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MONITORING SEASONAL VARIATION IN GROUND WATER QUALITY AND EVALUATION OF ITS SUITABILITY FOR IRRIGATION IN THE NIMRUD AREA SOUTH –EAST OF MOSUL –IRAQ

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ABSTRACT

Sixteen water wells have been chosen in different locations within Nimrud district, to study the variation of ground water quality during the dry and the wet season. Analysis including salinity, pH, temperature, total hardness, major cations and anions were performed. Ground water salinity (EC) has significant variation and ranged from (0.81 to 5.82) and (0.88 to 5.77) ds m^{-1} in dry and wet seasons respectively. About 75% of water samples have a higher EC in the wet season compared with the dry season. All samples are very hard water class. Half of the wells have higher calcium and chloride concentration in the wet season than in the dry season. Two third of samples have higher Magnesium in the dry season than the wet season. Around 87% of wells have higher sodium and potassium in the wet season than dry season. About three quarters of wells have a higher sulphate in the wet season in compared with the dry season. About 80 % of samples have a higher nitrate concentration in the dry season compared to the wet season. Water quality for irrigation has been evaluated using several parameters. All samples fall into three category groups, C_4S_1, C_4S_2 and C_3S_1 according to the US salinity diagram.

INTRODUCTION

Recently Iraq is facing a shortage in rainfall, long periods of drought, and a decline of water supplies, as a result of climate changes and dropping of rivers discharge from upstream countries like Turkey and Iran. Therefore, many farmers use ground water as an alternative to surface water, even if ground water is brackish and not fresh water, which has a detrimental effect on soil properties and plants. There are two types of soil salinity, primary and secondary (Hopmans *et al.*, 2021). The first type occurs as a result of geological factors (natural) like kinds of rocks/ minerals which are highly dissolved in water. The second type comes from human activity like the use of saline ground water for irrigation, or extensive use of chemical fertilizers in order to increase agricultural production (Knapp and Baerenklau, 2006). That leads to the deterioration of soil quality and its fertility (King and David, 2014). Periodically use of brackish ground water without leaching these salts via rainfall or fresh water. That leads to speeding up the secondary salinity processing which has a negative impact on soil, such as decline of hydraulic conductivity, destroy soil structure, drop of infiltration and forming of soil crust which prevent seeds germination (Al-Zu'bi, 2007). Getting data about ground water quality gives us significant information about the nature of aquifers and the geochemical processing that takes place in subsurface environments (Raju *et al.*, 2011). AL-Saffawi *et al.*, (2022) studied the ground water quality in groups of wells within Nimrud area, and find out around 70 % of water wells were not fit for animals drinking like cattle and poultry, due to the effect of geological formation on ground water quality. The aim of this research is to identify the spatial and temporal variation in ground water quality between the wet and dry seasons within the study area to evaluate its quality for irrigation purposes, for better management and sustainability of this precious water resource.

MATERIALS AND METHODS

The field work was included collection 36 water samples, from 16 water wells, sixteen samples from the dry season (October 2021) and the rest from the wet season (April 2022), see (Figure 1). All smaples collected after ten minutes of pumping from each well. The information about wells are listed in table 1. Temperature is measured using mercury thermometer. EC, pH and TDS are measured in the field using EC-pH meter. Calcium, magnesium, chloride, carbonate, bicarbonate and total hardness are measured using titration method. Sodium and potassium are measured using flamephotmeter. Finally sulphate, nitrate and phosphate are measured using spectrophometer method. All chemical analysis were carried out using standard methods.

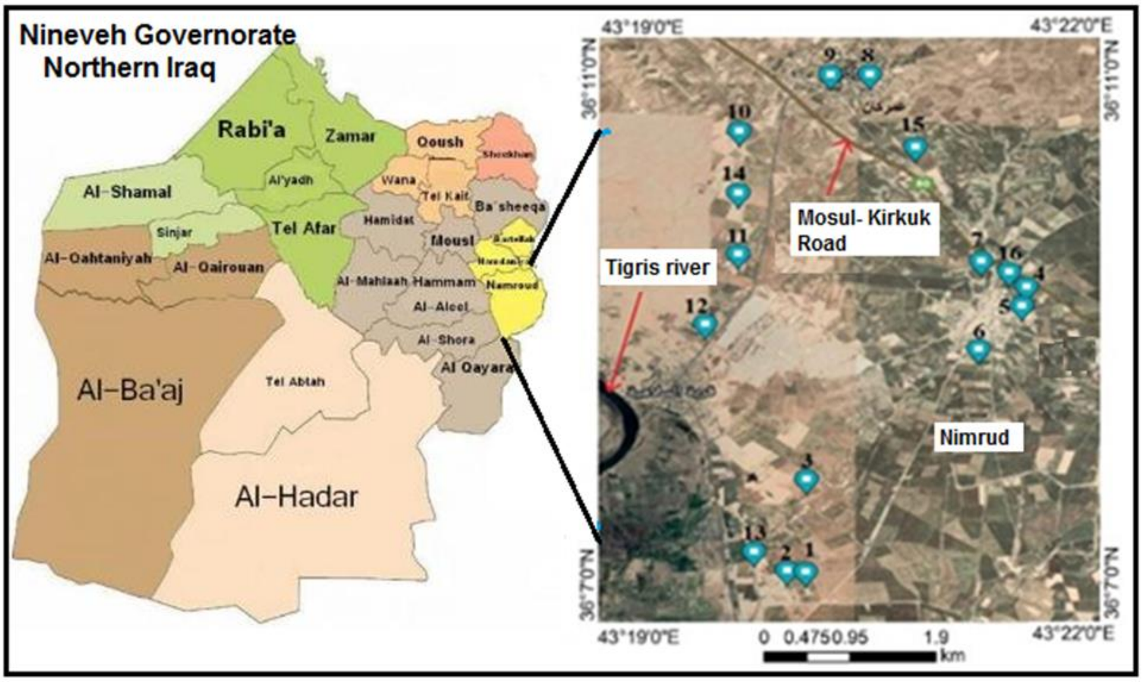

Figure (1): location map of the study wells.

Table (1): Name, coordination and some information about the study wells.

