EVALUATE THE GROUNDWATER SUITABILITY FOR IRRIGATION IN DUJAILA AREA – WASIT GOVERNORATE – MIDDLE OF IRAQ

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ABSTRACT

The selected area is Dujaila project, Wasit governorate, Iraq. Twelve water samples groundwater and drainage were collected during March 2016. Total dissolved solids (TDS), pH, electrical conductivity (EC), major ions Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-} and HCO_{3-}, and chemical analysis were determined. To evaluate the suitability of analyzed water for irrigation, Sodium adsorption ratio (SAR), residual sodium carbonate (RSC), sodium percent (Na%) and electrical conductivity were applied. The based on electrical conductivity classification of the analyzed water indicated that both the groundwater and drainage water are unacceptable for irrigation, except for very salt-tolerant plants (EC> 2250 µs/cm). These samples mostly have no harmful effects and no hazard in terms of RSC (RSC < 0), while for SAR, the groundwater samples have no harmful effects of sodium (SAR < 10) but it is unsatisfactory for irrigation for drainage water samples (SAR > 26) and groundwater samples are good (Na% range from 20 to 40) to permissible (Na% > 40) in terms of Na%, while, the drainage water samples indicate doubtful class for the three samples (Na% > 60). Applying the water-sediment relationship experiments with respect to dry and wet periods show that about 2.2% – 4.8% of the TDS were librated after the drying condition which is believed to be of the water-soluble salts that exist within the sediment column.

Keywords: Irrigation suitability; Groundwater; Water-sediment relationship; Iraq

INTRODUCTION

About half of the Iraqi land is affected by salts, especially in agricultural lands, most of them lies in the middle and south of Iraq due to the dams construction in the neighboring countries (Turkey, Syria, and Iran) (FAO, 2003). This problem increased in

Iraq, due to declining fresh water resources and a low efficiency of drainage system, in addition to the aridity condition in the study area. The washing lands are the main process for reclaiming saline lands with an efficient system of drainage. Geology and climate may affect regional differences in irrigation water characteristics (Ayers and Westcot, 1985; Rowe and Magid, 1995; and Shirazi *et al*., 2011). Recently the groundwater became important natural resources as a result of increasing water demand and decreasing rainfall amount and surface water supplies. The Dujaila project area – Wasit Governorate - Central Iraq is one of an important agricultural area in Iraq. The agriculture in this area depends on surface water but the farmers use the groundwater and drainage water {The drainage salty water that called locally (Al-Malih)} during water deficit periods.

The Dujaila project area is located between latitudes (32° 10' – 32° 40') N and longitude (45° 50' – 46° 20') E. It is occupy 1372 Km^2 (Fig. 1). It is a part of low relief plain known as the Mesopotamian Plain, which has a sandy silty clay surface. It is used heavily for agricultural purposes. The farms in these areas are randomly distributed utilize groundwater and drained water for irrigation, although it has a high salinity range from 3000 to 12000 ppm (Al-Mayyahi, 2016).

A variety of soil properties such as soil acidity, EC, clay and organic contents have been identified as affecting the behavior of TDS in soil in different parts of the world, although, the wetting and drying processes play an important role in transferring TDS between sediment and water (Al-Dabbas, 2002 and 2005; Al-Shihmani, 2015).

This study aims evaluating the groundwater quality in the Dujaila area for irrigation and to investigate the water-sediment interrelation, taking into account the rainfall and utilized groundwater for irrigation.

