Simulation Study of the effect of artificial recharge on the water quality of shallow Dibdibba Clastic Aquifer in Zubair-Safwan area, south of Iraq

Hussein B. Ghalib

Department of Geology, College of Science, University of Basrah, Basrah, Iraq

E-mail: hbggeo@hotmail.com

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Abstract

The Dibdibba clastic aquifer is a major source of brackish groundwater in Basra-Zubair-Safwan area, south of Iraq. The water has total dissolved solids ranging from 3810 to 9225 mg/l. Twenty five wells are selected to study the groundwater quality of the area being question, from which only four wells are used for testing the mixing experiment. Three types of water are chosen to test the effect of mixing schemes with different ratio of the native groundwater quality. These are: storm runoff (flood) which is observed during 2006 winter in the southern part of Basrah along the Iraqi-Kuwaiti boarder, water from Shatt Al-Arab River and tab water. To evaluate the mixing processes, the geochemical modeling code **AQUACHEM** and inherent geochemical modeling package **PHREEQC** was employed. The modeling results show the importance of the artificial recharge with the tested water to improve the groundwater quality of the aquifer and to lowering and control the concentration of nitrate in the resulting water after mixing. This study highly recommends to use meteoric water in artificial recharge to improve the water quality and quantity of Dibdibba clastic aquifer in south of Iraq.

Keywords: Artificial recharge, Water quality, Geochemical Modeling, Mixing Model, Dibdibba formation and Basrah-Zubair

INTRODUCTION

In the developing world, 80% of all diseases are directly related to poor drinking water and unsanitary contamination. A connection between agricultural and groundwater pollution is well established [1]. Normally, nitrate (NO_3) is probably the most widespread contamination in groundwater and originated from urban and agricultural activities. Groundwater NO_3^- and chloride Cl^- contaminations can result from the over application of manure and fertilizers [2]. Artificial recharge of groundwater is especially applied in semiarid region, also as a protection against saltwater intrusion [3]. Salinization of groundwater is the most important problem in the arid and semi-arid regions; therefore, the studies should be focused on the possible causes of this problem and hence taking the measures that are controlled, these causes.As shown by previous studies [4] [5] [6] and [7], the water quality of the upper part of Dibdibba sandy aquifer in the study area suffer from degradation due to urbanization and agricultural activities. Overexploitation of the groundwater resources in the study area has led to investigate the effect of a proposed artificial recharge program on the groundwater quantity of the interested aquifer [8] and [9]. Results of these experiments show the importance of artificial recharge to enhance the groundwater quantity and to prevent deterioration of the resource. Chemical composition of the groundwater in Basra-Zubair-Safwan depends on human activities. Normally, the groundwater of many of operated wells (hand dug or tube) is calcium-chloride type. After the intensively pumping period (from August to May) for agricultural purpose the salinity may increased and the chemical composition changes to sodium-chloride type [10].

The aim of this work is to use geochemical modeling to detect the effect of artificial recharge of the groundwater quality of the depleted aquifer in the area being question and to simulate the effect of mixing process on chemical composition of the native water.

STUDY AREA

Basra-Zubair-Safwan area is located in the northeast of Arabian Gulf between Latitude (33°70′-33°30′ N) and Longitude (47°30′-47°55′ E). It occupies an area of about 476.84 mi^2. The surveyed area is slightly declining along course of Euphrates River to its north and the Shatt Al-Arab River to its east and northeast **Figure (1)**. It is an important agricultural and industrial area in which the groundwater is the prime source for irrigation, domestic, and watering livestock except in area of extremely high salinity in east. The upper part of Dibdibba Formation represents the most important aquifer in the study area. It is unconfined with average thickness of 15m, underlying by hard clay layer of 2 m thick acting as barrier separating the upper aquifer from the deeper underlying semi-confined to confined aquifer[5]. According to the [11] the transmissivity values range from 235 to 5880 m^2/d, while the specific yield values range from 0.035 to 0.4. The flow direction is from northwest to southeast, i.e., toward Khor Al-Zubair. There are more than 3000 operating wells abstracting water mainly for agricultural usages.

