

Groundwater Quality Problems of a Gypsiferous and Urbanized Area Kifri City, Northeast of Iraq

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(Received 23/10/2005 , Accepted 16/3/2006)

ABSTRACT

The groundwater in Kifri City is being subjected to anthropogenic activities and enrichment of sulfate ions via high soluble rocks. The results showed that there are seasonal changes in ion concentrations due to dilution by rainfall, also the study concluded that the Fat'ha Formation has great impact on enriching the groundwater with sulfate ions, and the groundwater is polluted with nitrate and phosphate. The water type of the studied area is Ca-SO₄ when applied to Piper classification. From the areal map of ion distributions it is clear that the center and southern parts of the city contain high values of ions due to anthropogenic activity. The water samples are not suitable for drinking but are suitable for agricultural and some industries like textile, chemical pulp and paper industry.

مشاكل نوعية المياه الجوفية في المناطق الجبسية لمدينة كفري، شمال شرق العراق

الملخص

ان المياه الجوفية في مدينة كفري واقعة تحت تأثير الفعاليات البشرية و يتم اغنائها بأيون الكبريتات عن طريق الصخور العالية الذوبان في المنطقة. وظهرت النتائج بأن هناك تغاير موسمي لتركيز الأيونات نتيجة التخفيف بواسطة الأمطار، وهناك استنتاج اخر وهو ان تكوين الفتحة له تأثير كبير على اغناء المياه الجوفية بأيون الكبريتات، كذلك هناك تلوث للمياه بأيونات النترات والفوسفات. وعند استخدام تصنيف بايبر ظهر بان نوع المياه هو من نوع كالسيوم-كبريتات. اظهرت الخرائط الكونتورية بان مركز المدينة والجزء الجنوبي يحتوي على قيم عالية من الأيونات نتيجة الفعاليات البشرية. اثبتت الدراسة الحالية بأن نماذج المياه غير صالحة للشرب ولكنها صالحة للزراعة ولبعض الصناعات مثل الصناعات النسيجية وصناعة الورق.

INTRODUCTION

Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) has relatively high solubility in comparison to other minerals. The relationship between environment conditions and the solubility is simple, there is positive correlation between temperature, pressure and solubility of gypsum (Hem, 1989, Ford and William, 1989, Langmuir, 1997, Kacarogle et al., 2001). Because of these properties the surface and groundwater contacting gypsum becomes enriched in total dissolved salts with calcium and sulfate as the dominant ions (Kacarogle et al., 2001). The water samples in Kifri City exclusively depend on pumpage wells, therefore, in this city the groundwater is vulnerable to urbanization activities, which affect the quality of groundwater. The urban areas present three elements related to groundwater pollution (Massone et al., 1998):

- 1-They are traditionally been the location of industrial activities and other like (waste disposal area).
- 2-They are fit to agricultural activities, when the soil and climate conditions allow for them.
- 3-They are often both aquifer recharge and groundwater exploitation area. Kifri City is located at a distance of (184 km) to the southwest of Sulaimany City, Northeast of Iraq between the longitude ($44^\circ 56' 54''$, $44^\circ 58' 16''$) and latitude ($34^\circ 40' 45''$, $34^\circ 42' 07''$) (Fig.1). This study is aimed to evaluate the impact of human and geological setting on groundwater quality, for this purpose fifteen water samples were taken from the wells for two dry and wet seasons and analyzed.

GEOLOGICAL SETTING

The Geological setting of Kifri City is mainly based on the publications of (Bellen et al., 1959, Buday, 1980, Al-Rawi et al., 1992). Kifri City composed of different geological rock units which are shown in Fig. (2) and can be summarized as follows:

Fat'ha Formation:

This is the oldest formation and is exposed in the northeast part of the studied area, its age is middle Miocene. Lithologically characterized by the dominance of evaporitic (sulphatic and halogenous) facies. The rocks of the formation are anhydrite, gypsum and halite alternated with limestone, Marl and relatively fine grained clastics. This formation has general effect on groundwater quality of Kifri City.