Well NO.	Name/Village	Depth (m)	Static Water table (m)	Coordinates		Usage
				Latitude	Longitude	
1	Al Taufiqiea 1	60	16	36˚06′44.77″	43˚19′59.63″	fish farming agricultural use
2	Al Taufiqiea 2	57	8	36˚06′45.52″	43˚19′49.75″	agricultural use
3	Maahad Al Salamia	75	22.30	36˚07′37.49″	43˚19′59.71″	agricultural use
4	Tal Aagob1	45	17.40	36˚09′27.55″	43˚21′55.08″	agricultural use
5	Tal Aagob2	37	19.75	36˚09′16.65″	43˚21′52.67″	agricultural use
6	Tal Aagob3	59	32	36˚08′51.98″	43˚21′30.02″	agricultural use
7	Tal Aagob4	40	11.30	36˚09′41.99″	43˚21′31.03″	agricultural use
8	Omar Kan1	45	13.5	36˚11′28.04″	43˚20′31.75″	Domestic use
9	Omar Kan2	37	17.80	36˚11′27.71″	43˚20′11.04″	agricultural use
10	Bashtotmaz1	37	20.30	36˚10′55.52″	43˚19′23.19″	agricultural use
11	Bashtotmaz2	48	10.40	36˚ 09′ 45.6″	43˚19′22.98″	agricultural use
12	Al Salamiea	57	12.60	36˚09′05.68″	43˚19′05.88″	agricultural use
13	Al Salam	20	5.30	36˚06′56.18″	43˚19′32.31″	agricultural use
14	Bashtotmaz3	50	10.30	36˚10′20.31″	43˚19′22.89″	agricultural use
15	Omar Kan3	45	24	36˚10′46.88	43˚20′56.07″	agricultural use
16	Tal Aagob5	42	11.40	36˚09′35.98″	43˚21′45.81″	agricultural use

RESULTS AND DISCUSSION

Temperature:

The ground water temperature ranged from 24.3 to 28℃, with average 25.7℃ in the dry season, while it ranged from 23.5 to 26.4℃, with average 25.4℃ in wet season, table (2). The comparison between two seasons revealed that all values are closed to each other and almost constant in both seasons (figure 2). The maximum different in temperature between two season not exceed 2.4 ºC. That is a very slight variation of ground water temperature belonged to it is far away from the direct effect of atmosphere and other climatic factors such as surface water (Effendi and wardinato, 2015). These results slightly lower than results obtained by (AL-Saffawi *et al.*, 2022), which ranged from 19.3 to 22 ºC may be that belonge to the different in the season of collection samples for each study.

pH:

The pH ranged from 7.3 to 7.9 in dry season, while it ranged from 6.4 to 7.9 in wet season, table (2). The majority of water samples have neutral or slightly alkaline water because the abundant of carbonate minerals in rocks and soils. As we can see from the (figure 2) the majority of water samples have higher pH in dry season in compare with wet season.

Water salinity:

The EC values ranged from 0.81 in well No. 15, to 5.82 in well No. 2, with averaged 2.66 ds.m^{-1} in dry season , while it values vary from 0.88 in well No. 15 to 5.77 in well No. 1, with averaged 2.43 ds.m^{-1} in wet season ,table (2). There are significant variations of water salinity (EC) among samples, because the effect of rocks, sediments and minerals type within the aquifers, if ground water moves via geological layers which is rich with evaporates rocks like gypsum and anhydrite, then the water have higher salinity level. While water extraction from quaternary deposits which is rich with siltstone, sandstone and gravel has fresh water and it is poor of total dissolved salts , that means lower EC (Al-saffawi and Al-Sardar, 2018 and Ameloko *et al.,* 2018). These results are consistency with (AL-Saffawi *et al.,*2022) , it ranged from (1.8- 5.06) ds.m^{-1}. (figure 3) showed that wells No (2,6,10 and 12) have higher EC in dry season in compare with wet season. The rest wells have higher EC in wet season than dry season, may be caused by the sequence of drought, without recent recharge to the aquifers via rainfall to dilute salinity of ground water, and there is an extreme scare of rainfall during the year 2021-2022. The TDS varied from 403 to 2908, with average 1332 ppm in dry season, while it varies from 438 to 2887, with average 1241 ppm in wet season. As we know the TDS can be used as alternative to the EC. According (Freeze and Cherry, 1979) around 50 percentage of samples fall in fresh water class (TDS less than 1000 ppm), while the rest of samples fall under brackish water class (TDS range from 1000 to 10000 ppm).

Table (2): Physiochemical properties of ground water samples in both season

Well No.	Dry Season					Wet Season				
	pH	EC dS m^{-1}	TDS ppm	TH ppm	Temp. ºC	pH	EC dS m^{-1}	TDS ppm	TH ppm	Temp. ºC
1	7.6	5.57	2778	1663	25.4	7.3	5.77	2887	1862	25
2	7.6	5.82	2908	1709	25.9	7.9	5.08	2539	1705	23.5
3	7.4	1.85	916	840	25.4	6.9	2.23	1114	1286	24
4	7.6	1.1	543	571	26.6	6.7	1.17	576	666	26.3
5	7.6	1.58	787	826	26.5	7.6	1.66	831	868	26
6	7.4	4.63	2314	1335	26	6.7	2.72	1359	1124	26.4
7	7.9	1.47	733	590	25.7	7.1	1.58	788	505	26
8	7.3	2.55	1264	1050	25.4	6.4	2.72	1361	1094	25.4
9	7.5	1.24	618	608	25.4	6.9	1.05	523	653	25.2
10	7.5	2.09	1046	753	24.3	6.9	1.48	740	819	25.7
11	7.7	1.12	558	811	24.6	7	1.48	742	785	25
12	7.6	5.22	2610	1698	25.4	6.9	3.39	1696	1301	26
13	7.7	2.94	1477	1097	25.9	7.1	2.76	1831	1186	25
14	7.5	2.85	1425	820	25.9	6.9	2.80	1400	961	25.9
15	7.9	0.81	403	382	28	7	0.88	438	531	26.4
16	7.8	1.78	936	855	26.3	6.9	2.08	1038	855	26.1
Min	7.3	0.81	403	382	24.3	6.4	0.88	438	505	23.5
Max	7.9	5.82	2908	1709	28	7.9	5.77	2887	1862	26.4

Mean	7.6	2.663	1332	975	25.79	7.012	2.43	1241	1012	25.49
SD	0.6	1.650	824.1	406.0	0.821	0.342	1.340	686.2	377.9	0.816
C.V	7.89	61.96	61.86	41.64	3.18	4.87	55.14	55.29	37.34	3.20

Total Hardness:

Total hardness (TH) ranged from 382 in well No. 15 to 1709 in well No.2, with average 975 ppm in dry season. In compare with wet season the total hardness ranged from 505 in well No.7 to 1862 in well No.1, with average 1012 ppm, table (2). About 68% of water wells have higher TH in wet season in compare with dry season. Just wells No. (2,6,7,11,12 and 16) have higher TH in dry season in compare with wet season, (figure 4). The maxium different between two season reach to 455 ppm in well No.3. All water samples have been classified as very hard water (TH > 300 ppm), because the dissolution and hydrolois of evaporate minerals such as gypsum, anhydrite and carbonate minerals like calcite,argonite and dolomite , which is considerd the main reason of water harndess (Bouderbala, 2017).