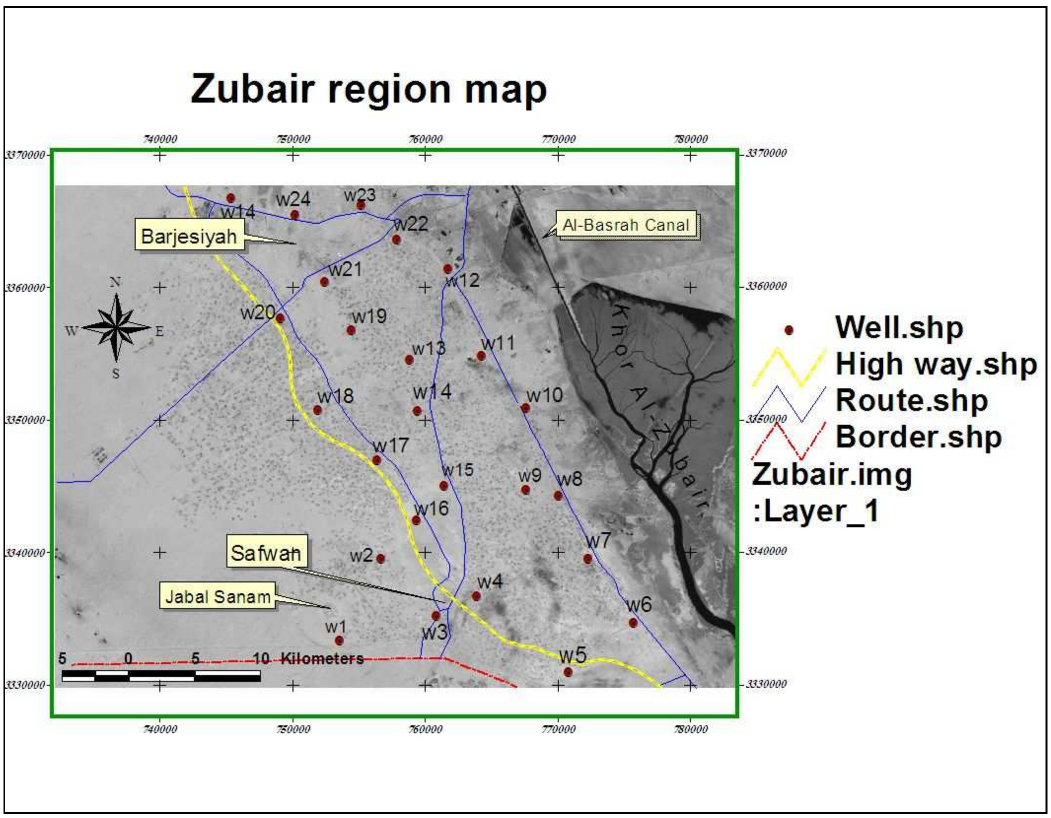

Fig. 1 Map of the study area

HYDROMETEOROLOGY

The climate of the study area, at the northern end of the Arabian Gulf, is characterized by long hot summer and short moderately cold winter seasons. Rainfall is the only form of precipitation in the region except for very rare hail, which may occur during brief thunderstorm. The amounts of recorded precipitation by the meteorological station in Basra province reflect the semi-arid nature of the climate. The mean annual precipitation is 146.4, mm. In the province of Basrah, the amount of water loss due to evaporation increase during the summer and decrease during the winter seasons, depending on the temperature, wind speed, humidity and vegetation covers. The annual potential evaporation far exceeds the annual rainfall **Figure 2** with a mean annual approximately 3534 mm for 1973-2000 periods. Consequently, the precipitation is never sufficient to saturate the soil and thus the annual rainfall scarcely contributes to the replenishment of the aquifer in the study area, indicating that recharge in this area is most likely coming from a source outside the country. Some temporary runoff may occur locally in small wadis and basins after intensive heavy rain storms, providing the only from of surface water in the region. Playas of precipitation water fill depressions for a short duration, depending on the evaporation. Some water from the wadis and playas may infiltrate in to the relatively shallow aquifer and replenish them.

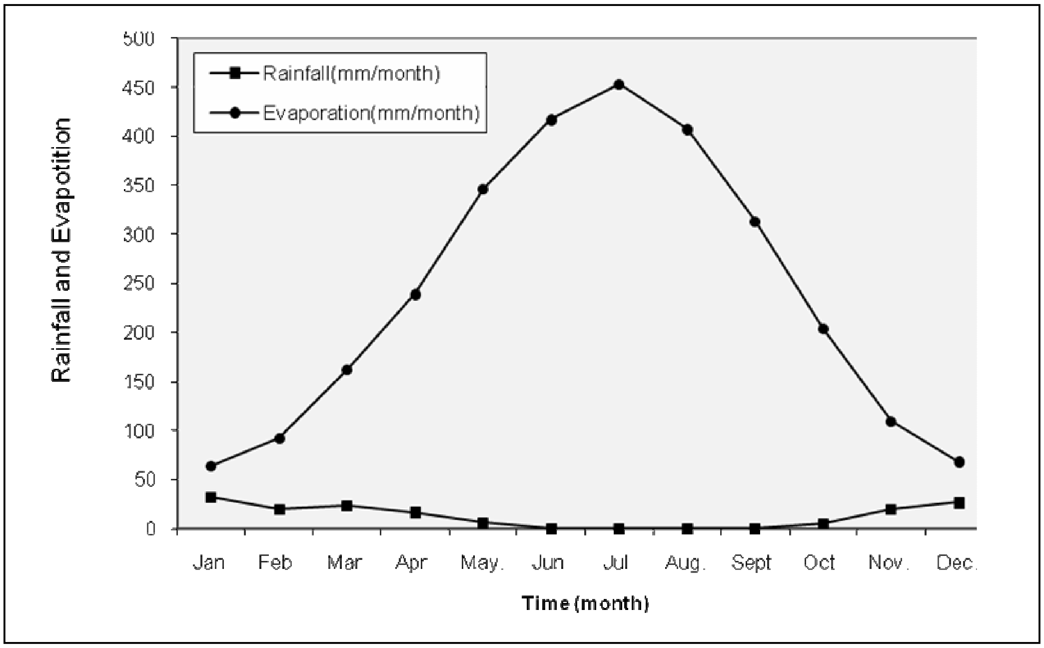

Fig.2 Monthly average of rainfall and Evaporation (based on data abstracted from New Eden Master Plan, 2006)

MATERIAL AND METHODS

The geological and geochemical data used in this study is abstracted and collected from different sources and reports [12] [13] and [14]. Chemical data analysis of rain water and tab water are collected by author, were carried out in the Marine Center at the University of Basrah **AquaChem** [15] and inherent geochemical modeling package **PHREEQC** (for windows version 2) [16] computer programs were employed here to calculate saturation indices and to simulate mixing process.