Injana Formation:

The formation is composed of mostly red or gray colored silty marlstones or claystones and siltstones of the same color and medium to coarse grained polymictic sandstones. The presence of gypsum is reported at several places but never forms thick beds. The thickness of the formation is very variable partly due to the original differences and partly due to erosion. The age is upper Miocene. This formation is outcropping outside of studied area due to existence of a major fault in the region.

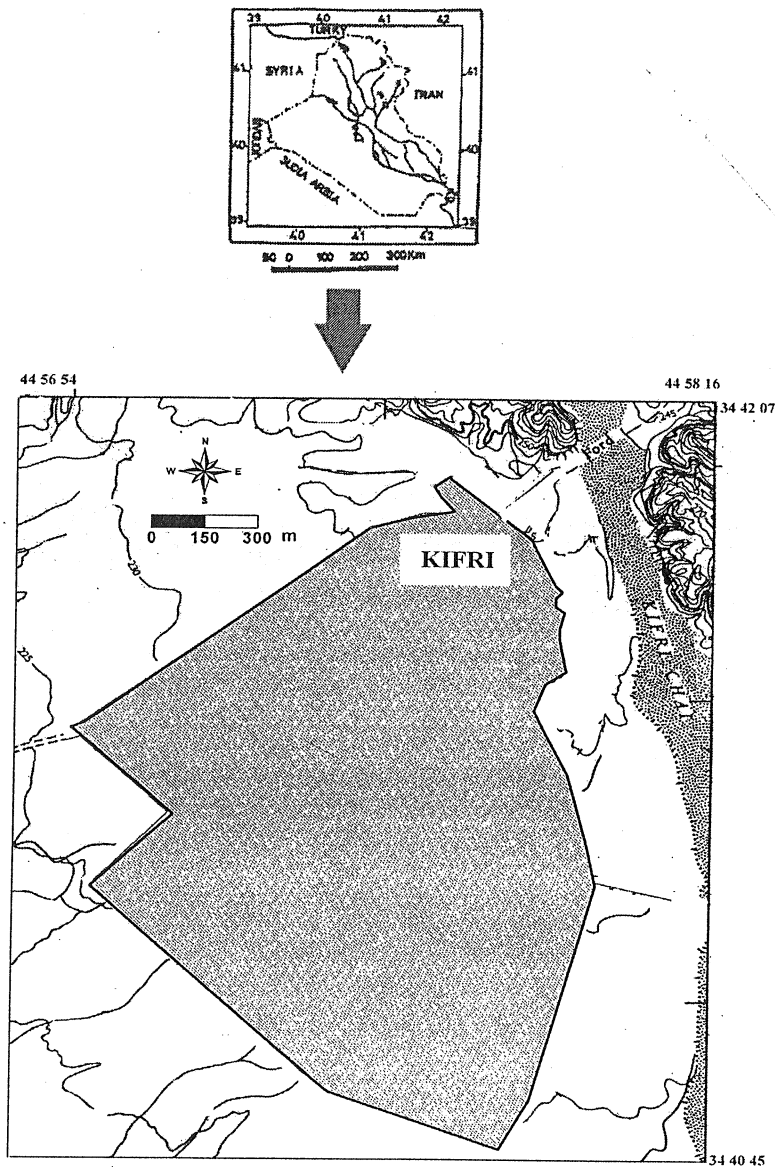


Fig.1: Location map of the studied area.

Miqdadyah Formation:

The formation is composed almost purely of terrigenous clastics from silt size to boulder conglomerates. In general, the grain size of the clastics increases upward, and its age is mostly Pliocene.

Bai Hassan Formation:

It is composed of claystone, conglomerate siltstone, it is characterized by the prevalence of conglomerate, its age is upper Eocene.