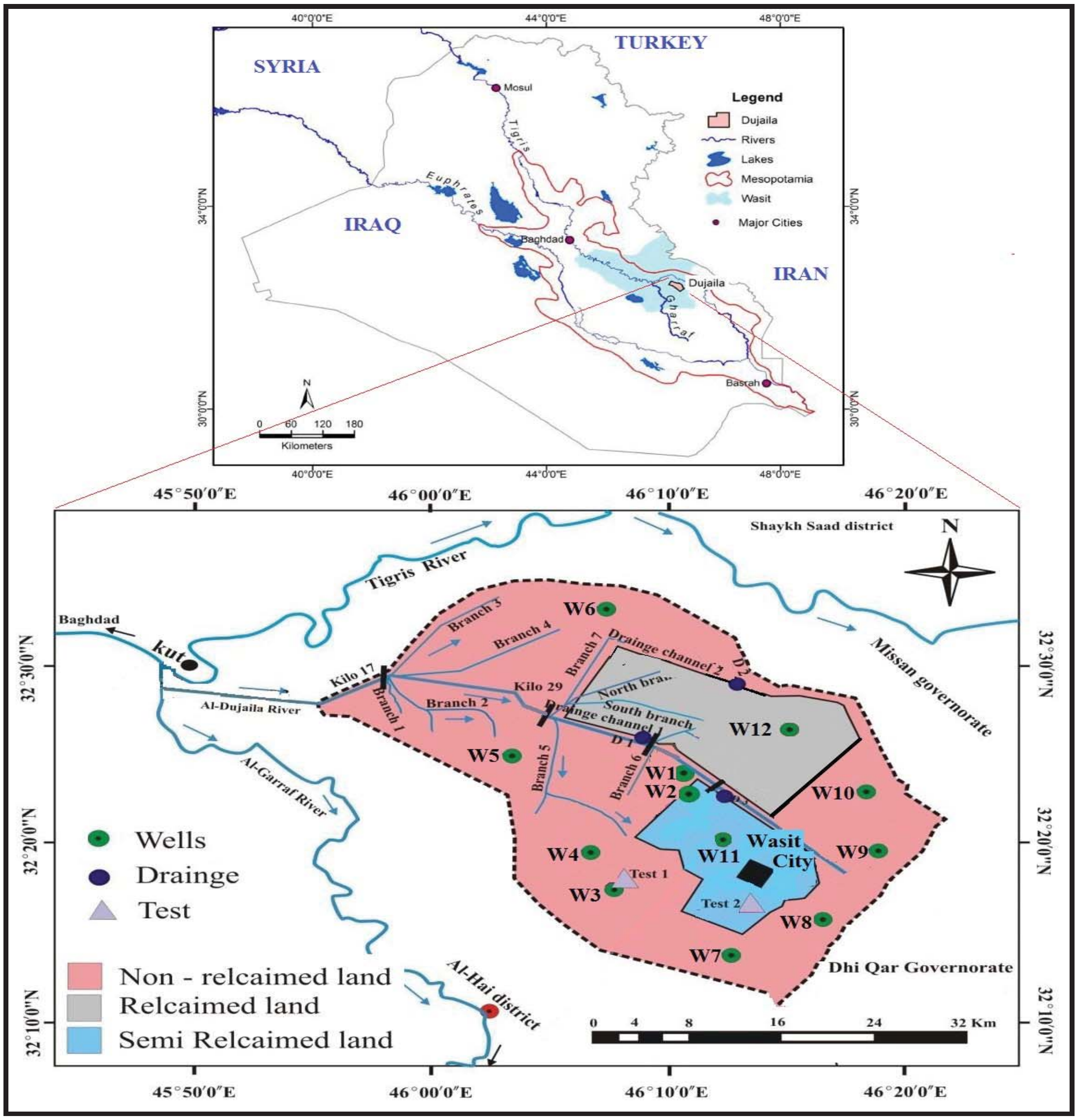

Fig. 1: Locations of groundwater and drainage water samples and the sediment-water interrelation tests in the study area

MATERIALS AND METHODS

1. Twelve groundwater and three drainage water samples were collected during March 2016 from Dujaila area (Fig. 1). The measurements were done using procedure of APHA (2005) at the service laboratory in the College of Science – University of Baghdad. All samples were analyzed for major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-} and HCO_3^{-}) (Table 1). Sodium and potassium were analyzed using flame photometer (APHA, 2005). Calcium, magnesium were analyzed using titration with EDTA

(Ethylene Diamine Tetracitic Acid), chloride was analyzed using Technecon autoanlyzer instrument (APHA, 2005). Carbonate and bicarbonate were determined by titrimetric method. Sulfate was determined using of spectrophotometer (U.V.). The hydrogen number (pH), electrical conductivity (EC), TDS were measured directly in the field using, HANA meter (HI 9811). Some of the high values of TDS water samples were measured by drying at 105 °C at the service laboratory in the College of Science – University of Baghdad (Boyd, 2000). The analytical accuracy was calculated according to Stoodly *et al*. (1980); and Hem (1985), accordingly the accuracy of results is accepted.