RESULTS AND DISCUSSIONS

Summary statistics

The major cations and anions of the groundwater, in addition to the electrical conductivity and pH were shown in **Table (1)**. Concentration of cations and anions are plotted in frequency diagrams of **Figure (3)**. The relative content of a cation or anion is defined as the percentage (meq./l) of total cation or total anions, respectively. **Figure (3)** indicates that the two dominant ions in the studied water are Cl^- and SO_4^{2-}, and they are only ions that extent to the zone of dominance. Although they are not reaching dominance level, the studied water contains large percentages of Na^+, Mg^{2+}, Ca^{2+} and HCO_3^-

ions. The HCO_3^- concentrations in water samples range between 39 and 427 mg/l, whereas the concentrations of Na^+ vary between 400 to 1448.3 mg/l. The concentrations of K^+ range between 18.7 and 64 mg/l, the Mg^{+2} concentrations range between 72.9 and 461.7 mg/l, and the Ca^{2+} concentrations range from360.7 to 1563 mg/l

Water type

Durov diagram is used to present the chemical data for different water. The advantage of this diagram is that it displays some possible processes that could be effective in the water genesis [17]. Durov diagram for water sample of the study area are shown in **Figure (4)**. According to this diagram, most of the groundwater samples are alkaline with prevailing chloride and sulfate and it is related to the ion exchange of Na^+-Cl^-. Durov diagram supports the previous proposed explanation concerning their water type.

Table 1 chemical composition (major elements) in the well waters (25 samples)

	Ca	Na	K	Mg	Cl	SO4	HCO_3	NO_3	pH	TDS	EC	SI_{cal}	SI_{dol}	SI_{gyp}
Max	68.64	73.99	1.64	19.00	79.82	35.31	6.79	1.77	8.3	9225	8950	1.38	2.25	0.36
Min	9.00	17.40	0.48	3.00	15.00	18.01	0.64	0.57	6.9	3810	642	-0.52	-1.46	-0.24
AM	21.57	44.96	0.92	9.69	45.40	26.57	2.11	1.02	7.4	6679	6355	0.38	0.48	0.04
STD	12.19	13.40	0.34	5.10	19.80	5.10	1.43	0.37	0.4	1367	1672	0.50	1.03	0.13

Concentration are expressed in mmol 1^{-1}, TDS in Mg 1^{-1} and EC in dS m^{-1}

Chemical equilibrium saturation

The quality of the recharge waters and its interactions with soil and rocks, during its percolation and its storage in the aquifers are key factors in the chemistry of groundwater. These interactions involve mainly dissolution and precipitation processes, which are controlled by the solubility products of different mineral phases involved. Generally, the saturation indices (SI) are used to expresses the tendency of water towards precipitation or dissolution. Equilibrium calculation has been used to assess whether groundwater is in equilibrium with respect to one or more minerals. When SI< 1, the minerals will dissolve, while, they will precipitate when SI> 1. The saturation indices (SI) of collected samples are calculated for the major mineral phase by using the software package **PHREEQC**. From **Table 1** the saturation index for gypsum range from (-0.24 to 0.36), indicating that gypsum is under-saturation in the groundwater. Most of the samples have positive calcite and dolomite indices, indicating over-saturation.

GEOCHEMICAL MODELING

Geochemical modeling is carried out to evaluate and explain the dilution effect of infiltrated flood water, Shatt Al-Arab River water, and tab water with different mixing ratios. Four well are selected which cover the studied area (W1, W10, W16 and W22). Construction of equilibrium models for chemical constituents in natural waters consists of computing the equilibrium concentration of the various dissolved constituents for the selected model.The computations of chemical models were carried out using a computer program **AquaChem 5.1** [16]. This program is based on the ion association theory by which the distribution of chemical species is formulated in two distinct thermodynamic approaches; the equilibrium constant and the Gibbs free energy. Therefore, the program computes these quantities during simulation of reaction.

Geochemical models for this study are performed over two steps:

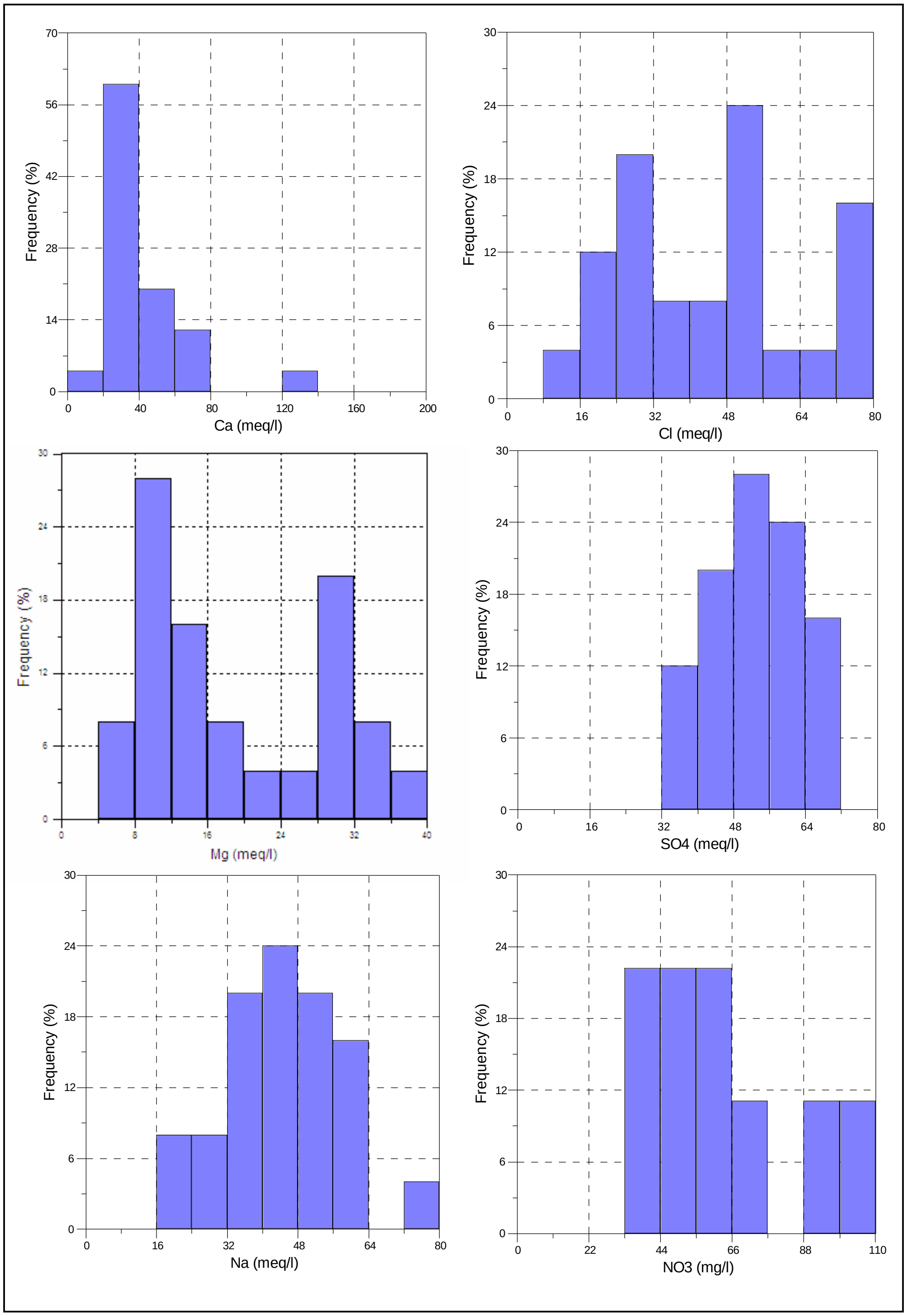

Fig.3 Relative frequency distribution of cations and anions in groundwater samples

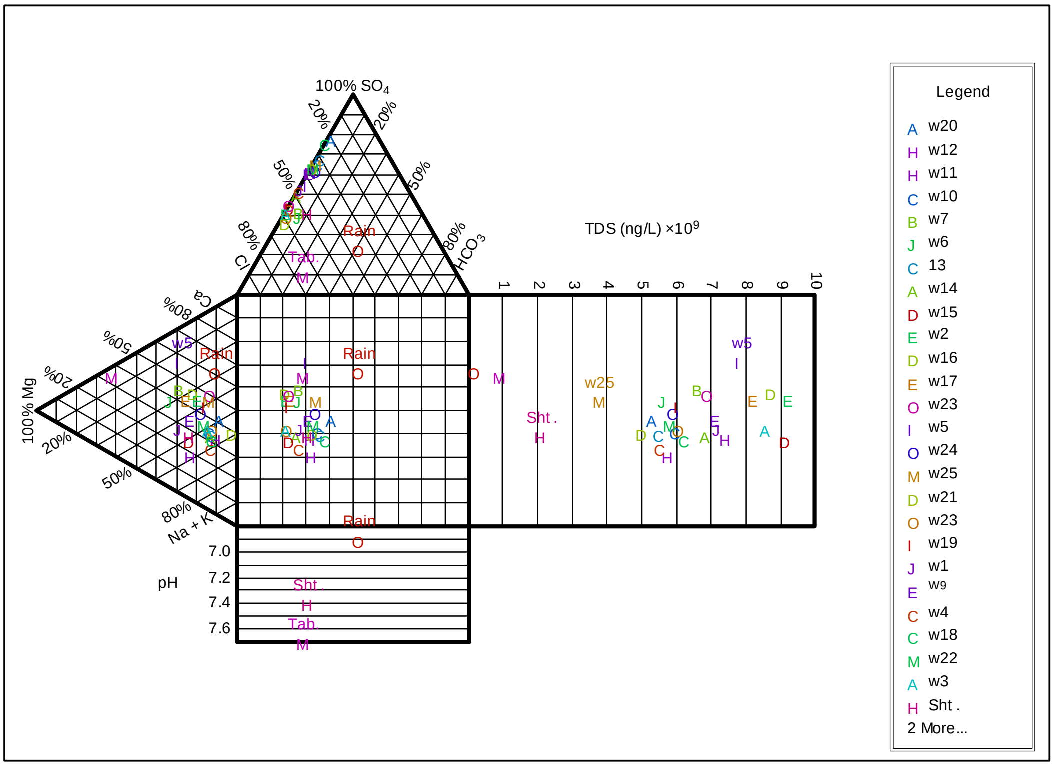

Fig. 4 Plot of wells and different water types sampled

Step-1:

This mixing model is performed by mixing the average chemical compositions of flood water draining from the north (discharge area) and ground water of well 22 with different mixing ratio (10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90%). The mix process with the same ratio is achieved between flood water draining from southeast part near Iraqi-Kuwaiti border (recharge area) of the study area and groundwater chemical compositions of wells (w1 and w16). The average chemical compositions of the measured flood water and simulated water are illustrated in **Tables 2, 3, 4 and 5**. Comparing the resulting chemical compositions of the simulated flood water with that of measured, it can be stated that no major difference between the chemical composition of two solutions. This simulation is done to show the effect of flood water on the groundwater quality if the whole quantity of flood water becomes the dominant water in the aquifer. The resulting of this water is similar to chemistry of the previous water chemical composition with some changes in concentrations of ions. By comparing the composition of the modeled mixed water with the groundwater compositions, it is notice that, the water quality becomes better by increasing the ratios of infiltrated flood waters.

Step-2:

Nitrate (NO_3^-) is a very important anion to be controlled in drinking water due to its negative effect on the human health especially infants less than two years old. Elevated nitrate concentrations in drinking water are assumed to be responsible for an increased risk to developed stomach and intestinal cancer if consumed for long periods. This is based on the reduction of NO_3^- to NO_2^- in the stomach and intestinal tract [17]. Nitrate is generally an indication of concentration from major nitrogen sources such as a sewage disposal system, animal manure or fertilizers. Concentration of the nitrate in the study area range between 40-85 *mg/l*, indicating that these values are beyond acceptable limits. Thus the water of these resources is not suitable for drinking. According to discussion mentioned above, the mixing model is tested to lower the high levels of nitrate. The mixing could be done in the house cisterns and the root tanks. In the study area the well 1 represents groundwater in the south part (recharge area) and well 22 represents groundwater in the north part of the study area. The average chemical composition of the water for (w1, w10, w16, and w22) is mixed with different percentages (0.9:0.1, 0.8:0.2, …, 0.1:0.9) with Shatt Al-Arab River water, rain water, and tab water). The changes in the nitrate concentration of wells water are summarized in **Table 6**. From Table 6, 50% or less mixing percentage of well 1 with 50% or more mixing form Shatt Al-Arab water, rain water, and tab water is necessary to lower the nitrate concentration in this well to less than WHO (50 mg/l) acceptable level of nitrate concentration in drinking water[18]. On the other hand, the percentages for well 22 are ≤ 60% with ≥ 40% of Shatt Al-Arab water, rain water and tap water and ≤ 70% with ≥30% of rain water. Nitrate content is only an example of the water characteristics that could be improved and controlled by mixing. Thus mixing could be considered as an effective water "treatment" method.

Table (2) Change in the chemistry of the dug well water of W1 as a result of Mixing with Shatt Arab River, Rain Water and Tab water

Parameter	Mixing Water		W1	Mixing Percentages (W1 :Mixing Water)								
				0.9:0.1	0.8:0.2	0.7:0.3	0.6:0.4	0.5:0.5	0.4:0.6	0.3:0.7	0.2:0.8	0.1:0.9
pH	Sht. Arab	7.4	8.3	8.07	7.92	7.81	7.72	7.64	7.58	7.53	7.48	7.43
	Rain Water	6.9		7.76	7.53	7.38	7.27	7.18	7.11	7.047	6.99	6.94
	Tap Water	7.7		8.19	8.10	8.02	7.96	7.90	7.85	7.81	7.77	7.73
Ca	Sht. Arab	175.69	629.3	583.939	538.577	493.216	447.856	402.495	357.134	311.773	266.412	221.051
	Rain Water	34		569.77	510.24	450.71	391.18	331.65	272.12	212.59	153.06	93.53
	Tap Water	88.0		575.17	521.04	466.91	412.78	358.65	304.52	250.39	196.26	142.13
Mg	Sht. Arab	90.77	369.5	341.627	313.754	285.881	258.008	230.135	202.262	174.389	146.516	118.643
	Rain Water	3.5		332.9	296.3	259.7	223.1	186.5	149.9	113.3	76.7	40.1
	Tap Water	97.2		342.27	315.04	287.81	260.58	233.35	206.12	178.89	151.66	124.43
Na	Sht. Arab	356	1070	998.6	927.2	855.79	784.4	713	641.6	570.2	498.8	427.4
	Rain Water	16		964.6	859.2	753.79	648.4	542.99	437.6	332.2	226.8	121.4
	Tap Water	10.19		964.02	858.04	752.06	646.08	540.10	434.11	328.13	222.15	116.17
K	Sht. Arab	8.21	21.9	20.531	19.162	17.793	16.424	15.055	13.686	12.317	10.948	9.579
	Rain Water	2.6		19.97	18.04	16.11	14.18	12.25	10.32	8.3899	6.46	4.53
	Tap Water	1.13		19.82	17.75	15.67	13.59	11.52	9.44	7.36	5.28	3.21
HCO_3	Sht. Arab	212.41	100	111.241	122.482	133.723	144.964	156.205	167.446	178.687	189.928	201.169
	Rain Water	70.7		97.07	94.14	91.21	88.28	85.35	82.42	79.49	76.56	73.63
	Tap Water	240		114.00	128.00	142.00	156.00	170.00	184.00	198.00	212.00	226.00
Cl	Sht. Arab	586.94	1800	1678.69	1557.38	1436.08	1314.77	1193.47	1072.16	950.858	829.552	708.246
	Rain Water	35		1623.5	1447	1270.5	1094	917.49	740.99	564.49	388	211.5
	Tap Water	390.5		1659.05	1518.10	1377.15	1236.20	1095.25	954.30	813.35	672.40	531.45
SO_4	Sht. Arab	697.89	2914	2692.38	2470.77	2249.16	2027.55	1805.94	1584.33	1362.72	1141.11	919.501
	Rain Water	31		2625.70	2337.40	2049.10	1760.80	1472.50	1184.20	895.90	607.60	319.30
	Tap Water	76.38		2630.24	2346.48	2062.71	1778.95	1495.19	1211.43	927.67	643.90	360.14
NO_3	Sht. Arab	10.7	88.04	80.306	72.572	64.838	57.104	49.37	41.636	33.902	26.168	18.434
	Rain Water	6.9		79.93	71.81	63.70	55.58	47.47	39.36	31.24	23.13	15.01
	Tap Water	11.9		80.43	72.81	65.20	57.58	49.97	42.36	34.74	27.13	19.51