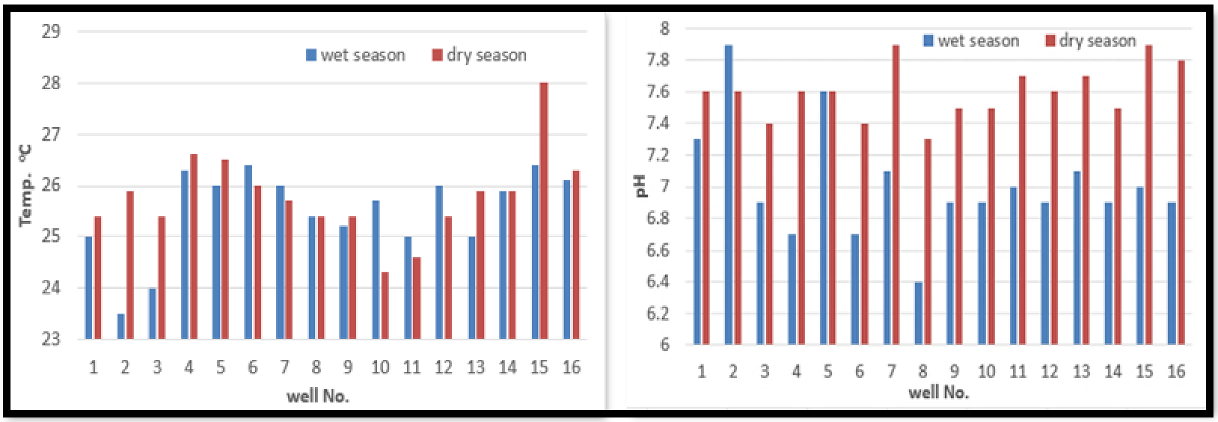

Figure (2): varation of ground water temperture and pH in both seasons.

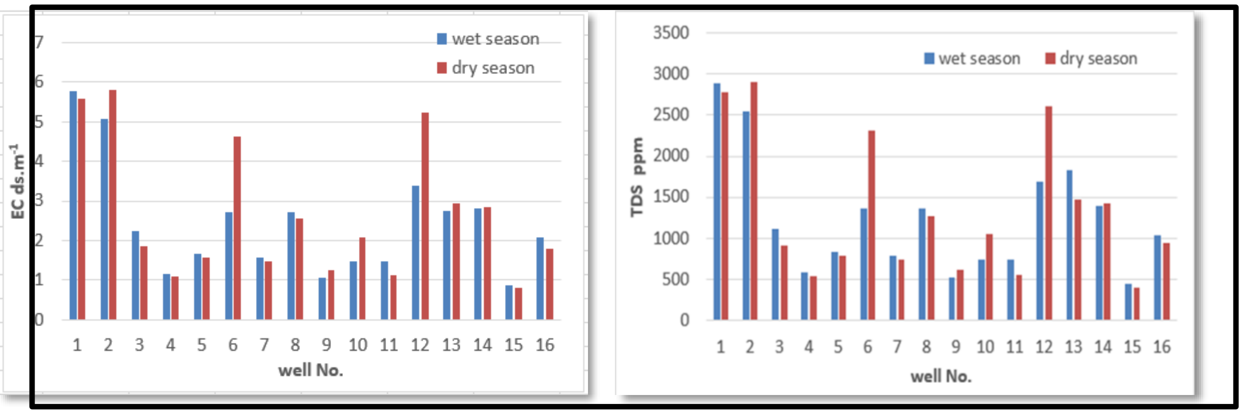

Figure (3): varation of ground water salinity in both seasons.

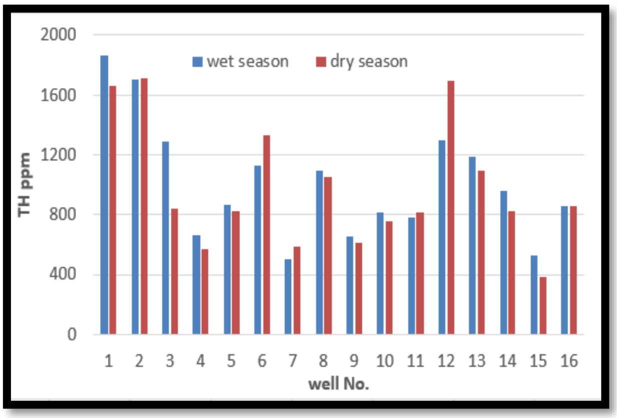

Figure (4): varation of total hardness of ground water in both seasons.

Cations :

Calcium concentration ranged from 74.2 in well No.15, to 388 in well No.1, with averaged 182 ppm in dry season, while it ranged from 89 in well No.15 to 345 in well No.1, with average 184 ppm in wet season, table (3) and (4). These results are consististly with (Al-Obaidi, 2019), which was studied the water wells in the west bank of Tigiris river in Mosul city and it ranged from (86 to 474) ppm and (122 to 564) ppm in dry and wet season respectively. Around more than half samples (56%) the calcium content is high in wet season in compare with dry season, see figure(5). Magnesium concentration ranged from48.5 in well No.15, to 264 in well No.2, with averaged 128 ppm in dry season, while it ranged from 61 in well No.7, to 264 in well No.1, with average 135.9 ppm in wet season, these range slightly lower than ranged got by (Al-obadi ,2019) who studied the ground water quality in Mosul city. About two thirds of studied wells have higher content of magnesium is wet season in compare with dry season (figure 5). The elevation concentration of Magnesium and calcium in ground water come from to the dissolution of calcite, dolomite and gypsum minerals (Bouderbala, 2017). Theses minerasl are abundant in the geological formation (Fatha formation) in the study area. Sodium concentration varies from 31 in well No. 11 to 385 in well No.2, with averge 135 ppm in dry season. In the other hand it conconcentration varied from 18.5 in well No.3 to 399 in well No.2 with averge 169.8 ppm in wet season. These results are lower than the ranged obtian by (AL-Saffawi *et al.*, 2022), which ranged from 109 to 664 ppm. The reason for that belonge to the different in lithology and depth of wells. Around 87% of studied wells have higher sodium content in wet season in comapre with dry season. In general the concentration of sodium in ground water is not high in the studied wells. Postasium concentration ranged from 1.4 in well No. 4 to 15.3 in well No. 2, with average 3.2 ppm in dry season. while in wet season it ranged from 0.55 to 9.35, with average 2.05 ppm. The concentration of potassium in all wells are higher in dry season than wet season except wells No. 6 , figure 6. The low concentration of potasium in ground water as a result of high ability of clay minerals to sorption dissolved potassium, which leads to drop its concentration sginficanlty in ground water (Ibrahim and Nofal, 2020 and Ganiyu *et al.*, 2018).

