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Hydrological and Qualitative Properties of Selected Shallow Wells within Mosul City

Mooatasim Daood Sulayman Agha*, and Shaymiaa Ghanim Dawood Al- Taie
Soil and Water Resources Dep, College of Agriculture and forestry, University of Mosul, Mosul, Iraq

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Corresponding Author

E-mail: mooatasim@uomosul.ed.iq

Mobile:

Abstract

Ten locations were chosen for surface wells within Mosul city. The depth of the ground water ranged between (1.1 – 18 m). The saturated water conductivity measured in the field is medium to very rapid (3.97 - 47.01 cm hr^{-1}), depending on the distance of the Tigris River edge, soil layers' properties and the presence of wastewater. Irrigation water discharge ranges between (2.1 - 11 m^3 hr^{-1}) it depends on several factors, including the horsepower of the pump and the ability to recover the water, as some wells such as Al-Qusour and Pharmacy (2) Wells suffer from interruptions in water recovery. In general, the studied water contains a high percentage of sulfuret ions reach up (2392 ppm), which negatively affects the suitability of the water. The degree of hardness is high in most of the study's water. The studied water is classified as medium to high salt concentration. The standards of Sodium Adsorption Ratio & Soluble Sodium Percentage show that the sodium ion has a low concentration effect on the plant growth. Repeated irrigation of gardens, nurseries and fields with this water often led to the accumulation of salts reaching (6 dS/m) and sulfate compounds reaching (5540 ppm) in particular.

Introduction:

Studying hydrological and qualitative properties of shallow wells is of great importance with the scarcity of water and the increased need for it, especially in dry seasons.

Most wells (especially the Central Library well) are considered unsuitable for use, as the sulfate ion concentration exceeds 460 ppm. While the Rashedia well was more suitable (less than 200 ppm) according to classification (1, 2). The salt concentration of well water ranges from (suitable for all crops to irrigating - very tolerate plant only, according (3) .

It may be considered that much of the well water is considered permissible for some crops, where the total dissolved salt value is higher than 500 ppm, according (3) .

Turbidity is an expression of light – scattering property of water caused by the presence of fine suspended mater such as clay, silt, plankton and microscopic organisms (4) ,it's values ranged between (0.43- 54) F.T.U with a clear significant difference .The definition of the [5] to water hardness is the ability of water to deposit soap, soap deposition in hard water due to

the presence of divalent calcium and magnesium ions and other multivalent ions. Hardness salts are in the form of carbonates or bicarbonates, chlorides and sulfates. All water 0f the well is considered hard, as its hardness (500-1250 ppm) [1,2].

According to classification (3) the water of the studied wells is considered suitable for crops, as it is within the first classification (SAR : less than 10 meq L^{-1}) .

Materials and methods

Ten locations were chosen for surface wells, including eight within the University of Mosul [the nursery of the College of Agriculture and Forestry in the presidential palaces, the College of Administration and Economics, the College of Nursing 1 and 2, the College of Pharmacy 1 and 2, Al-Hadbaa Gate, the Central Library, the Nineveh Forest Nursery, and finally Al- Rashedia location, which is far away. About 15 kilometres from Mosul city centre. The following table shows the latitude, longitude, and elevation (high from sea surface) for the study location.

Table 1. Latitude, longitude, and elevation for the studied location

Well Number	Location	Latitude	Longitude	Elevation\ meter
1	Al – qussor	36.23.45-N	43.07.57-E	251
2	Administration and Economics	36.22.51-N	43.08.37-E	239
3	Nursing(1)	36.23.07-N	43.08.36-E	245
4	Nursing(2)+	36.23.08-N	43.08.38-E	246
5	Pharmacy (1)	36.23.10-N	43.08.40-E	248
6	Pharmacy (2)	36.23.13-N	43.08.42-N	249
7	Al-Hadbaa Gate	36.23.21-N	43.8.43-E	252
8	central Library	36.20.48-N	43.08.00-E	219
9	Nineveh Forest Nursery	36.22.02-N	43.07.38-E	219
10	AL – Rashedia	36. – 24-12N	43-04-04-E	220

Hydrological data were taken from each well to estimate the saturated hydraulic conductivity by applying an Jonsons, equation and Scheme [6] as explained