Table (3) Change in the chemistry of the dug well water of W10 as a result of Mixing with Shatt Arab River, Rain Water and Tab water

Parameter	Mixing Water		W10	Mixing Percentages (W10 :Mixing Water)								
				0.9:0.1	0.8:0.2	0.7:0.3	0.6:0.4	0.5:0.5	0.4:0.6	0.3:0.7	0.2:0.8	0.1:0.9
pH	Sht. Arab	7.4	7.8	7.73	7.68	7.63	7.59	7.55	7.51	7.48	7.45	7.42
	Rain Water	6.9		7.57	7.42	7.31	7.22	7.14	7.08	7.032	6.98	6.93
	Tap Water	7.7		7.78	7.77	7.76	7.75	7.74	7.73	7.72	7.71	7.70
Ca	Sht. Arab	175.69	641	594.47	547.94	501.41	454.88	408.35	361.81	315.28	268.75	222.22
	Rain Water	34		580.3	519.6	458.9	398.2	337.5	276.8	216.1	155.4	94.7
	Tap Water	88.0		585.7	530.4	475.1	419.8	364.5	309.2	253.9	198.6	143.3
Mg	Sht. Arab	90.77	145.8	140.29	134.79	129.29	123.79	118.29	112.782	107.279	101.776	96.28
	Rain Water	3.5		131.57	117.34	103.11	88.88	74.65	60.42	46.19	31.96	17.73
	Tap Water	97.2		140.94	136.08	131.22	126.36	121.5	116.64	111.78	106.92	102.06
Na	Sht. Arab	356	1103.4	1028.66	953.92	879.18	804.44	729.7	654.96	580.22	505.48	430.74
	Rain Water	16		994.66	885.92	777.18	668.44	559.7	450.96	342.22	233.48	124.74
	Tap Water	10.19		994.08	884.76	775.44	666.12	556.79	447.47	338.15	228.83	119.51
K	Sht. Arab	8.21	36.4	33.58	30.762	27.943	25.12	22.305	19.48	16.67	13.84	11.02
	Rain Water	2.6		33.02	29.64	26.26	22.88	19.5	16.12	12.74	9.36	5.98
	Tap Water	1.13		32.873	29.346	25.819	22.292	18.765	15.23	11.711	8.184	4.657
HCO_3	Sht. Arab	212.41	134.2	142.02	149.84	157.663	165.484	173.31	181.13	188.95	196.77	204.58
	Rain Water	70.7		127.85	121.5	115.15	108.8	102.45	96.1	89.75	83.39	77.05
	Tap Water	240		144.78	155.36	165.94	176.52	187.1	197.68	208.26	218.84	229.42
Cl	Sht. Arab	586.94	992.5	951.94	911.39	870.83	830.27	789.72	749.164	708.61	668.05	627.49
	Rain Water	35		896.75	800.99	705.24	609.49	513.75	418	322.25	226.5	130.75
	Tap Water	390.5		932.3	872.1	811.9	751.7	691.5	631.3	571.1	510.9	450.7
SO_4	Sht. Arab	697.89	2785.8	2577.0	2368.22	2159.42	1950.63	1741.84	1533.05	1324.26	1115.47	906.68
	Rain Water	31		2510.3	2234.84	1959.36	1683.88	1408.4	1132.92	857.43	581.96	306.48
	Tap Water	76.38		2514.8	2243.91	1972.97	1702.03	1431.09	1160.14	889.20	618.26	347.322
NO_3	Sht. Arab	10.7	60.14	55.19	50.25	45.30	40.364	35.42	30.476	25.53	20.588	15.64
	Rain Water	6.9		49.236	44.532	39.828	35.124	30.42	25.716	21.01	16.308	11.60
	Tap Water	11.9		55.32	50.49	45.69	40.84	36.02	31.19	26.37	21.55	16.72

