in the soil is possible [20] table-4.

Table 4- Classification of irrigation water based on RSC values [20].

RSC	**Hazard**
< 0	None.
0-1.25	Low, with some removal of calcium and magnesium from irrigation water.
1.25-2.50	Medium, with appreciable removal of calcium and magnesium from irrigation water.
> 2.50	High, with most calcium and magnesium removed leaving sodium to accumulate.

Results and discussion

Groundwater assessment

EC, SAR, Na% and RSC values for the groundwater samples of the study area were calculated and listed in the table-5. In respect of EC values according to Turgeon (2000) classification table-1, sample W-15 is of the zone (C2), samples W-6, W-7, W-8, W-12, W-13, W-14 are of the zone (C3) and other groundwater samples are of the zone (C4) which indicates that most of the groundwater samples are Generally unacceptable for irrigation, except for very salt-tolerant plants, excellent drainage, frequent leaching, and intensive management. According to the classification of Don (1995) table-6, groundwater sample W-15 is of a good class, samples W-6, W-7, W-8, W-12, W-13 and W-14 are of permissible class, samples W-5, W-11, W-22, W-26 and W-29 are of doubtful class, all other ground water samples are of unsuitable class in respect of EC values.

In respect of SAR values according to Don (1995) classification, samples W-5, W-7, W-12, W-13, W-15, W-20, W-23 and W-27 are of excellent class. Samples W-1, W-8, W-11, W-14, W-21 and W-24 are of good class. Sample W-26 is of doubtful class and other groundwater samples are of Permissible class. According to Turgeon (2000) classification the groundwater sample W-26 is of the S2 class and other groundwater samples are of the S1 class.

In respect of Na% values according to Don (1995) classification, samples W-5, W-7, W-11, W-12, W-13, W-14, W-20, W-23 and W-27 are of good class and other groundwater samples are of permissible class.

In respect of **RSC** All ground water samples of the study area are of the first class of the Turgeon (2000) classification of irrigation water.

Groundwater classification

The US Salinity Laboratory's diagram is used widely for rating irrigation water, where SAR is plotted against EC figure-3. SAR is an index of sodium hazard and EC is an index of salinity hazard. Most of groundwater samples of the study area lie in C4S2 field and the remainder lie in C4S1, C4S3, C3S1,C3S2 and C2S1 fields indicating that most of the groundwater samples in the area are poor, very poor and marginal for irrigation, except three samples that are good as shown in table-7.

Table 5- EC, SAR, Na% and RSC values of groundwater samples

Sample Number	EC(µs/cm)	SAR	Na%	RSC
W-1	5400	4.68	43.18	-13.09
W-2	5040	5.71	42.46	-26.69
W-3	3760	5.91	52.27	-9.05
W-4	4680	5.51	43.30	-23.21
W-5	2500	2.15	30.08	-12.79
W-6	1675	7.87	74.45	-0.53
W-7	780	1.69	39.41	-3.16
W-8	1671	4.86	52.37	-8.83
W-9	7260	7.27	45.96	-28.37
W-10	7320	7.58	45.37	-32.65
W-11	2350	3.63	37.86	-15.89
W-12	780	1.54	35.66	-2.04
W-13	650	1.71	39.52	-3.20
W-14	1298	4.36	52.22	-6.64
W-15	730	1.63	36.03	-3.98
W-16	3630	5.20	45.76	-16.31
W-17	4900	7.26	53.39	-14.19
W-18	8510	6.58	40.68	-38.02
W-19	7820	5.84	43.58	-25.19
W-20	3660	2.65	28.08	-20.98
W-21	3250	4.86	45.86	-9.39
W-22	2630	5.40	53.06	-10.57
W-23	4010	2.23	31.50	-11.76
W-24	3280	4.99	47.38	-8.32
W-25	3590	5.95	52.25	-8.98
W-26	2680	10.18	73.94	-2.36
W-27	3810	2.92	28.79	-22.71
W-28	7080	7.88	48.10	-36.99
Minimum	650.0	1.5	28.1	-38.0
Maximum	8510.0	10.2	74.5	-0.5
Average	3740.9	4.9	45.1	-14.9

Table 6- Classification of Don (1995) for irrigation water.