Anions

Chloride concentration ranged from 42.6 in well No. 15 to 355 in well No.2, with averaged 135.4 ppm in dry season. In the other hand it concentration ranged from 24.8 in well No. 3 to 414 in well No.2, with average 122.1 ppm in wet season table (3),(4), theses ranges are higher that range got by (Al-Obaidi, 2019) in dry and wet season. Fifty percentage of studied wells have higher chloride concentration in dry season than wet season figure(7). These fluctuation of chloride is due to the variation of geological formation, or may be come from domestic waste water which is polluted shallow ground water (Danhalihu., *et al* 2018). Sulphate concentration ranged from 165 in well No. 15 to 1645 in well No.2, with averaged 733.6 ppm in dry season. While it concentration ranged from 419 in well No. 15 to 1497 in well No.1, with average 854 ppm in wet season. These results are similar to the range got by (Al-Aarajy, 2022) in dry season while our results are higher than the range got from (Al-Aarajy, 2022) in wet season , may be the reason for that there is no rainfall took place during this season (dry year). About three- quarter of studied wells have higher concentration in wet season than dry season, (figure 7). Sulphate is the domination anions, and it concentration is extremely high because the dissolution of gypsum and anhydrite minerals .

Table (3): Major cation and anions concentration in dry season.

Sample No.	Ca^{+2}	Mg^{+2}	Na^{+1}	K^{+1}	Cl^{-}	SO_4^{-2}	HCO_3^{-}	NO_3^{-}	PO_4^{-3}
	ppm								
1	388.96	172.67	305.05	4.10	330.15	1574	195.20	41.34	10.27
2	282.88	246.78	385.86	15.30	355.00	1654	195.20	34.33	3.02
3	215.00	76.24	42.00	2.20	143.00	447	244	5.90	1.81
4	91.94	84	81.82	1.40	60.35	370	186	32.45	1.61
5	144.00	115	102.02	2	118	549.	134	31.90	3.02
6	212.16	198.07	273.74	1.60	220.10	1342	280.60	37.66	3.62
7	81.33	94.97	112.12	2.30	49.70	436	268.40	33.22	1.61
8	212.16	128.81	81.82	2.50	106.50	687	384.30	35.58	1.81
9	155.58	55.22	41.41	2.10	81.65	297	262.30	33.35	5.44
10	162.66	86.06	91.92	2	71	487	305	36.97	0.81
11	143	112	31.31	2	121	365	231	29.74	1.61
12	342	209	203.03	3.10	145.55	1306	250.10	27.59	4.63
13	113.15	199.14	102.02	4.40	124.25	943	213.50	31.90	5.64
14	144.98	112.84	132.32	2.60	102.95	594	274.50	33.08	3.62
15	74.26	48.55	51.62	2.70	42.60	165	286.70	30.23	2.62
16	161	112	122.22	2.30	95.85	523	278	31.34	1.61
Min	74.26	48.55	31.31	1.40	42.60	165	134	5.90	0.81
Max	388.96	246.78	385.86	15.30	355	1654	384.30	41.34	10.27
Mean	182.82	128.21	135.02	3.29	135.48	733.69	249.30	31.66	3.30
SD	87.30	57.35	100.38	3.20	88.81	461.56	56.18	7.39	2.28
CV	47.76	44.73	74.35	97.34	65.55	62.91	22.54	23.34	69.15

Table (4): Major cations and anions concentration in wet season.

sample No.	Ca^{+2}	Mg^{+2}	Na^{+1}	K^{+1}	Cl^{-}	SO_4^{-2}	HCO_3^{-}	NO_3^{-}	PO_4^{-3}
	ppm								
1	345.28	246.95	390.27	3.07	337.25	1497	337.25	32.50	0.55
2	318	225	399.12	9.35	414	1262.40	376.30	31.35	1.13
3	303	132.21	18.58	0.55	24.85	979	75	35.19	1.42
4	124	88	107.08	0.55	56.80	589	56.80	30.58	1.71
5	146	124	115.93	0.55	81.65	684	145	19.42	1.57
6	232	135	209.00	1.81	149	913	227	41.35	1.57
7	103.58	60.97	142.48	1.81	53.25	692	53.25	38.27	1.86
8	110.49	200	124.78	1.81	85.20	1076	85.20	42.12	1.71
9	145.02	72.25	62.83	0.55	56.80	544	56.80	34.42	1.86
10	146	112	115.93	1.81	93	619	159	26.35	1.28
11	138.11	108.61	115.93	0.55	56.80	682	56.80	38.27	1.71
12	276.22	151.66	230.97	3.07	156.20	1082	173	37.12	1.57
13	185	178	177.88	4.32	120.70	994	120.70	42.50	1.28
14	151.92	143	222.12	0.55	114	854	165	38.27	1.42
15	89	76	89.38	0.55	49	419	116	30.58	1.42
16	145.02	121.42	195.58	1.81	106.50	792	106.50	35.96	2.14
Min	89	60.97	18.58	0.55	24.85	419	53.25	19.42	0.55
Max	345.28	246.95	399.12	9.35	414	1497	376.30	42.50	2.14
mean	184.92	135.94	169.87	2.05	122.19	854.90	144.35	34.64	1.51
SD	80.03	52.25	101.90	2.19	103.04	276.08	94.11	5.91	0.35
CV	43.28	38.44	59.99	107.08	84.33	33.12	65.20	17.06	23.17

Carbonate CO_3^{-2} not detect during the chemical analysis, (Freeze and Cherry, 1979) point out at pH level below 8.2, carbonation (CO_3^{-2})combination with hydrogen(H^+) to form bicarbonate(HCO_3^-), all the water samples have pH not exceed 7.9 in both season, that reason why not recording any concentration . Bicarbonate concentration ranged from 134 in well No. 5 to 384.3 in well No .8, with averaged 249 ppm in dry season. while it concentration ranged from 53.2 in well No. 7 to 376 in well No.2, with average 144 ppm in wet season. Except wells No. 1, 2 and 5, all the water samples have higher concentration of bicarbonate in dry season than wet season (figure 8). The main sources of bicarbonate are come from carbonate minerals, as well as may be from oxidation of organic water in the rhizospheres zone and from agricultural activity, furthermore may be come from the combination of carbon dioxide (CO_2) with water during the hydrological cycle (Freez and Cherry, 1979). Nitrate concentration ranged from 5.9 in well No. 3 to 41.3 in well No.1, with averaged 31.6 ppm in dry season. while it concentration ranged from 19.4 in well No. 5 to 42.5 in well No.13, with average 34.6 ppm in wet season, (figure 8). These results that are within the same range which got by (Al-Aarajy, 2022) in dry and wet season. Some wells are contamination with nitrate as a results of agricultural activities and intensive use of fertlizers in term of using this water for drinking purpose. About 70 % of water samples have higher nitrate concentration in wet season than dry season. Finally Phosphate concentration ranged from 0.81 in well No.10 to 10.2 in well No.1, with average 3.3 ppm in dry season. while it concentration ranged from 0.55 in well No. 1 to 2.1 in well No.16, with average 1.5 ppm in wet season (figure 9). About 70 % of water samples have higher phosphate concentration in dry season than wet season. Phosphate content in ground water is relatively low because it high ability of clay and some organic compounds to adsorption it, that lead to drop it concentration signficanlty (Karsa and Houston, 2006).