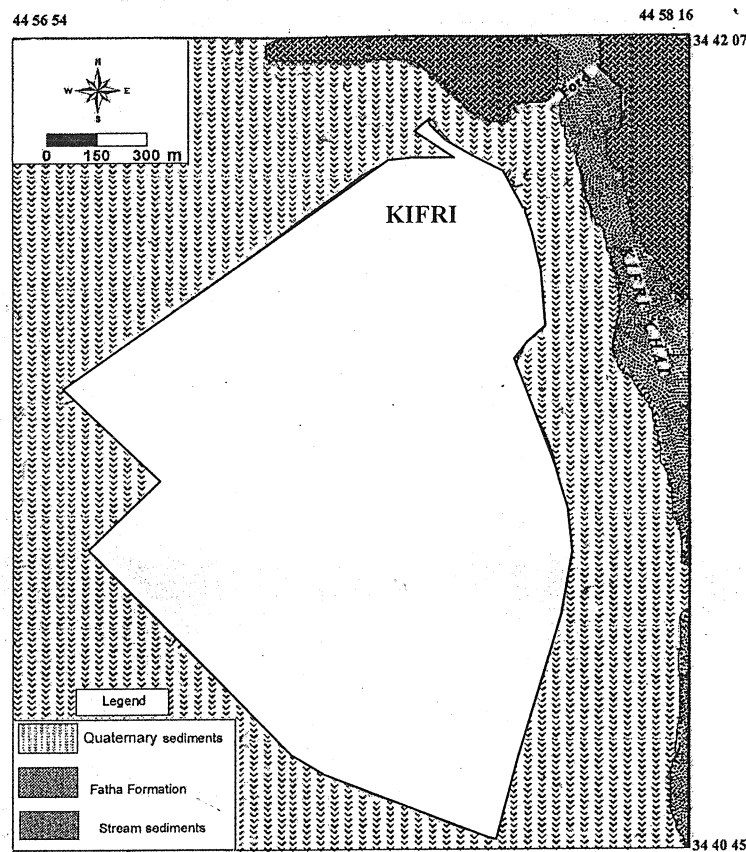


Fig.2: Geological map of the studied area.

Quaternary Sediments:

The age of these sediments is Pleistocene, it covers a wide area of the Kifri City and consists of clay, loam, silt, sand and conglomerate. It is poorly sorted and contains weathered products of Fat'ha Formation which contain gypsum particles, and considered to be a good aquifer quantitatively but not qualitatively. The thickness is variable in the area, it increase toward the south and west of the city, these sediments overly the Miqdadyah and Bai Hassan formations and prevent their exposures at the surface.

HYDROGEOLOGY

The main aquifers system in the area are the Miqdadyah and Bai Hasan unconfined aquifer which is considered to be a good aquifer, but most of Kifri City is underlain by Quaternary sediments (Fig.2) which contain the weathered product of Fat'ha Formation. This is the second main aquifer system in the area and also is unconfined aquifer. This lithology affects the ground water quality, and the recharge area located in the north east which consists of Fat'ha Formation contributes an excess source of sulfate to the groundwater due to high solubility of gypsum when it interacts with rainfall then the soluble product become runoff and infiltrate to the main aquifers. Most of the wells drilled through the Quaternary sediments (the range of depth is 65-140m), have a good productive water. Details on aquifer properties are not available.

Dissolution of the Gypsum, Halite and Calcite:

Evaporite rocks are mainly chemical sediments which have been precipitated from water following the concentration of the dissolved salts via evaporation. The principal evaporite minerals are gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), anhydrite (CaSO_4) and rock salt/halite (NaCl) (Tucker, 1991; Appelo and Postma, 1999).

Dissolution reactions and solubility of some minerals that dissolve congruently in water are presented in table (1). Evaporitic minerals such as gypsum and halite have high solubility in comparison to those of the other minerals. The solubility of gypsum is (10) to (30) times greater than that of the limestone (Drever, 1997). The saturation concentration of the gypsum in water at 25°C and pH 7 is about 2400 mg/L as $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ (Freeze and Cherry, 1979). The maximum in the solubility curve is at 40°C . At 58°C and 1 atm., gypsum starts to lose its water of crystallization and becomes anhydrite. Halite (rock salt) is extremely soluble in groundwater. The solubility is 35.5% by weight at 25°C and increases rapidly with temperature (White, 1997).