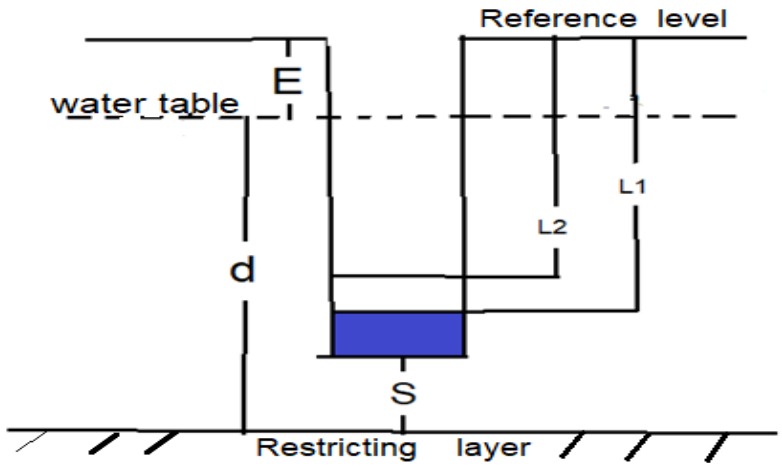

Fig. 1 Scheme for application Johnson s, equation [6]

The symbols are defined in the Scheme in Figure 1 and as follows:

$$K_S = \frac{\pi R^2}{A \Delta t} lin \frac{L_1 - E}{L_2 - E}$$

K_S = hydraulic conductivity (cm per min)
R = inside radius of the liner (cm)
E = distance from top of liner to water table (cm)
L_1 = distance (cm) from top of liner to water level in liner at time t_1.
L_2 = distance (cm) from top of liner to water level in liner at time t_2.
$\Delta t = t_2 - t_1$ time increment for water to rise from L_1 to L_2 (min)
A = geometry factor (cm) which is a function of R, d the distance from the bottom of the hole (calculated from specific table).
S = the distance from the bottom of the hole to a restricting layer.

The pump discharge was estimated from knowing the time required to fill a known volume.

The longitude and latitude, the elevation of location its distance from the side of the Tigris River were measured using the Google Earth program.

Sulfat in water sample was determined by the method of deposition with barium chloride (Ba CL_2), according to the method described by [5]. Sulfate in soil extract was determined by deposition method with barium chloride according to [7].

The electrical conductivity and degree of reaction (pH) of the water sample and the soil extract 1/1 were measured using a WTW Multi 3400 device and according to the method described by [8].

Total Dissolved Solid (T D S) was determined using a device model (YL-TDS2-A), turbidity was determined using device model (H I 93703) according to the method described in [10] .

Water hardness can be found using titration with Na_2 – EDTA [9].

Dissolved ions in water samples were measured after filtering the samples using filter paper (Medium Fast, Ash: < 0.20 %). The positive ions Ca^{++} and Mg^{++} were estimated using the Na_2-EDTA titration method and according to the method described by [5], As for Na+ and K+, they were estimated using a flame photometer (JENWAY TYPE MODEL PFP7)

$$S\,A\,R = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

$$S.S.P = \frac{Na^{+}\ meq\ L^{-1}}{Total\ soluble\ \ Cation\ \ meq\ \ L^{-1}} 100$$

Size distribution of soil components: Use the hydrometer method and according to the method described by [10] .

Statistical analysis was done using SAS. By following a randomized complete block design (RCBD) and testing the least significant difference (LSD) at the level of 0.05, as mentioned (11)

Results and Discussion

Table (2) shows some properties of the studied wells water, the depth of the wells range between (6 - 85 meter) depending on the economic aspect and the water recovery time in the well in addition to the irrigated area. Most of the diameters of the study wells are 0.2 meter, as they are located in public gardens and parks, while the rest of the wells have a diameter of (3-2.5 meter) for the Nineveh Forest Nursery and the location of AL-Rashedia, respectively, which are located between nurseries and farms.