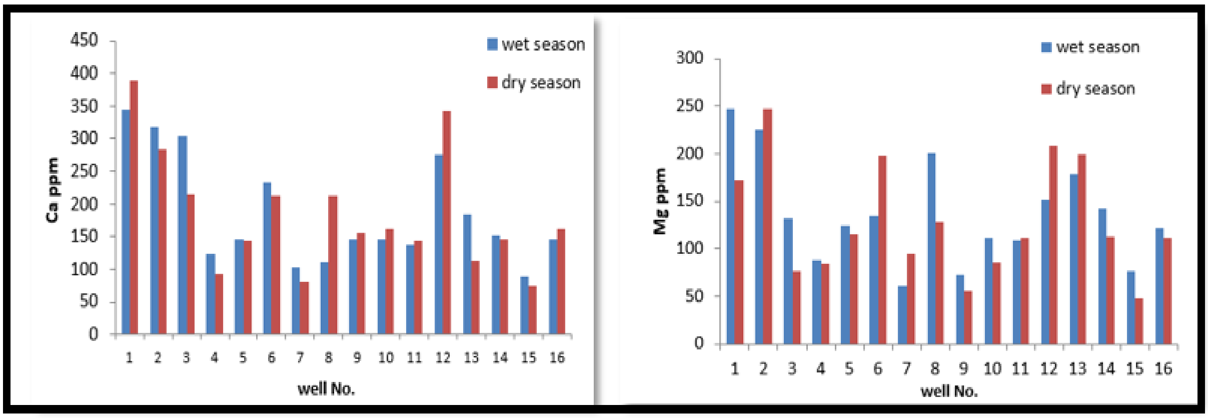

Figure (5): varation of calcium and magnesium in both seasons .

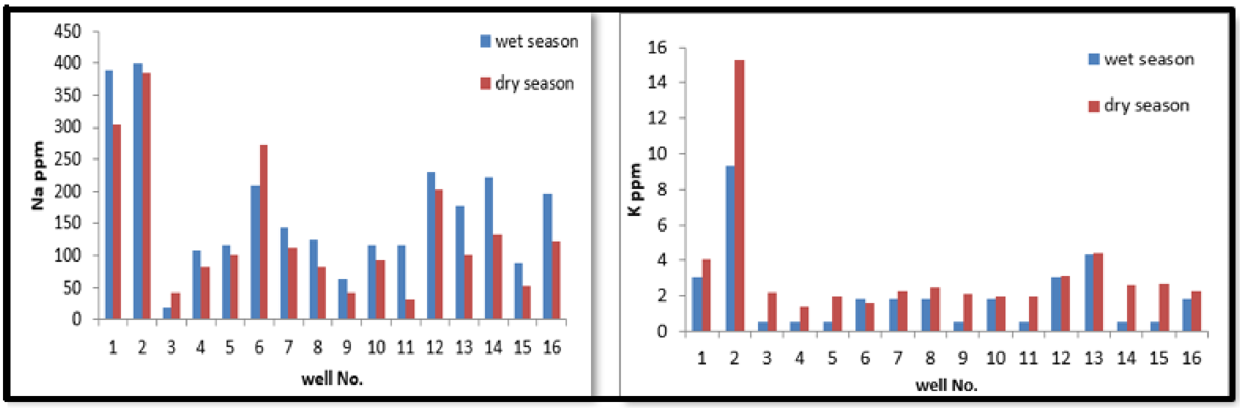

Figure (6): varation of sodium and potassium in both seasons.

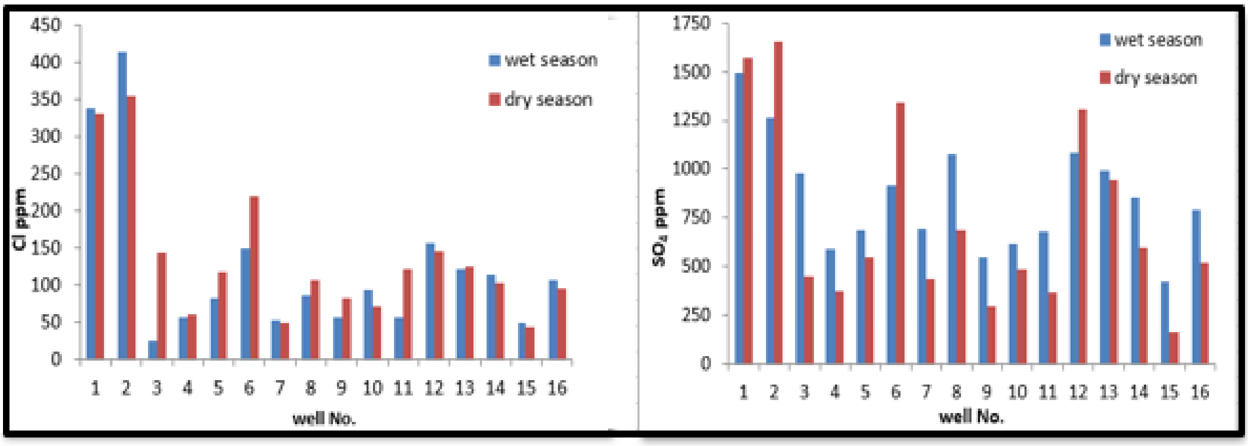

Figure (7) varation of chloride and sulphate in both seasons.