2. The sediments of Dujaila project area are composed of sand, silt and clay. They are characterized from the top soil to 1.2 m depth by sandy silty clay (Median = 0.008 mm), sandy clayey silt (Median = 0.05 mm), clayey silt (Median = 0.03 mm) and silty clay (Median = 0.007 mm) respectively. The mineral composition of the Dujaila project area sediments revealed that the principal components of the studied samples are quartz, feldspar, gypsum, calcite and clay minerals which represented by montmorillonite, chlorite, illite, kaolinite, mixed layer and to less extent palygorskite (Al-Mayyahi, 2016).

In attempt to construct a suitable model for the water-sediment interaction that represents the natural conditions of the recycles water of irrigation as an additional recharge which leads to salinity increase. Proposed method was applied in this research. This method is dealing with the extracted water from the sediment samples after washing with distilled and well waters or drainage water. This method is used by continuous immersion and washing of the sediment column by many liters of water during the required time period. The infiltrates were analyzed for the total dissolved salts (TDS), as well as measuring the electrical conductivity (EC). Groundwater sampling from wells have been carried out from 12 wells to investigate TDS variability in space during March 2016 (Al-Mayyahi, 2016).

In the present work experiments were carried out to investigate the "TDS cyclicity between groundwater and soils, taking into consideration the soil type, dry and wet periods and the environmental conditions in terms of rainfall and human impact. A sample of average condition was selected in silty clay sediments of the studied two sites locations. The proposed method was applied for the sediment – water interrelation. The electrical conductivity (EC) and TDS measurements for the infiltrate were considered for this purpose. Two sites were selected for washing soil experiment (Test 1) and (Test 2), (Fig. 1). The sampling was done by using the hand auger for the top soil which is essential for planting at depth (0 – 120 cm) to show the effect of the leaching effect in the soil section (Al-Shihmani, 2015). The soil section is situated in plastic tube with perforated end (designed by the searchers), (Fig. 2). The distilled water was used (to represent rainfall) for the purpose of washing the soil and then dried for two weeks and re-wash with distilled water again, and then dried two weeks to represent the dry and wet periods effect. Then the soil section in the tube was re-washed by drainage water (represent irrigation by high salinity water). This method is described by continuous immersion of the sediment column by distilled water. The EC is measured for each liter of infiltrate at different time of immersion (Al-Dabbas, 2002 and 2005; Al-Hamdani, 2009; and Al-Shihmani, 2015). In fact, the time consuming for infiltration is depend on the lithology of the selected sediment samples, where for, site one (A) (Test 1), needed about 8.2 hours for 10 liters poured water while for, site two (B) (Test 2), took 9.5 hours for 10 liters poured water infiltration. The EC measurements for each experiment show decrease with time, i.e. further reduction of EC at the last liter, which is obvious due to the continuous washing of the sediment sample. The infiltrated liters of distilled water that used to wash the two sites were taken separately and analyzed for their TDS and EC (Tables 2 and 3). The results reflect that most of the major anions and cations will be wash out from the sediment sample by using the first five liters and their concentrations decrease to the minimum at the last liter.