Table 2. Some hydrological properties of the studied well locations

Well Number	Location	Total depth of well / meter	Dimeter of well hole /meter	Depth of water from soil surface /meter
1	Al – qussor	36	0.2	10
2	Administration and Economics	60	0.2	18
3	Nursing (1)	60	0.2	15
4	Nursing (2)	60	0.2	15
5	Pharmacy (1)	85	0.2	8
6	Pharmacy (2)	60	0.2	14
7	Al-Hadbaa Gate	60	0.2	16
8	central Library	50	0.2	1.1
9	Nineveh Forest nursery	6	3	4
10	Al-Rashedia	40	2.5	11

It is clear from Figure (2) the polynomial relationship between the elevation of the well location and depth of water in well. By applying the equation

$Y = - 0.0319 X^2 + 15.276 X – 1811.5$

Y = Depth of water in the well

X = Elevation of well location

The possibility of estimating the depth of the ground water level from the surface of the field soil from knowing the elevation of the field was with a coefficient of determination R^2 = 0.73, therefore there are other factors that play an effective role in estimate the depth of the ground water, such as the arrangement of the soil layers, the variation in its texture and the presence of layers that are impermeable to water.

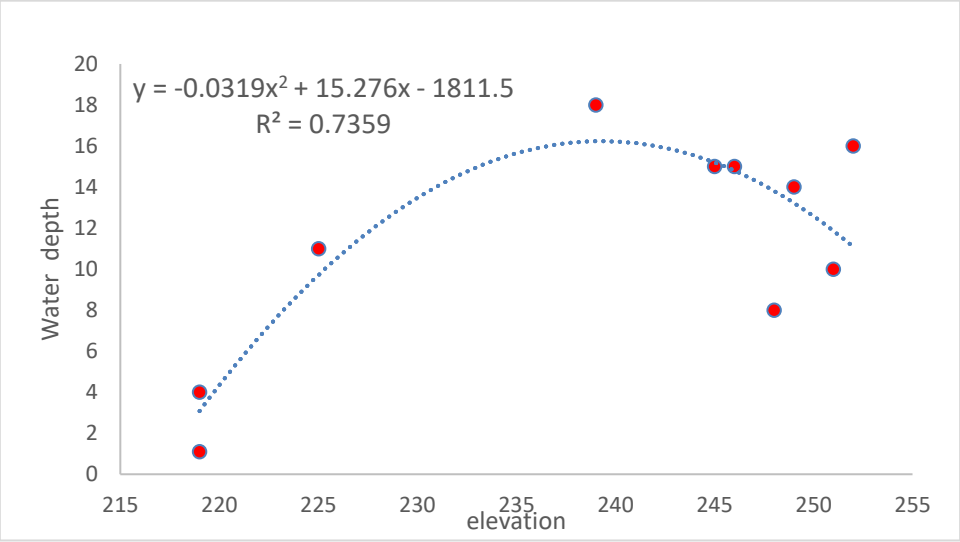

Fig. 2 Location elevation and water depth in the well

Table (3) shows the experimental pumping data: (t) Period for each reading, (S) the final depth of water in the well during pumping. as well as the data for recovery and returning water in the well to the original level :(T) accumulative time, (t) the period for restoring the water level inside the well versus displacement (S).

Table 3. Experimental pumping and recovery data for the study wells

Well Number	Location	Pumping Data		Recovery Data		
		t(min)	S(m)	T(min)	t(min)	S(m)
1	Al – qussor	0	0	15	5	10
		5	5	20	5	5
		10	16	32	12	0
2	Administration and Economics	0	0	12	2	1.75
		5	1	30	20	1
		10	2	40	10	0
3	Nursing (1)	0	0	65	5	7
		20	4	70	5	5

		60	8	82	12	0
		0	0	40	10	8
4	Nursing (2)	15	5	60	20	4
		30	10	1.30	30	0
		0	0	1.35	5	15
5	Pharmacy (1)	10	6	1.40	5	8
		1.30	17	1.50	10	0
		0	0	20	5	2.5
6	Pharmacy (2)	8	1	50	30	1,5
		15	3	1.25	35	0
		0	0	22	2	1.8
7	Al-Hadbaa Gate	10	1	25	3	1.5
		20	2	30	5	0
		0	0	3	1	2.5
8	central Library	1	1.5	8	5	1.5
		2	3	12	4	0
		0	0	35	5	0.3
9	Nineveh Forest nursery	5	0.30	40	5	0.08
		30	0.40	45	5	0
		0	0	45	5	0.40
10	Al-Rashedia	10	0.3	50	5	0.2
		40	0.45	52	2	0

Table (4) the discharge of pumping water measured in the field, knowing the time required to fill a known volume of irrigation water in units of (m^3 h^{-1}, litter sec^{-1}). The water conductivity was estimated by applying the Johnson's equation. According to the classification of [6], it is clear that the saturated conductivity is very raped for the Rashedia location and the Nineveh Forest Nursery because of its proximity to the edge of the Tigris River, while the saturated conductivity is described as being raped due to sewage water. Especially at the Central Library location, then Administration and Economics, and finally Nursing (1).