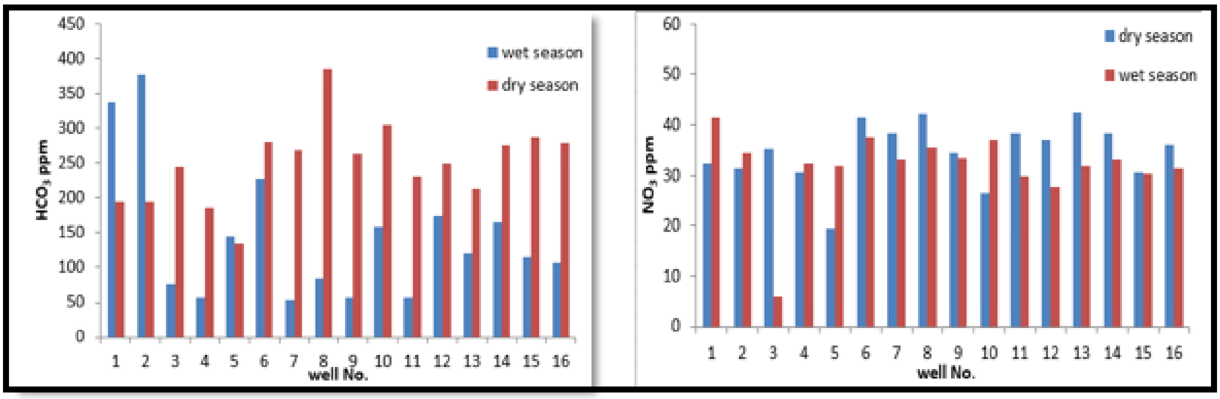

Figure (8): varation of bicarbonate and nitrate in both seasons.

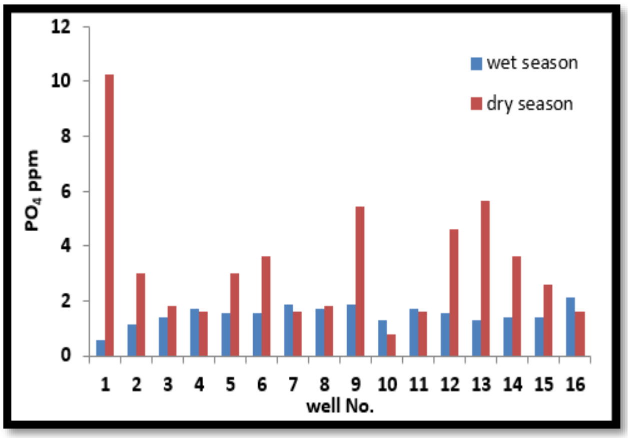

Figure (9): varation of phosphate of ground water in both seasons.

The variation coefficient :-

The coefficient of variance CV has been calculate acoording to the flowing equation

$$CV = \frac{SD}{m} * 100$$

CV= variation Coefficient, SD= standard Deviation, m = mean

If the value is less than 50 %, that indicate the variable is homogenous, and the values are close to each other and not variable too much . However, if the value is more than 50%, that indicate the result have wide range and heterogeneous (Macko, 1994). (figure 10) showed the plot of CV% against all variables. Results were divided into two groups. Group one have CV% values less than 50 percentage, which included pH, temperature, total hardness, calcium, magnesium, and Nitrate. Just bicarbonate in dry season, sulphate and phosphate in wet season. Second group wich have CV% values greater than 50 percentage, which included EC, TDS, sodium, potassium, and choride. Just sulphate and phosphate in dry season, and finally bicarbonate in wet season. The higher value of CV% for some parmenters like EC and TDS , give us indicator that most wells are penentration more than one aquifer , which lead to mix fresh water with saline water and give us wide varation of water salinity.

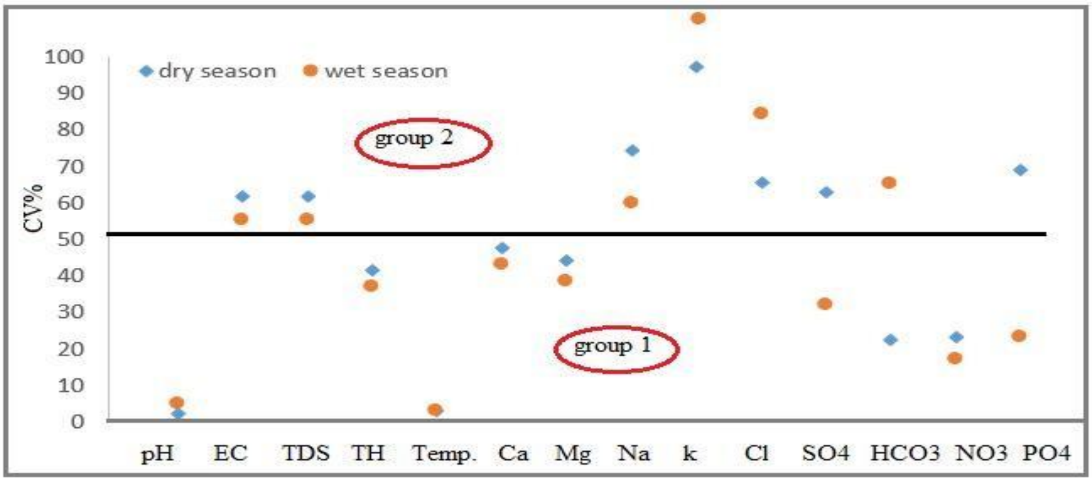

Figure (10): variation of coefficient of variance for all studied parameters.

Evaluation of ground water for irrigation: -

Several parameters have been used to assessment of ground water for agricultural such as Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Potential Salinity (P.S), Magnesium hazard (MH), Permeability index (P.I) and Kelly ratio (KR), table (5) explain the details .

Table (5): irrigation equation which used in this study

Variables	Equation	Source
Potential salinity (P.S)	$P.S = Cl + \frac{1}{2} SO_4$	Delgado *et al* (2010)
Sodium Adsorption Ratio (SAR)	$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$	(Wilcox, 1955)
Permeability index (PI)	$PI = \left[\left(\frac{Na + \sqrt{HCO_3}}{Na + Mg + Ca} \right) \times 100 \right]$	(Donnen, 1964)
Residual Sodium Carbonate (RSC)	$RSC = [(HCO_3^- + CO_3^{-2}) - (Ca^{+2} + Mg^{+2})]$	(Eaton, 1950)
Kelley ratio (KR)	$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}}$	(Kelly, 1940)
Magnesium hazard (MH)	$MH = \frac{Mg^{+2}}{Ca^{+2} + Mg^{+2}} \times 100$	Szabolcs & Darab (1964)

SAR ranged from (0.47 to 4.02) with average 1.76 in dry season. In wet season it ranged from (0.22 – 4.16), with average 2.25. These results slightly higher than the ranged obtained by (Al-Hamdany, 2020), which various from 0.2 -1.25. The reason of low SAR values as a result of high concentration of calcium and magnesium in compare with sodium in ground water (Adejumo *et al.*, 2018). According to SAR classification for irrigation, all water samples belong to S_1 class, which is indicate low sodium hazard, without negative impact on the soil infiltration and destroy soil structure because it high content of sodium (Nag and Das, 2014). potential salinity ranged from (2.92-27.2) and (5.74-25.07) meq l^{-1} in dry and wet season respectively. RSC ranged from (-31.24 to -3.01) meq l^{-1} in dry season, while it ranged from (-