Table 1: Dissociation reactions and solubilities of some minerals that dissolve congruently in water, at 25°C and 1 bar pressure (after Freeze and Cherry, 1979; Ford and Williams, 1989).

Mineral	Dissolution reaction	Solubility at pH 7 (mg L^{-1})	Common range of abundance in meteoric waters (mg L^{-1})
Gibbsite	$\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O} + \text{H}_2\text{O} = 2\text{Al}^{3+} + 6\text{OH}^-$	0.001	trace
Quartz	$\text{SiO}_2 + 2\text{H}_2\text{O} = \text{Si}(\text{OH})_4$	12	1-12
Amorphous silica	$\text{SiO}_2 + 2\text{H}_2\text{O} = \text{Si}(\text{OH})_4$	120	1-65
Calcite	$\text{CaCO}_3 = \text{Ca}^{2+} + \text{CO}_3^{2-}$	100 ^a , 500 ^b	10-300
Dolomite	$\text{CaMg}(\text{CO}_3)_2 = \text{Ca}^{2+} + \text{Mg}^{2+} + 2\text{CO}_3^{2-}$	90 ^a , 480 ^b	10-300 ^c
Gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O} = \text{Ca}^{2+} + \text{SO}_4^{2-} + 2\text{H}_2\text{O}$	2400	0-1500
Halite	$\text{NaCl} = \text{Na}^+ + \text{Cl}^-$	360000	5-10000

^a $\text{PCO}_2 = 10^{-3}$ bar. ^b $\text{PCO}_2 = 10^{-1}$ bar. As CaCO_3

There are positive correlations between solubility of gypsum or halite in water and temperature and pressure. Solution rates and concentrations are controlled primarily by the amount of water contacting these minerals (Ford and Williams, 1989). The wetted film thickness on the mineral surface decreases with increasing groundwater flow rate, thus increasing the gypsum dissolution rate. Gypsum dissolution rate also increases with ionic strength (Langmuir, 1997).

Dissolution of calcite in water is primarily controlled by dissolved CO_2 , in water and temperature. When CO_2 pressure increases and temperature decreases, the solubility of calcite increases. CO_2 pressure of the groundwater is generally controlled

by the soil atmosphere in the recharge area. Dolomite dissolves more slowly than calcite due to the role of magnesium in modifying the surface reactions that are rate controlling near equilibrium. Approaching equilibrium with respect to these minerals takes from weeks to months (White, 1988; Drever, 1997; Langmuir, 1997).

The driving mechanism for calcite precipitation is loss of CO₂ Carbon dioxide may be lost to the atmosphere by purely physical means such as diffusion or agitation in riffles and waterfalls. Carbon dioxide may also be utilized by cyanobacteria and other organisms during photosynthesis and thus be lost to the water (White, 1997). A rapid temperature rise, mixing of waters, the addition of a common ion can also create supersaturation and cause calcite precipitation (Langmuir, 1997).

METHODOLOGY

In order to determine chemical characteristics and quality of the water in Kifri City water samples at (15) sampling points were collected from groundwater for two seasons, wet season (20/3/2003) and dry season (10/10/2003) (Fig.3). All water samples were stored in (500 ml) polyethylene bottles and stored in cool box until analysis in the (Sulaimany Health and Environmental Protection Office lab.). Temperature (Tc), pH, electrical conductivity, (Ec) were measured at sampling site, using portable (field type) instruments. Ec values were reported at 25°C. The procedures given by APHA et al. (1995) were followed during the field and lab work. Ca and Mg, were measured volumetrically by EDTA using E.B.T indicator. Na and K were determined by digital flame photometer type (Genway PFP7). Bicarbonate and carbonate were measured by acid titration using Methyl orange and phenolphthalein indicator. Chloride by AgNO₃.NO₃, PO₄ and SO₄, determined spectrophotometrically using type (HATCH) at (Sulaimany Health and Environmental Protection Office lab.).