Table 4. Pump discharge and field saturated hydraulic conductivity

Well Number	**Location**	**Pump discharge Liter sec^{-1}**	**Pump discharge m^3 hr^{-1}**	**Field Saturated hydraulic conductivity cm hr^{-1}**	**Classify Recovery**
1	Al - qussor	0.8	2.88	14.27	Rapid
2	Administration and Economics	0.81	2.91	17.2	Rapid
3	Nursing (1)	1.41	5.1	16.41	Rapid
4	Nursing (2)	1.44	5.2	6.45	Moderate
5	Pharmacy (1)	1.38	5	10.81	Moderately Rapid
6	Pharmacy (2)	0.61	2.2	3.97	Moderate
7	Al-Hadbaa Gate	0.58	2.1	21.0	Rapid

8	central Library	1.38	5	46.0	Very rapid
9	Nineveh Forestry nursery	3.05	11	43.10	Very rapid
10	Al-Rashedia	1.97	7.1	47.01	Very rapid

Figure (3) shows the positive relationship between the saturated hydraulic conductivity (cm hr $^{-1}$) and the discharge measured by the equation

$Y = 0.1046 X + 2.4833$

A low coefficient of determination $R^2 = 0.41$ indicates that there are another factor besides water conductivity that have an impact on the ability of the well to drain water from it, such as the presence, nature and texture of the soil surface layers, and the horsepower of the pump also plays a role. For example, at the Nineveh Forest Nursery and Al-Rashedia location that the water discharge from the well is high (11 - 7.1 m^3 h^{-1}) in proportion to the hydraulic conductivity (43.1 and 47.01 cm hr^{-1}), respectively, and that water is available without interruption. While the irrigation process encounters interruptions in water discharge from the well of the

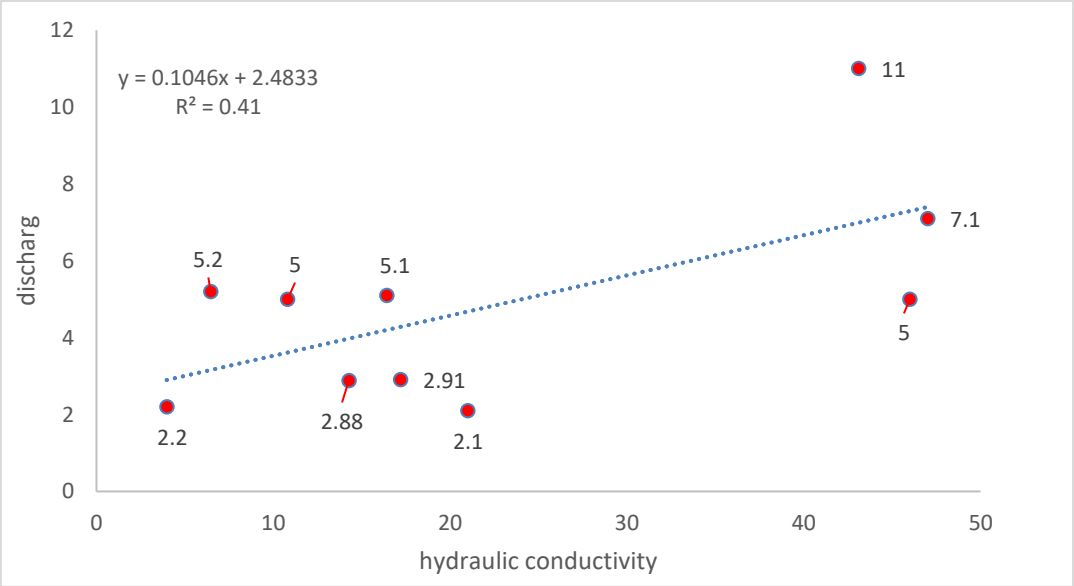

Fig. 3 hydraulic conductivity and water discharge

Al-Qusour and Pharmacy (2) location, where the water conductivity reaches 3.97 cm hr $^{-1}$. Figure (4) shows the effect of the distance between the sides of the Tigris River from the study location, and the values of saturated water conductivity measured in the field. In the well of the Nineveh Forest nursery, as well as the well as AL – Rashedia location, which are near to the edges of the Tigris River (1098 - 161 meters from the river), the saturated water conductivity was (43.1 - 47.01 cm hr^{-1}), respectively. The effect of that distance is represented by the logarithmic equation.