32.04 to -8.8) in wet season. All the results have negative values because the concentration of Ca and Mg are higher than carbonate and bicarbonate, that is not lead to dominate of sodium ion in soil solution (Eruloa *et al.*, 2020). These ranged are similar to the ranged of study carried out by (Al-Hamdany, 2020). All the values are suitable for irrigation according to this parameter. Permeability index ranged from (18.4 to 43.08)%, with average 30.4 % in dry season. While it ranged from (7.08 to 42.6%), with average 30.91 in wet season. All water samples fall in the class I, as we can see from (figure 11), which indicate good water quality for irrigation in term of it effect on soil infiltration (Nag and Das, 2014). Magnesium hazard ranged from (36.8 to 74.32) %, with average 53.5 % in dry season. While it ranged from (41.7 to 74.8 %), with average 54.8 %, in wet season. If MH >50 % water is classification not suitable for irrigation (Szabolcs and Darab, 1964). About two–third of water samples are not fit for irrigation according to this parameter. Kelley ratio ranged from (0.08 to 0.48), with average 0.28 in dry season. While it ranged from (0.03 to 0.6), with average 0.36 %, in wet season. These results are agree with the results obtained by (Al-Hamdany, 2020), which it ranged from (0.01 to 0.35). If KR greater than one, water is considered not suitable for irrigation. All the results have KR values lower than 1 (see table 6) in both seasons, therefore all ground water samples are fit for irrigation crops and vegetables (Moghimi, 2016).

Table (6): Parameters for assessment of ground water for irrigation in both seasons.

Sample No.	Season	P.S	SAR	RSC	PI%	MH%	KR
		meq L^{-1}					
1	Dry	25.67	3.22	-30.45	31.60	42.20	0.39
	Wet	25.07	3.89	-32.04	35.15	54.05	0.45
2	Dry	27.20	4.02	-31.24	35.69	58.93	0.48
	Wet	24.80	4.16	-28.23	37.90	53.78	0.50
3	Dry	8.68	0.62	-13.02	20.11	36.84	0.11
	Wet	10.87	0.22	-24.79	7.08	41.78	0.03
4	Dry	5.55	1.48	-8.46	34.65	60.04	0.31
	Wet	7.72	1.79	-12.51	30.62	53.86	0.34
5	Dry	9.03	1.53	-14.46	27.62	56.78	0.26
	Wet	9.41	1.70	-15.12	28.86	58.28	0.29
6	Dry	20.15	3.23	-22.30	35.84	60.56	0.44
	Wet	13.69	2.68	-18.98	34.29	48.90	0.40
7	Dry	5.93	1.99	-7.48	40.89	65.76	0.41
	Wet	8.69	2.73	-9.32	42.68	49.19	0.60
8	Dry	10.14	1.09	-14.90	24.24	49.96	0.17
	Wet	13.58	1.63	-20.58	23.85	74.86	0.25
9	Dry	5.39	0.72	-8.02	26.76	36.86	0.15
	Wet	7.25	1.06	-12.26	22.86	45.04	0.21
10	Dry	7.06	1.44	-10.21	32.08	46.53	0.26
	Wet	9.06	1.75	-13.90	30.50	55.79	0.30
11	Dry	7.21	0.47	-12.57	18.45	56.30	0.08
	Wet	8.69	1.78	-14.91	28.44	56.40	0.32
12	Dry	17.68	2.12	-30.19	24.89	50.13	0.26
	Wet	15.65	2.76	-23.45	31.94	47.45	0.38
13	Dry	13.30	1.33	-18.53	23.36	74.32	0.20

	Wet	13.73	2.23	-21.91	28.52	61.28	0.32
14	Dry	9.08	1.99	-12.03	34.80	56.14	0.35
	Wet	12.09	3.09	-16.65	38.59	60.76	0.50
15	Dry	2.92	1.14	-3.01	43.08	51.81	0.29
	Wet	5.74	1.67	-8.80	35.51	58.41	0.36
16	Dry	8.14	1.80	-12.70	32.57	53.36	0.31
	Wet	11.23	2.88	-15.49	37.69	57.93	0.49

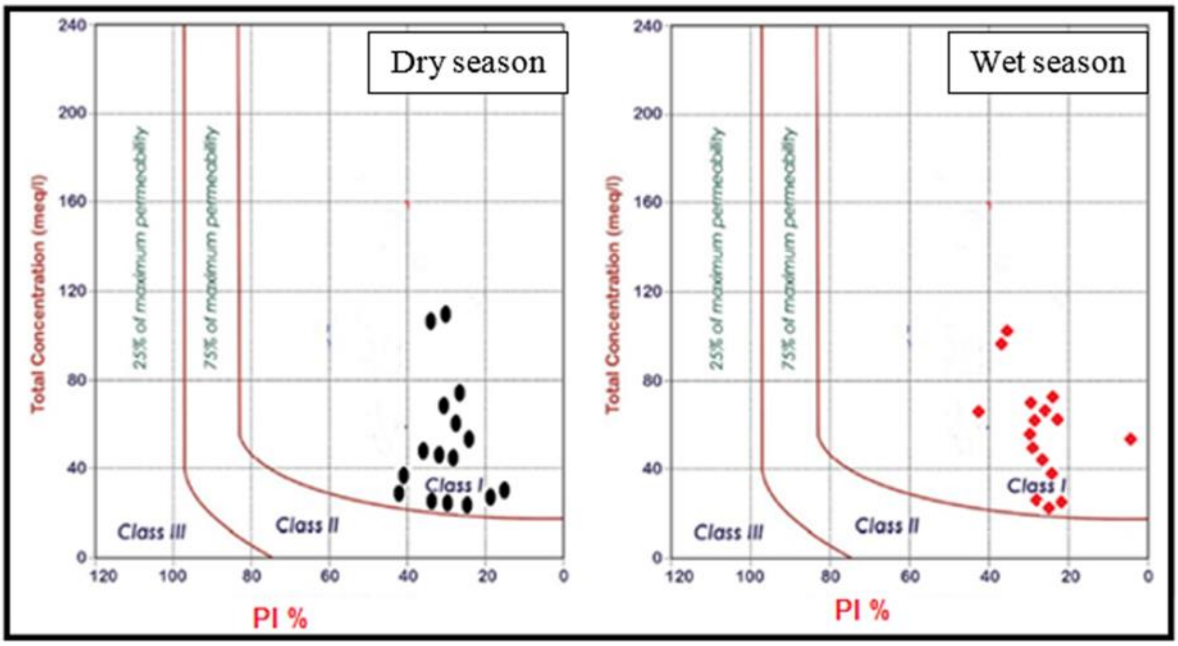

Figure (11): permeability index values for both seasons.