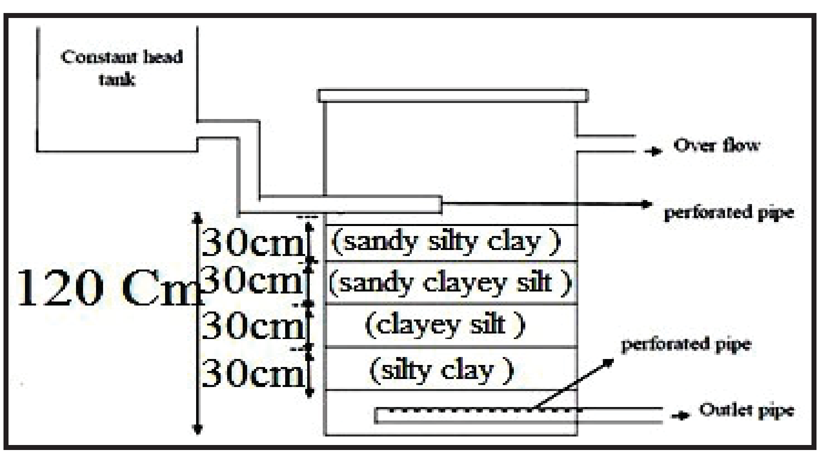

Fig. 2: The laboratory set up of the filtration process

Table 1: Chemical properties of water samples during March 2016

Sample No.	K^+	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HCO_3^-	TDS	pH	EC (µs/cm)
	Mg/L									
W1	6	260	160	88	330	550	270	1650	7.5	2620
epm	0.15	11.3	8	7.3	9.3	11.5	4.4			
W2	8.8	314	200	350	670.4	962.5	502.6	3150	7.1	3405
epm	0.23	13.6	10	28.7	18.9	20	8.2			
W3	6.2	350	230	95	265	845	440	2300	7.6	4150
epm	0.15	15.2	11.5	7.9	7.5	17.6	7.2			
W4	5.1	310	210	90	240	755	435	2200	7.4	4000
epm	0.13	13.5	10.5	7.5	6.8	15.7	7.1			
W5	14	295	172	86	520	610	19.4	1790	7.15	2990
epm	0.4	12.8	8.6	7.2	14.9	12.7	0.32			
W6	14	290	172	86	550	605	19.4	1810	7.2	2900
epm	0.4	12.6	8.6	7.2	15.7	12.6	0.3			
W7	14	350	137	69	550	690	24	1830	7.3	2850
epm	0.4	15.2	6.9	5.8	15.7	14.4	0.4			
W8	14	350	135	68	560	688	23.5	1826	7.2	2800
epm	0.4	15.2	6.8	5.7	16	14.3	0.4			
W9	7.7	296.9	57.5	372.5	745.50	770.83	434.2	2836	7.4	3808
epm	0.2	12.9	2.9	30.5	21.0	16.0	7.1			
W10	3.9	257.2	225.0	380.0	488.13	1166.6	444.6	3176	7.3	3858
epm	0.1	11.2	11.2	31.2	13.8	24.3	7.3			
W11	10	300	133	71	534	495	26.8	1542	7.5	2650
epm	0.3	13	6.7	5.9	15.3	10.3	0.44			
W12	7.0	300.0	337.5	312.5	532.50	1808.33	353.8	3972	7.0	4347
epm	0.2	13.0	16.8	25.6	15.0	37.6	5.8			
D1	10.6	3200	338	258	3400	3210	580	11620	7.2	19700
epm	0.27	139.1	16.9	21.6	95.8	66.9	9.5			
D2	18.4	3800	390	310	3800	3450	710	12510	7.2	20870
epm	0.5	165.2	19.5	25.8	107	71.9	11.6			
D3	13	2800	360	250	3500	3000	620	10950	7.6	17250
epm	0.33	121.7	18	21	98.6	62.5	10.2			

W = groundwater samples, D = drainage water samples

RESULTS AND DISCUSSION

1. Assessment Parameters of Irrigation Water

There are four most popular criteria to assess water quality for irrigation: TDS or EC, sodium adsorption ratio (SAR), soluble sodium percentage (Na%), chemical concentration of elements like Na^+, Cl and residual sodium carbonate (RSC) (Ayers and Westcot, 1985; Michael, 1992; and Qannam, 2003).

- **Salinity Hazard**

To assess the quantity of salts in solution the irrigation water were classified 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 (Glover, 1996; and Turgeon, 2000) Table 2. Based on this classification, the groundwater samples of Dujaila area are of class (C4) for the groundwater samples and the drainage water, that reflect unacceptable for irrigation, except for very salt-tolerant plants with excellent drainage, frequent leaching, and intensive management (Tables 1 and 2).

Table 2: 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 salt 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.

- **Sodium Adsorption Ratio (SAR)**

The sodium adsorption ratio (SAR) are calculated according to the following equation (Hem, 1985; and Todd, 1980 and 2007):

$$SAR = r\,Na / \sqrt{r\,Ca + r\,Mg}/2$$

Where: SAR = sodium adsorption ratio.

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

Turgeon (2000) classified irrigation water according to SAR values (Table 3).