RESULTS AND DISCUSSION

The results of chemical analysis of water samples for two seasons are shown in tables (2 and 3). It is clear that Ca²⁺ and SO₄²⁻ are the dominant ions, and the second species in abundance are Na⁺, Mg²⁺ for cations and Cl⁻, HCO₃⁻ for anions. The Ca²⁺ concentration range from (52-125 mg/l) for wet season and (55-140 mg/l) for dry season, while Mg²⁺ from (23-53 mg/l) for wet season and (25-66.8 mg/l) for dry season. The Na⁺ ion from (29-92 mg/l) and (35-95 mg/l), while K⁺ from (1.35-7.87 mg/l) and (1.69-8.27 mg/l) Cl⁻ from (20-93 mg/l) and (21-110 mg/l) HCO₃⁻ from (160-240 mg/l) and (150-210 mg/l) SO₄²⁻ from (245-423 mg/l) and (270-481 mg/l).

The concentrations of major ions decrease in the first season and change significantly due to excess rainfall in spring which normally dilutes dissolved elements. The source of SO₄²⁻ and Ca²⁺ ions is essentially from dissolution of gypsum of Fat'ha Formation, this is clear from the positive linear relation of these two ions (Fig.4), (R²=0.775) for wet season and (R²=0.886) for dry season, also the other source of SO₄²⁻ may be from anthropogenic activity in the city.