$Y = -10.33 \text{ Lin } (X) + 99.296$

With a low coefficient of determination of ($R^2 = 0.31$), which indicates that there are another factors that have a more pronounced effect on recover the well water and returning it to the natural level, and among those factors are the presence of soil layers with varying

permeability values, in addition to the presence of sources of human toilet waste, as is evident on the location Al-Hadbaa and the Central Library location, where the water conductivity with high values (21 - 46 cm hr^{-1}), respectively.

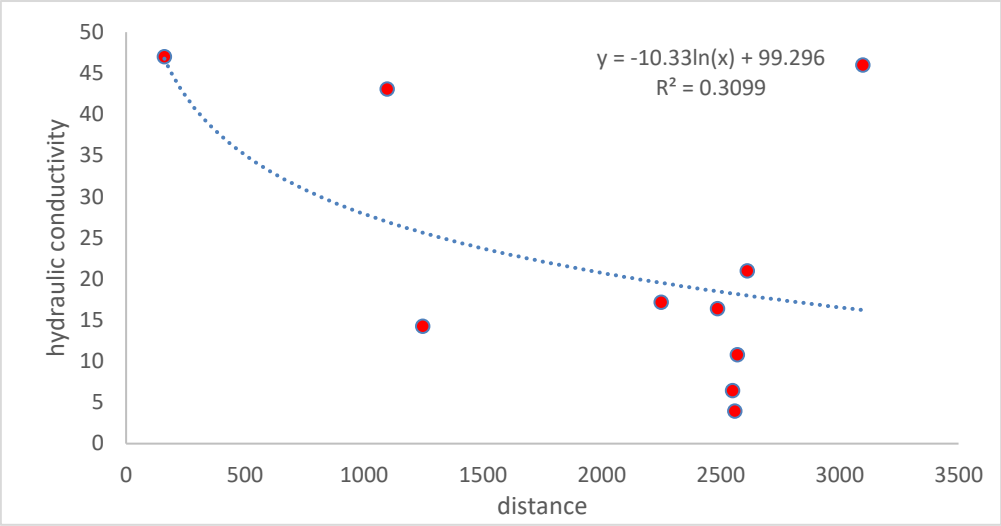

Fig. 4 The Tigris river distances and well water hydraulic conductivity

Table 5. Water properties of the study wells

Well No:	Location	SO_4 ppm	EC ds m^{-1}	pH	T D S Ppm	Turbidity F.T.U	hardness ppm
1	Al - qussor	92.67	0.95	7.6	432	0.43	1640
2	Administration and Economics	2158	2.58	7.2	1182	5.39	2540
3	Nursing (1)	501.44	1.00	6.6	400	28.80	1700
4	Nursing (2)	428.98	1.00	6.9	388	5	1200
5	Pharmacy (1)	948.38	1.6	7.1	640	54	1600
6	Pharmacy (2)	371.0	0.9	7.3	391	14.23	1400
7	Al-Hadbaa Gate	607.25	1.4	7.0	454	2.12	1900
8	central Library	2392	2.53	7.3	1048	5.55	2400
9	Nineveh Forest nursery	521	1.5	7.1	586	3.58	1240
10	Al-Rashedia	42.93	0.5	7.3	191	0.72	500
L S D $_{0.05}$		32.680	0.42	0.57	51.70	1.11	74.46

Table (5): According to [1,2], the sulfate ion concentration with diserd in Al- Rashedia and the Al-Qussor location, while the ion concentration exceeds the critical limit of 460 PPM, especially in the Library location (2392 PPM). The salinity results were parallel to what was found by [12] in his study of six wells within the city of Mosul, where the salinity reached 2.27dS. The high electrical conductivity values are due to the processes of dissolution of rocks and mineral salts surrounding the well site when water passes through it [13] . Almost the sample was neutral to weakly acidity values (6.6 - 7.6) . Increasing the value of Total Dissolved Salts (TDS) above 500 PPM, especially in the administration and the library location, has a negative impact on sprinkler and drip irrigation system .