Table 3: Classification of irrigation water based on SAR values (Turgeon, 2000)

Level	SAR	Hazard
S1	≤ 10	No harmful effects of sodium
S2	11 – 18	An appreciable sodium hazard in fine – textured soil 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

Accordingly, all of the groundwater samples belong to (S1) excellent water class with no harmful effects of sodium, in which SAR < 10.0, while drainage water samples are poor water belong to (S4) in which SAR > 26 which is generally unsatisfactory for irrigation (Tables 3 and 4).

Table 4: SAR, Na% and RSC values of groundwater and drainage water samples

Samples No.	March 2016		
	SAR	Na%	RSC
W1	4.1	42.8	-10.9
W2	5.7	26.3	-30.5
W3	4.9	44.17	-12.2
W4	4.5	43.1	-10.9
W5	4.6	45.5	-15.5
W6	4.4	45.1	-15.5
W7	6.1	55.1	-12.3
W8	6.1	55.5	-12.1
W9	3.1	28.2	-26.3
W10	2.4	21.0	-35.1
W11	5.2	51.4	-12.2
W12	2.8	23.7	-36.6
D1	31.8	78.35	-29
D2	34.8	78.53	-33.7
D3	27.6	75.79	28.8

W = groundwater samples, D = drainage water samples

- **Residual Sodium Carbonate (RSC)**

RSC was calculated using the following equation:

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

Where, the ionic concentrations in meq/l units. (Turgeon, 2000) Table 5.

Accordingly, all the samples showed (RSC) values less than zero; therefore, all the samples are suitable for irrigation uses regarding RSC, Tables 4 and 5.

Table 5: Classification of irrigation water based on RSC values, according to Turgeon (2000)

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

- **Soluble Sodium Percentage (Na%)**

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

$$Na\ \% = \frac{(Na + K)}{(Ca + Mg + Na + K)} \times 100$$

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

Don (1995) classified the quality of irrigation water according to Na% values (Tables 6 and 4). Accordingly, the sodium percentages in groundwater samples indicate good water (for wells W2, W9, W10 and W12) to permissible water for the rest samples. While, the drainage water samples indicate doubtful class for the three samples (Tables 4 and 6).

Table 6: Classification of irrigation water based on Na% values (Don, 1995)

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

2. The Water-sediment Relationship

According to, Al-Hamdani, 2017, the geo-chemical behavior of TDS is mainly affected by the environmental conditions prevailing during its migration between sediment and water at wet and dry periods. In this research an attempt was made to verify this situation during wet and dry periods where the experiment was carried out with a design to simulate these environmental conditions (Van Hoorn, 1970). Two sites of sediments columns were selected and tested under dry and wet conditions using simulated rainwater and drainage salty water of 10950 and 12510 ppm TDS concentration for washing the sediment column (Fig. 2). Ten liters of distilled water for continuous immersion of sediment column were used in both locations (Test 1 and Test 2). All of these liters were collected from the perforated end of the plastic tube that designed for TDS measurements. The TDS results of the collected distilled water are shown in Tables 7A and 8A. The sediment columns were left to dry at room temperature for two weeks, then the same experiment repeated again by six liters of distilled water, the results were shown in Tables 7B and 8B. The TDS of water extract for the first liter was very high (21500 ppm) in Test 1, compared with last washing liter that was (3150 ppm) (Table 7). Comparing the extracted salt percentages of the sediment column by the first liter distilled water is (35.8%) to that of the last liter (85.3%) in Test 1, indicated that within each liter more salt removed from the soil to reach 85.3%. The extracted salt percentages in Test 2 of the sediment column by the first liter distilled water (TDS is 18300 ppm represent 44% of removable salt from the soil) to that of the last liter (TDS is 2740 ppm represent 85% of removable salt from the soil) in Test 2, indicated that within each liter more salt removed from the soil to reach 85% (Table 8). More salts were liberated from the sediment column after drying and washing with distilled water (Table, 7A and B in Test 1; Table 8A and B in Test 2).