EC µs/cm	TDS ppm	AR	Na%	pH	Water Quality
250	175	3	20	6.5	Excellent
250-750	175-525	3-5	20-40	6.5-6.8	Good
750-2000	525-1400	5-10	40-60	6.8-7	Permissible
2000-3000	1400-2100	10-15	60-80	7-8	Doubtful
>3000	>2100	>15	>80	>8	unsuitable

Table 7- Classification of groundwater samples according to Richard Diagram.

Index	Water class	Groundwater samples
C1S1	Excellent	--
C1S2	Good	--
C1S3	Admissible	--
C1S4	Poor	--
C2S1	Good	W-13, W-15
C2S2	Good	--
C2S3	Marginal	--
C2S4	Admissible	--
C3S1	Admissible	W-7, W-8, W-12, W-14
C3S2	Marginal	W-6
C3S3	Marginal	--
C3S4	Poor	--
C4S1	Poor	W-5, W-11, W-20, W-21,W-23, W-24, W-27,
C4S2	Poor	W-1, W-2, W-3, W-4, W-9, W-16 , W-17, W-18, W-19, W-22, W-25
C4S3	Very Poor	W-10, W-26, W-28
C4S4	Very Poor	--

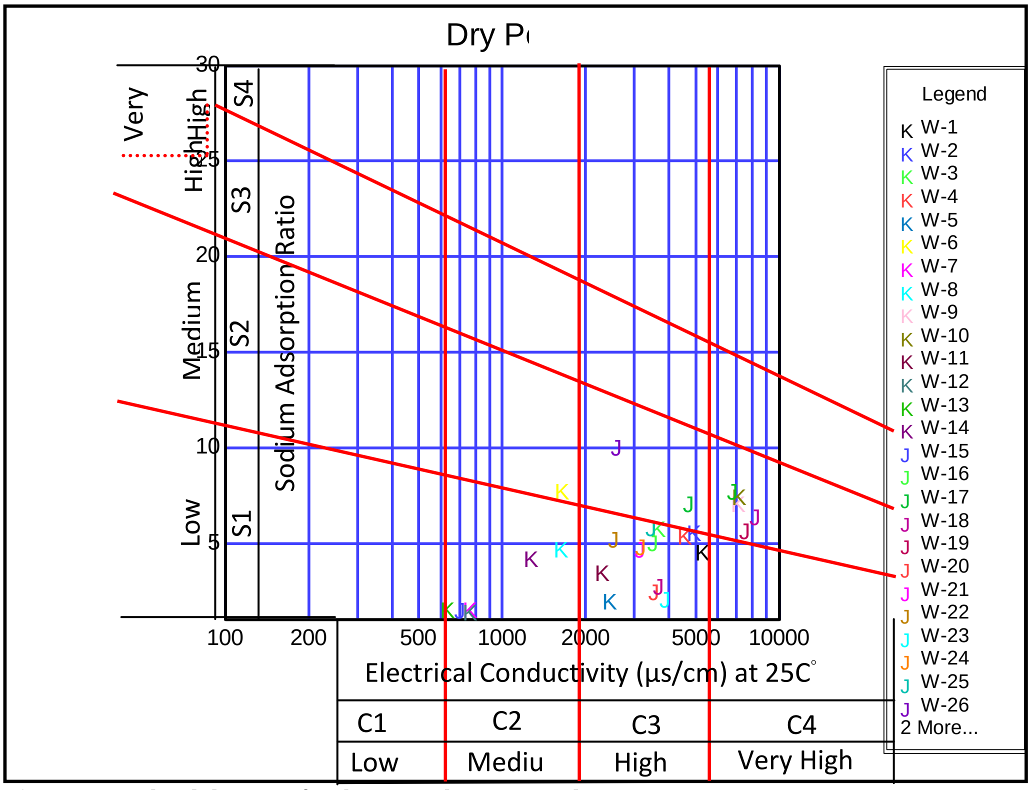

Figure 3- Richard diagram for the groundwater samples.

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