Table (4) Change in the chemistry of the dug well water of W16 as a result of Mixing with Shatt Arab River, Rain Water and Tab water

Parameter	Mixing Water		W16	Mixing Percentages (W16:Mixing Water)								
				0.9:0.1	0.8:0.2	0.7:0.3	0.6:0.4	0.5:0.5	0.4:0.6	0.3:0.7	0.2:0.8	0.1:0.9
pH	Sht. Arab	7.4	7.3	7.31	7.32	7.33	7.34	7.35	7.36	7.37	7.38	7.39
	Rain Water	6.9		7.24	7.19	7.14	7.09	7.06	7.02	6.99	6.96	6.93
	Tap Water	7.7		7.33	7.36	7.39	7.42	7.46	7.49	7.54	7.59	7.64
Ca	Sht. Arab	175.69	1563	1424.2	1285.54	1146.81	1008.08	869.35	730.61	591.88	453.15	314.42
	Rain Water	34		1410.1	1257.2	1104.3	951.4	798.49	645.6	492.7	339.8	186.9
	Tap Water	88.0		1415.5	1268.0	1120.50	973.00	825.50	678.00	530.50	383.00	235.50
Mg	Sht. Arab	90.77	437	402.38	367.75	333.13	298.51	263.89	229.26	194.64	160.02	125.39
	Rain Water	3.5		393.65	350.3	306.95	263.6	220.25	176.9	133.55	90.2	46.85
	Tap Water	97.2		403.02	369.04	335.06	301.08	267.10	233.12	199.14	165.16	131.18
Na	Sht. Arab	356	1179.5	1097.1	1014.80	932.45	850.10	767.75	685.40	603.05	520.70	438.35
	Rain Water	16		1063.1	946.79	830.44	714.1	597.74	481.4	365.05	248.7	132.35
	Tap Water	10.19		1062.5	945.64	828.71	711.78	594.85	477.91	360.98	244.05	127.12
K	Sht. Arab	8.21	45.7	41.95	38.20	34.45	30.70	26.96	23.21	19.46	15.71	11.96
	Rain Water	2.6		41.39	37.08	32.77	28.46	24.15	19.84	15.53	11.22	6.91
	Tap Water	1.13		41.24	36.79	32.33	27.87	23.42	18.96	14.50	10.04	5.59
HCO_3	Sht. Arab	212.41	244	240.84	237.68	234.52	231.36	228.21	225.05	221.89	218.73	215.57
	Rain Water	70.7		226.67	209.34	192.01	174.68	157.35	140.02	122.69	105.36	88.03
	Tap Water	240		243.60	243.20	242.80	242.40	242.00	241.60	241.20	240.80	240.40
Cl	Sht. Arab	586.94	2765	2547.1	2329.39	2111.58	1893.78	1675.97	1458.16	1240.36	1022.55	804.75
	Rain Water	35		2492	2219	1946	1673	1400	1127	853.99	580.99	308
	Tap Water	390.5		2527.5	2290.10	2052.65	1815.20	1577.75	1340.30	1102.85	865.40	627.95
SO_4	Sht. Arab	697.89	2257	2101.0	1945.18	1789.27	1633.36	1477.45	1321.53	1165.62	1009.71	853.80
	Rain Water	31		2034.4	1811.8	1589.2	1366.6	1144	921.4	698.8	476.2	253.6
	Tap Water	76.38		2038.9	1820.88	1602.81	1384.75	1166.69	948.63	730.57	512.50	294.44
NO_3	Sht. Arab	10.7	60.14	55.20	50.25	45.31	40.36	35.42	30.48	25.53	20.59	15.64
	Rain Water	6.9		54.81	49.49	44.16	38.844	33.52	28.19	22.87	17.54	12.22
	Tap Water	11.9		55.32	50.49	45.67	40.84	36.02	31.20	26.37	21.55	16.72

Table (5) Change in the chemistry of the dug well water of W22 as a result of Mixing with Shatt Arab River, Rain Water and Tab water