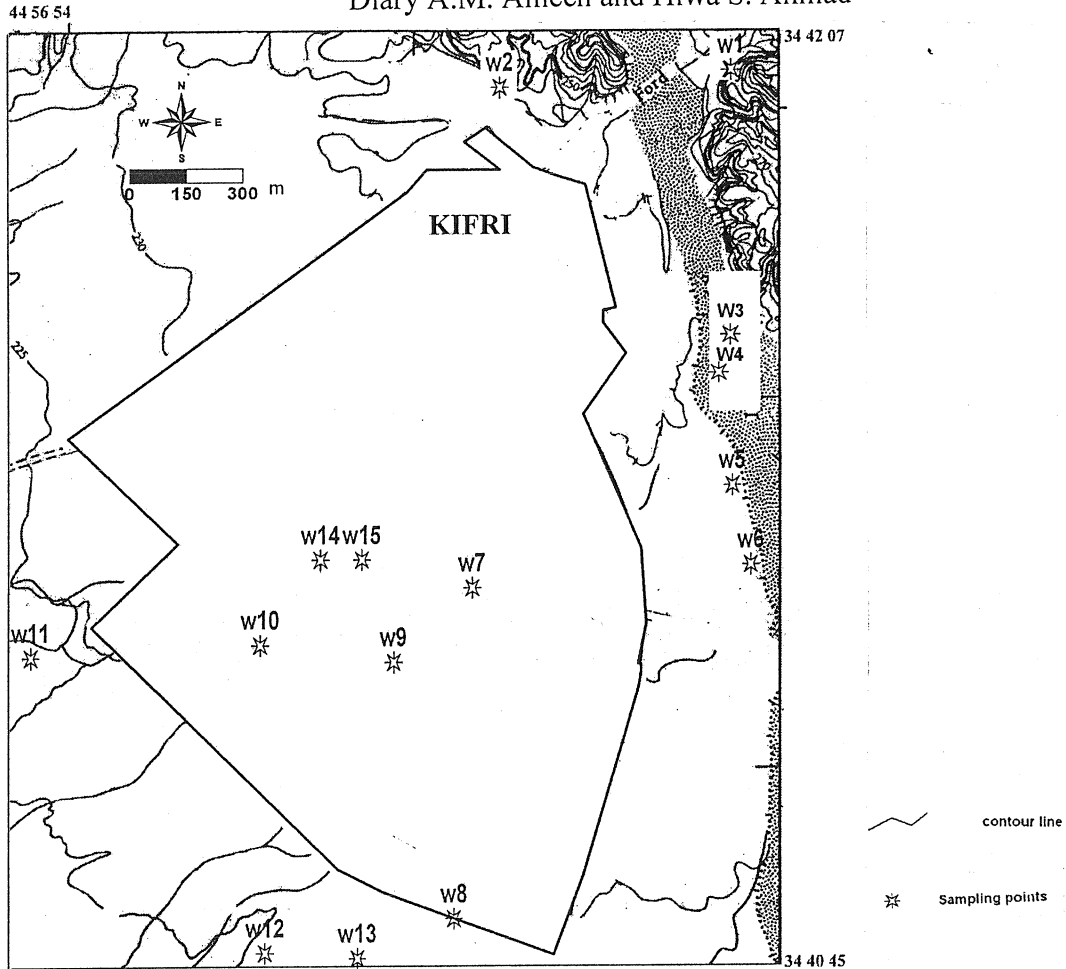


Fig.3: Location of sampling points.

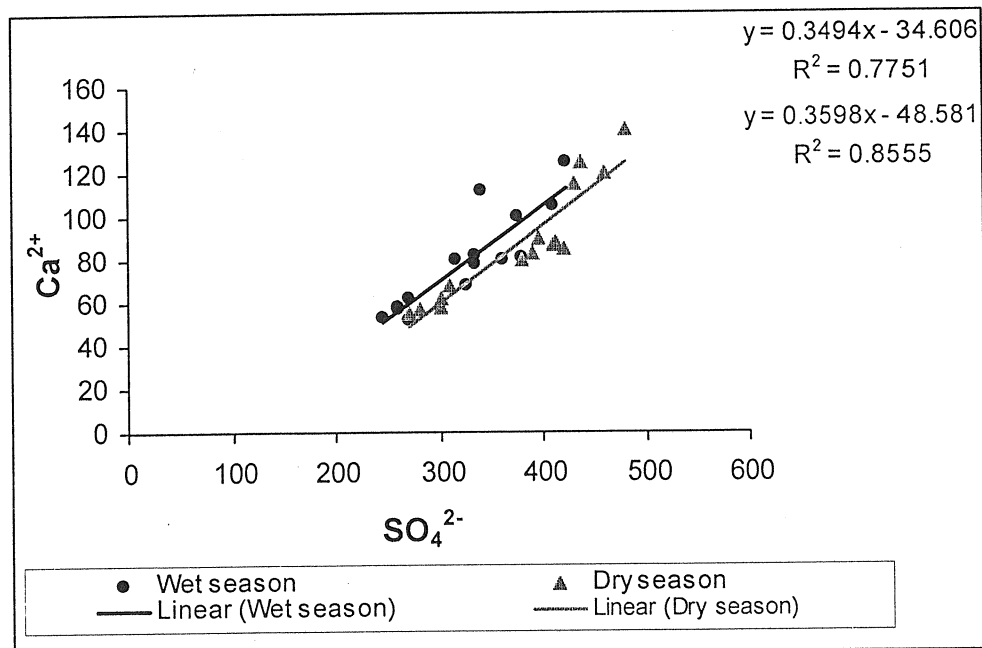


Fig.4: Relation between SO_4^{2-} and Ca^{2+} for two seasons.