Table 6. Cation properties for water well

Location	Ca	Mg	Na	K	SSP %	SAR	Water class
			meq L $^{-1}$				
Al - qussor	4	12.4	3.56	1.97	16.23	1.24	C_3S_1
Administration and Economics	20	5.4	4.39	2.46	13.61	1.23	C_4S_1
Nursing (1)	6	11	2.91	0.69	14.12	1	C_3S_1
Nursing (2)	5	7	5.78	0.82	31.07	2.35	C_3S_1
Pharmacy (1)	4.8	2.8	9.95	2.15	50.50	5.12	C_3S_1
Pharmacy (2)	4	10	2.26	1.43	12.77	2.64	C_3S_1
Al-Hadbaa Gate	5.2	13.8	6.91	1.25	25.44	2.24	C_3S_1
Central Library	19	5	5.30	1.33	14.16	1.53	C_4S_1
Nineveh Forest nursery	5	7.4	4.34	12.8	14.69	1.75	C_3S_1
Al- Rashedia	3	2	2.26	1.23	26.61	1.43	C_2S_1

Turbidity values range (0. 43 - 54) F.T.U . It was also noted that the hardness value is high, especially at the Administration (2540 ppm), which is equivalent to 10 times the maximum hardness limit (100 ppm) according to the [1,2] classification ,the reason is due to the increase in the concentration of calcium and magnesium ion compounds.

Table (6) explain the concentration of some cations, and the classification of the well water . Most of the location high salinity readings C_3, range between 0.9 - 2.85 dS m^{-1}, with the exception of the AL-Rashedia location, where it is classified with medium salinity, C_2, which is equivalent to 0.5 dS m^{-1}, approximating the water salinity of the Tigris River near the location. The Sodium Absorption Rasio (SAR) values, which represent the concentration effect of sodium in relation to the concentration of calcium and magnesium ions, the water in general is classified as S_1, according to[3] that is the effect of low S A R, which ranging between (1 - 5.12 meq L^{-1}), as the water is suitable for irrigation in almost all types of soils with little risk of forming dangerous concentrations of exchangeable sodium, especially for sodium-sensitive plants .

All results were parallel to [14] reported in her study of several wells on the left side of the Mosul city, where he explained the high values of most parameters studied, such as electrical conductivity, total hardness, and sulfate ion. She also mentioned that most of the water under study is of the C_3 class, and another of the C_4 class, according to the American Salinity Laboratory.

Tabl 7. Soil properties for study location

Location	Texture				Unirrigated soil		Irrigated soil	
	Clay gm Kg $^{-1}$	Silt	Sand	name	EC dS m^{-1}	SO_4 ppm	EC dS m^{-1}	SO_4 ppm
Al - qussor	600	250	150	Sa.L	1.1	1000	1.92	2409
Administration and Economics	280	576	144	Si.C.L	1.2	960	4.2	2300
Nursing (1)	67	413	520	Si.L	1.9	900	6.0	4711
Nursing (2)	80	310	610	Sa.L	1.0	700	1.9	1209
Pharmacy (1)	20	410	570	Sa.L	0.9	800	2.48	3309
Pharmacy (2)	30	360	610	Sa.L	1.0	1000	2.0	2000
Al-Hadbaa Gate	33	550	417	Si.L	2.0	1200	5.3	5540
central Library	300	510	190	Si.C.L	1.1	950	4.1	5000
Nineveh Forest Nursery	260	550	190	Si.L	1.2	771	5.21	3970
AL-Rashedia	70	520	410	Si.L	0.41	300	0.52	707

Table (7) shows some properties of the soils irrigated and non irrigated with water from the studied wells, where the soil texture ranged from sandy loam to silty clay loam. The irrigation process led to increased soil degradation and increased salinity. The increased concentration of salinity ranged between (20-76%). .

Figure (5) shows the extent of the increase in the sulfate ion concentration in the soil as a result of the irrigation process,as the sulfate ion concentration increased by a rate ranging between (42 - 81%) in the gardens soil of the College of Nursing (2) and Al Hadba gardens .