Parameter	Mixing Water		W22	Mixing Percentages (W22:Mixing Water)								
				0.9:0.1	0.8:0.2	0.7:0.3	0.6:0.4	0.5:0.5	0.4:0.6	0.3:0.7	0.2:0.8	0.1:0.9
pH	Sht. Arab	7.4	7.45	7.44	7.44	7.43	7.43	7.42	7.42	7.41	7.41	7.40
	Rain Water	6.9		7.35	7.27	7.20	7.14	7.09	7.05	7.01	6.97	6.93
	Tap Water	7.7		7.46	7.48	7.51	7.53	7.55	7.58	7.60	7.63	7.66
Ca	Sht. Arab	175.69	675	625.07	575.14	525.21	475.28	425.35	375.41	325.48	275.55	225.62
	Rain Water	34		610.90	546.80	482.70	418.60	354.50	290.40	226.30	162.20	98.10
	Tap Water	88.0		616.3	557.6	498.9	440.2	381.5	322.8	264.1	205.4	146.7
Mg	Sht. Arab	90.77	177.5	168.83	160.15	151.48	142.81	134.14	125.46	116.79	108.12	99.44
	Rain Water	3.5		160.10	142.70	125.30	107.90	90.50	73.10	55.70	38.30	20.90
	Tap Water	97.2		169.47	161.44	153.41	145.38	137.35	129.32	121.29	113.26	105.23
Na	Sht. Arab	356	988.5	925.25	862.00	798.75	735.50	672.25	609.00	545.75	482.50	419.25
	Rain Water	16		891.25	794.00	696.75	599.50	502.25	405.00	307.75	210.50	113.25
	Tap Water	10.19		900.16	811.83	723.50	635.17	546.84	458.51	370.18	281.85	193.52
K	Sht. Arab	8.21	32	29.62	27.24	24.86	22.48	20.11	17.73	15.35	12.97	10.59
	Rain Water	2.6		29.06	26.12	23.18	20.24	17.30	14.36	11.42	8.48	5.54
	Tap Water	1.13		28.913	25.826	22.739	19.652	16.565	13.478	10.39	7.30	4.217
HCO_3	Sht. Arab	212.41	78.1	91.53	104.96	118.39	131.82	145.26	158.69	172.12	185.55	198.98
	Rain Water	70.7		77.36	76.62	75.88	75.14	74.40	73.66	72.92	72.18	71.44
	Tap Water	240		94.29	110.48	126.67	142.86	159.05	175.24	191.43	207.62	223.81
Cl	Sht. Arab	586.94	1063	1015.3	967.79	920.18	872.58	824.97	777.36	729.76	682.15	634.55
	Rain Water	35		960.20	857.40	754.60	651.80	549.00	446.20	343.40	240.60	137.80
	Tap Water	390.5		995.75	928.49	861.24	794	726.75	659.5	592.25	525	457.75
SO_4	Sht. Arab	697.89	2630	2436.7	2243.58	2050.37	1857.16	1663.95	1470.73	1277.52	1084.31	891.10
	Rain Water	31		2370.1	2110.20	1850.30	1590.40	1330.50	1070.60	810.70	550.80	290.90
	Tap Water	76.38		2374.6	2119.27	1863.914	1608.55	1353.19	1097.82	842.46	587.103	331.74
NO_3	Sht. Arab	10.7	68.2	62.45	56.70	50.95	45.20	39.45	33.70	27.95	22.20	16.45
	Rain Water	6.9		62.07	55.94	49.81	43.68	37.55	31.42	25.29	19.16	13.03
	Tap Water	11.9		62.57	56.93	51.30	45.68	40.05	34.42	28.79	23.16	17.53

Table(6) Concentration of Nitrate after Mixing for W1 and W22

		W1(88.09 mg.NO_3^-/L)			W22(68.2 mg.NO_3^-/L)		
Mixing Water		Shatt Al-Arab water	Rain Water	Tab. water	ShattAl-Arab water	Rain Water	Tab. Water
		11.9	6.9	10.7	11.9	6.9	10.7
Mixing Percentage	0.9:0.1	80.31	79.93	80.43	62.45	62.07	62.57
	0.8:0.2	72.57	71.81	72.81	56.70	55.94	56.93
	0.7:0.3	64.83	63.70	65.20	50.95	49.81	51.30
	0.6:0.4	57.11	55.58	57.58	45.20	43.68	45.68
	0.5:0.5	49.37	47.47	49.97	39.45	37.55	40.05
	0.4:0.6	41.63	39.36	42.36	33.70	31.42	34.42
	0.3:0.7	33.90	31.24	34.74	27.95	25.29	28.79
	0.2:0.8	26.16	23.13	27.13	22.20	19.16	23.16

CONCLUSIONS

Recharging the depleted aquifer in Zubair area by tow proposed methods. The first way by storm runoff and the second by transport of water by appropriate technology form Shatt Al-Arab River are so important to improve and induce positive effects on groundwater quality of the interested aquifer. The water characteristics such as nitrate concentration could be improved and controlled by mixing process, thus mixing could be considered as an effective water "treatment" technology.

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دراسة محاكاة تأثير التغذية الصناعية على نوعية المياه الجوفية لمكمن الدبدبة الفتاتي في منطقة الزبير- سفوان (جنوب العراق)

حسين بدر غالب

قسم علم الارض، كلية العلوم، جامعة البصرة، البصرة- العراق

الملخص

يعد مكمن الدبدبة الفتاتي المصدر الرئيسي للمياه الجوفية المويلحة في منطقة الزبير سفوان،جنوب العراق. تمتلك هذه المياه ملوحة تتراوح بين 3610 إلى 9225 ملغم/لتر . تم اختيار خمسة وعشرون بئرا موزعة عشوائيا على المنطقة قيد البحث، واستخدمت أربعة أبار منها فقط لمحاكات عمليات الخلط فيما بين المياه الجوفية وأنواع مختلفة من المياه وهي: مياه الفيضان الناتجة من التساقط المطري والتي لوحظت خلال عام 2006 قرب الحدود العراقية الكويتية، وكذلك مياه شط العرب بالإضافة إلى مياه الإسالة. ولتقييم عمليات المزج، استخدمت حزمة برامج النمذجة الجيوكيميائية AQUACHEM AND PHREEQC . أظهرت نتائج النمذجة أهمية التغذية الصناعية في تحسن نوعية المياه الجوفية بشكل جيد بالإضافة إلى خفض مستويات تركيز النترات والسيطرة عليها بعد عمليات الخلط. توصي هذه الدراسة باستغلال مياه الفيضانات الناتجة من العواصف المطرية في حقن مكمن الدبدبة لتحسين نوعية وكمية المياه الموجودة فيه.