Table (2) Major Ion Concentrations in Water Samples for Wet Season

No.	Tc	PH	Ec µ/cm	TDS mg/l	unit	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	SUM	SO ₄ ²⁻	Cl	HCO ₃	CO ₃ ²⁻	SUM
W1	19.2	7.61	1120	711.6	ppm epm %epm	78 3.90 44.39	38 3.17 36.04	38 1.65 18.81	2.6 0.07 0.76	156.6 8.79 100.00	335 6.98 64.15	25 0.70 6.47	195 3.20 29.38	0 0 0	555 10.88 100.00
W2	21.5	7.6	1040	667.7	ppm epm %epm	80 4.00 48.80	32 2.67 32.53	33 1.43 17.51	3.7 0.09 1.16	148.7 8.20 100.00	315 6.56 64.26	26 0.73 7.17	178 2.92 28.57	0 0 0	519 10.21 100.00
W3	20.5	7.66	910	571.2	ppm epm %epm	62 3.10 45.92	28 2.33 34.56	29 1.26 18.68	2.2 0.06 0.84	121.2 6.75 100.00	270 5.63 63.84	20 0.56 6.39	160 2.62 29.77	0 0 0	450 8.81 100.00
W4	20.6	7.24	1000	634.5	ppm epm %epm	58 2.90 48.80	26 2.17 27.58	63 2.74 34.86	2 0.05 0.65	149 7.86 100.00	260 5.42 56.83	35.5 1.00 10.49	190 3.11 32.68	0 0 0	485.5 9.53 100.00
W5	21	7.46	980	636.5	ppm epm %epm	57 2.85 38.60	23 1.92 25.96	59 2.57 34.74	2 0.05 0.69	141 7.38 100.00	260 5.42 55.87	35.5 1.00 10.31	200 3.28 33.82	0 0 0	495.5 9.70 100.00
W6	19.5	7.08	950	605.4	ppm epm %epm	53 2.65 36.44	25 2.08 28.84	57 2.48 34.07	2.4 0.06 0.85	137.4 7.27 100.00	245 5.10 55.79	33 0.93 10.16	190 3.11 34.05	0 0 0	488 9.15 100.00
W7	18.5	7.12	1285	833	ppm epm %epm	81 38.72 105	38 3.17 30.28	72.5 3.15 30.14	3.52 0.09 0.86	195.02 10.46 100.00	380 7.92 61.43	63 1.77 13.77	195 3.20 24.80	0 0 0	638 12.89 100.00
W8	20.8	7.11	1470	949.22	ppm epm %epm	105 40.10 125	52 33.10 51.5	78.5 26.07 90	3.72 0.10 4.1	239.22 13.09 270.6	410 8.54 423	85 2.39 16.56	215 3.52 24.37	0 0 0	14.46 100.00 738
W9	19	7.08	1560	1008.6	ppm epm %epm	62.5 42.93 100	4.29 29.48 46	3.91 26.88 83	0.11 0.72 5	14.56 100.00 234	8.81 58.47 375	2.62 17.38 78	3.84 24.15 185	0 0 0	15.07 100.00 638
W10	21	7.7	1355	872	ppm epm %epm	50.0 39.78 80	3.83 30.50 36	3.61 28.71 80	0.13 1.02 7.87	12.57 100.00 203.87	7.81 59.90 360	2.20 16.85 53	3.03 23.25 186	0 0 0	13.04 100.00 599
W11	21.2	7.25	1270	802.87	ppm epm %epm	40.0 37.45 68	3.00 28.09 34	3.48 32.57 71	0.20 1.89 5.2	10.68 100.00 178.2	7.50 62.28 325	1.49 12.40 28.4	3.05 25.32 285	0 0 0	12.04 100.00 588.4
W12	20.6	7.2	1190	766.6	ppm epm %epm	34.0 35.97 52	2.83 29.97 23	3.09 32.65 61.5	0.13 1.41 2.81	9.45 100.00 139.31	6.77 59.27 250	0.80 7.00 28	3.85 33.72 195	0 0 0	11.42 100.00 473
W13	21	6.5	970	632.31	ppm epm %epm	35.80 42.38 112	26.39 31.27 53	36.82 30.4 77.5	0.99 0.06 1.35	100.00 100.00 243.85	56.65 6.56 340	8.58 10.77 88	34.77 33.44 205	0 0 0	9.19 100.00 633
W14	21.4	7.17	1205	804	ppm epm %epm	82.5 42.38 112	30 25.69 53	70 31.27 77.5	2.5 0.66 1.35	185 100.00 243.85	315 6.56 340	45 10.77 88	240 33.44 205	0 0 0	600 11.76 100.00
W15	20.1	7.08	1385	876.85	ppm epm %epm	56.0 41.73 125	4.42 32.91 53	3.37 28.11 90	0.03 0.26 7.87	13.42 100.00 243	7.08 54.81 423	19.18 19.78 93	3.36 26.01 240	0 0 0	12.92 100.00 160
Max.	21.5	7.7	1560	1008.6		105	51.5	90	4.1	270.6	423	93	222	0	738
Min.	18.5	6.5	910	571.2		57	1.92	29	0.05	141	245	20	160	0	450
Average	20.35333	7.26	1179.3	758.2		79.6	35.7	64.2	3.4	326.8	49.09333	199.4			