The plot of SAR against EC, which represent wilcox diagram (wilcox, 1955), according to US Salinity laboratory guideline, see (figure 12). The results revealed that well No. 1 and 2 fall in the class C_4S_2, which is indicate a very high salinity hazard and medium sodium hazard . In the other hand well No. 6, 8, 12, 13 and 14 fall in the class C_4S_1 which is a very high salinity hazard and low sodium hazard. The rest of wells which represented more than 56 % of studied wells fall in the class C_3S_1, which means a high salinity and low sodium hazard.

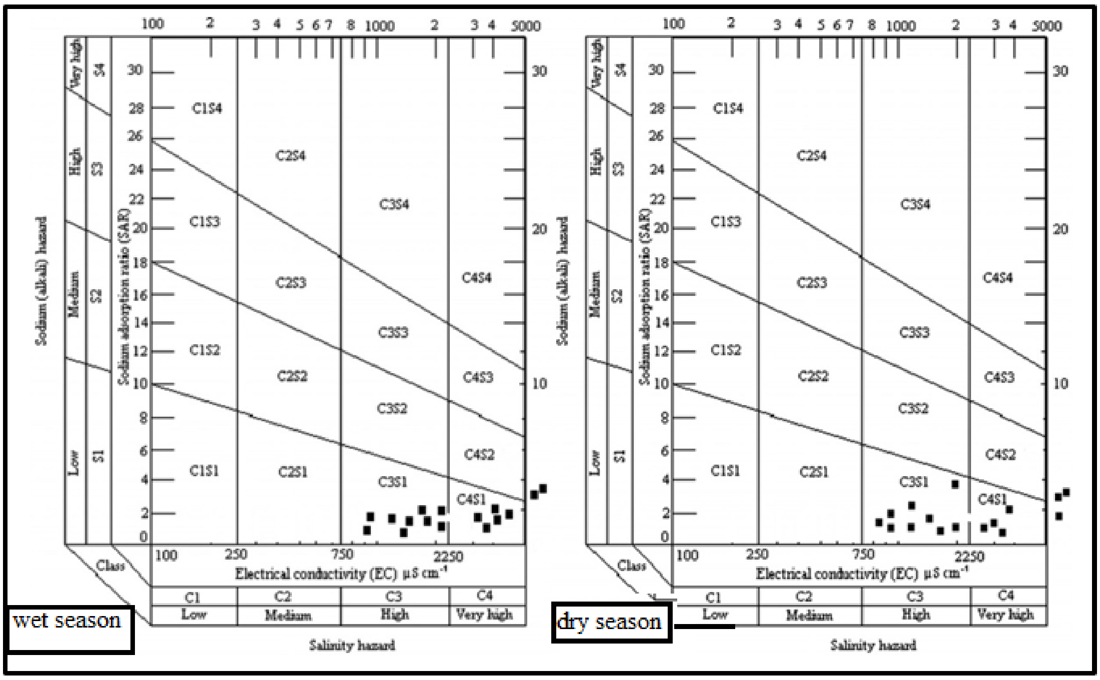

Figure (12): Us salinity diagram for classification of groundwater for irrigation .

CONCLUSION

There is significant variation of majority of variable in ground water samples between dry and wet season. The number of wells which have lower concentrations in the dry season compared to the wet season are; for salinity (6), water hardness (3) and pH (1) out of 16 wells. For cations the number of wells which have lower concentrations in the dry season than the wet season are: Calcium (7), Magnesium (6), sodium (2) and potassium (All). For anions the number of wells which have lower concentration in the dry season compared to the wet season are: chloride (8), nitrate (5), phosphate (5), sulphate (4) and bicarbonate (3). According to (FAO) and based on average water salinity in both season, three-quarter of studied wells are fit for irrigation, while the rest of wells are not suitable for irrigation.There no risk of present of sodium in water in term of SAR, which it effect on soil in negative way. We recommended to use water wells for agricultural crops that have medium to high tolerant to salinity, with continue leaching of salts from soil surface to avoid build up of soil salinity and degradation it over time. The sequence of recent drought lead to drop water level and depletion of ground water storage and deteriorate it quality. Management of ground water is considered top priority in term of quantity and quality in order to preserves and sustainability this precise water resources for next generation.

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CONFLICT OF INTEREST

None of the authors has a financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of the paper.

مراقبة التغاير الموسمي في نوعية المياه الجوفية و تقييمها لاغراض الري في منطقة النمرود جنوب- شرق الموصل – العراق

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الخلاصة

تم اختيار ستة عشر بئراً موزعة في مواقع مختلفة ضمن ناحية النمرود لدراسة نوعية المياه الجوفية خلال الموسمين الجاف و الرطب ومراقبة تغايرها. شملت التحاليل كلاً من الملوحة، الدالة الحامضية, درجة الحرارة، العسرة الكلية وتراكيز الايونات الرئيسية الموجبة والسالبة في المياه. كان تغاير ملوحة المياه الجوفية كبير وتتراوحت بين (0.81 إلى 5.82) و (0.88 إلى5.77) ديسيمنز م$^{-1}$ في الموسم الجاف والرطب على التوالي. حوالي 75٪ من النماذج كانت ملوحتها أعلى في الموسم الرطب مقارنة بالموسم الجاف. جميع العينات كانت ذات عسرة مياه عالية جداً. نصف الآبار المدروسة كانت تراكيز كل من الكالسيوم والكلورايد اعلى في موسم الرطب مقارنة بالموسم الجاف. حوالي ثلثي النماذج كان تركيز المغنيسيوم أعلى في موسم الجاف بالمقارنة بالموسم الرطب. حوالي 87٪ من الآبار كان تراكيز كل من الصوديوم والبوتاسيوم اعلى في الموسم الرطب من الجاف. حوالي ثلاثة أرباع الآبار المدروسة كان تركيز الكبريتات أعلى في موسم الرطب بالمقارنة بالجاف. حوالي 80٪ من الآبار كان تركيز النترات أعلى في موسم الجاف من الموسم الرطب. تم تقييم نوعية مياه الري باستخدام العديد من معايير الري, جميع نماذج الآبار وقعت ضمن الاصناف C_4S_1 و C_4S_2 و C_3S_1 حسب مختبر الملوحة الامريكي.

الكلمات المفتاحية: الجبس, الري, طبقة المياه الجوفية, نوعية المياه.

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