The sediment columns were dried again for two weeks at room temperature. Then sediment column were washed by using high salinity water (TDS 12510 ppm in Test 1), and (TDS 10750 ppm in Test 2) representing the drainage water that may be used for irrigation by the farmers during the water deficit periods (summer months), and the seven liters were collected from the perforated end for TDS measurements (Tables 7C, and 8C). The TDS of water extract for the first liter was TDS (2400 ppm) that indicate about 80.8% of the salt amount within the used water was stayed in the sediment column compared with last washing liter that was (9300 ppm) that indicate about 25.6% of the salt content of the used water was stayed in soil for Test 1. This experiment indicted salts accumulation in the sediment column section that within each liter more salt is stay in the sediment column (Table 7C). While for Test 2, the TDS of water extract for the first liter was TDS (1530 ppm) that indicate about 85.8% of the salt amount within the used water was stayed in the sediment column compared with last washing liter that was (8600 ppm) that indicate about 20% of the salt content of the used water was stayed in the sediment column for Test 2. This experiment indicted that the salts accumulate in the sediment column section (Table 8C).

The increasing of the salts from the sediment after drying which is about 4.8% for the first test (Table 7) and about 2.2% for the second test (Table 8). Such results are in concordance with Al-Hamdani (2017) findings.

Table 7: The TDS and TDS% of the washing sediment column by distilled water and drainage water to site (Test 1)

Extract Liter. No.		Extract Liter TDS ppm	Extracted Salt % from the soil by distilled water
Wash with distilled water			
A	1	21500	35.8
	2	13800	57.6
	3	9100	71.1
	4	6200	75.1
	5	5350	77.7
	6	4800	80.5
	7	4200	82.8
	8	3700	89.5
	9	3150	85.3
	10	3150	85.3
After drying two weeks, Wash with distilled water			
B	1	3300	3
	2	3200	12.4
	3	2890	19.1
	4	2670	25.7
	5	2450	25.7
	6	2450	25.7
Extract Liter. No.	**TDS resulting from soil washing by Drainage water used in irrigation**		**% of difference between the drainage water and the extracted water**
After drying two weeks, Wash with Drainage water TDS = 12510 ppm			
C	1	2400	80.8
	2	4230	66.2
	3	5500	56
	4	6350	49.2
	5	7720	38.3
	6	8200	34.5
	7	9300	25.6

Table 8: The TDS and TDS% of the washing sediment column by distil water and drainage water to site (Test 2)

Extract Liter. No.		Extract Liter TDS ppm	Extracted Salt % from the soil by distilled water
Wash with distilled water			
A	1	18300	44
	2	10240	76.3
	3	4336	77
	4	4200	78.7
	5	3900	80.2
	6	3616	83
	7	3100	84.4
	8	2850	84.9
	9	2740	85
	10	2740	85
After drying two weeks, Wash with distilled water			
B	1	2800	8.9
	2	2550	16
	3	2350	19.6
	4	2250	23.2
	5	2150	23.2
	6	2150	23.2
Extract Liter. No.		**TDS resulting from soil washing by Drainage water used in irrigation**	**% of difference between the drainage water and the extracted water**
After drying two weeks, Wash with Drainage water TDS = 10750 ppm			
C	1	1530	85.8
	2	2460	77.1
	3	3500	67.4
	4	4190	61.0
	5	4940	54
	6	6600	38.6
	7	8600	20

CONCLUSIONS

1. Groundwater Assessment

The irrigation water classification based on electrical conductivity indicated that the water samples are of class (C4) for both the groundwater and the drainage water. Such results refer to unacceptable water for irrigation, except for very salt-tolerant plants.

According to SAR values, all of the groundwater samples belong to (S1) excellent water class with no harmful effects of sodium, in which SAR < 10.0, while drainage water samples are poor water belong to (S4) in which SAR > 26 which is generally unsatisfactory for irrigation. While based on RSC, all the water samples showed (RSC) values less than zero; therefore, all the samples are suitable for irrigation uses regarding to this parameter.

According to Na% values, the sodium percentages in groundwater samples indicate good water (for wells W2, W9, W10 and W12) to permissible water for the rest samples. While, the drainage water samples indicate doubtful class for the three samples.

2. The Water-sediment Relationship

There is continuous decrease of available salt content within the sediment column by washing the sediment column with a distil water, and increase of salt in the sediment column by using the high salinity water.

The increase of the TDS concentration in the water extracted either by using distilled water or drained water after drying the sediment samples for two weeks may give an indication of the significance of the wetting and drying processes in TDS release from the soil.

If this is indeed the case, then there will be always available TDS in the soils of the Dujaila project area at the end of the irrigation period (May – June) ready to be leached again by the first percolated rainfall (effective rainfall).

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