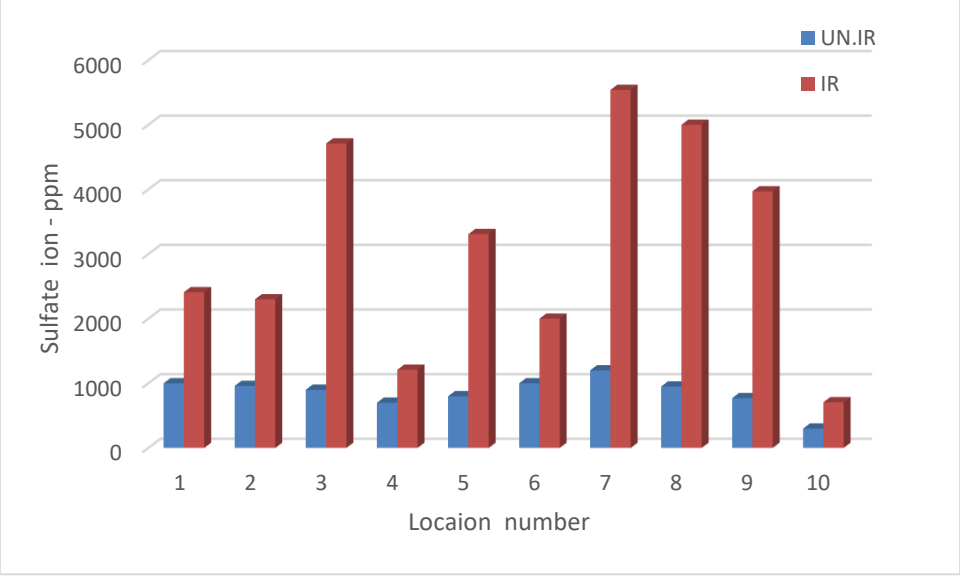

Fig. 5 The increase sulfate ion concentration in irrigated soil

Conclusions

The study concerns the water of some surface wells within the Mosul city for use it, especially in irrigating some gardens, nurseries and fields. These wells have the ability to restore the water level moderately to very quickly. Some of these wells suffer from water interruptions during irrigation. In general, the studied water contains a high percentage of sulfate ions, which negatively affects the suitability of the water. The degree of hardness is high in most of the study water. The studied water is classified as having a medium to high salinity concentration, and sodium ion has a low concentration effect on plant growth. Repeated irrigation of gardens, nurseries and fields with this water often leads to the accumulation of salts and sulfate compounds.

It is preferable to study the location in terms of hydrology and the water conductivity of the soil layers before drilling wells, and avoid the influence of sewage water when drilling, it has a bad effect on well s, water, in addition to approval better methods of storing, desalinating that water, applying modern irrigation methods, and choosing plants suitable for these waters.

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الخصائص الهيدرولوجية والنوعية لبعض الآبار السطحية المختارة ضمن مدينة الموصل

معتصم داود سليمان اغا*، شيماء غانم داود الطائي
قسم علوم التربة والموارد المائية، كلية الزراعة والغابات، جامعة الموصل، العراق

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الموبايل:

الخلاصة:
تم اختيار عشرة مواقع لأبار سطحية ضمن مدينة الموصل. تراوح عمق المياه السطحية بين (1.1 - 18 م). ان قيم الايصالية المائية المشبعة المقاس حقليا متوسطة الى سريعة جدا (3.97-47.01 سم ساعة$^{-1}$) اعتمادا على بعد حافة نهر دجلة، خصائص طبقات التربة ووجود مياه الصرف الصحي. ويتراوح تصريف مياه الري ما بين (11 - 2.1 م 3 ساعة$^{-1}$) ويعتمد على عدة عوامل منها قوة المضخة وقدرت البئر على استعادت المياه حيث تعاني بعض الآبار مثل بئر القصور والصيدلة (2) من انقطاع في استعادة المياه. وبشكل عام تحتوي المياه المدروسة على نسبة عالية من أيونات الكبريتات تصل إلى (2392 جزء في المليون) مما يؤثر سلباً على صلاحية المياه. وكانت درجة العسرة عالية في معظم مياه الدراسة. وتصنف المياه المدروسة ذات تركيز ملوحة متوسط إلى عالٍ. تشير معايير نسبة امتزاز الصوديوم ونسبة الصوديوم الذائب إلى أن أيون الصوديوم له تأثير تركيز منخفض على نمو النبات. وكثيراً ما أدى الري المتكرر للحدائق والمشاتل والحقول بهذه المياه إلى تراكم الأملاح التي تصل إلى (6 دسمنز م $^{-1}$) ومركبات الكبريتات التي تصل إلى (5540 جزء في المليون) على وجه الخصوص.