Tc: Degree Centigrade
 Ec: Electrical Conductivity
 TDS: Total Dissolved Salts
 epm: Equivalent Per Million

Table (3) Major Ion Concentrations in Water Samples for Dry Season

No.	Tc	PH	Ec µc/cm	TDS mg/l	unit	Ca ⁺⁺	Mg ⁺	Na ⁺	K ⁺	SUM	SO4 ²⁻	Cl ⁻	HCO3 ⁻	CO3 ²⁻	SUM
W1	19.4	7	1220	799.2	ppm	87	45	45	3.8	180.8	410	28.4	180	0	618.4
					ppm	4.35	3.75	1.96	0.10	10.15	8.54	0.80	2.95	0	12.29
					%epm	42.84	36.93	19.27	0.96	100.00	69.49	6.51	24.01	0	100.00
W2	21.8	6.79	1160	751.5	ppm	83	48	35	3.4	169.4	390	28.1	164	0	582.1
					ppm	4.15	4.00	1.92	0.09	9.76	8.13	0.79	2.69	0	11.61
					%epm	42.53	40.99	15.59	0.89	100.00	70.01	6.82	23.17	0	100.00
W3	21	6.98	965	624.7	ppm	68	35	38	2.4	143.4	310	21.3	150	0	481.3
					ppm	3.65	2.92	1.65	0.06	8.03	6.46	0.60	2.46	0	9.52
					%epm	42.34	36.32	20.57	0.77	100.00	67.86	6.30	25.84	0	100.00
W4	21.2	6.72	1100	740.8	ppm	60.5	30	78	2.3	170.8	320	65	185	0	570
					ppm	3.03	2.50	3.39	0.06	8.98	6.67	1.83	3.03	0	11.53
					%epm	33.70	27.85	37.78	0.66	100.00	57.82	15.88	26.30	0	100.00
W5	21.1	7.38	992	648.69	ppm	55	25	65	1.89	146.69	270	42	190	0	502
					ppm	2.75	2.08	2.83	0.04	7.70	5.63	1.18	3.11	0	9.92
					%epm	35.70	27.05	36.69	0.56	100.00	56.69	11.92	31.39	0	100.00
W6	19.7	7.23	1025	671	ppm	53.8	30	66.66	2.6	153.06	290	48	180	0	518
					ppm	2.69	2.50	2.90	0.07	8.15	6.04	1.35	2.95	0	10.34
					%epm	32.99	30.66	35.54	0.82	100.00	58.40	13.07	28.53	0	100.00
W7	18.8	6.85	1350	876.2	ppm	85.1	45	76.7	3.4	210.2	420	71	175	0	666
					ppm	4.26	3.75	3.33	0.09	11.43	8.75	2.00	2.87	0	13.62
					%epm	37.24	32.82	29.18	0.76	100.00	64.25	14.89	21.07	0	100.00
W8	21.2	7.03	1590	1033	ppm	120	60.3	81.7	4.02	266.02	460	107	200	0	767
					ppm	6.00	5.03	3.55	0.10	14.68	9.58	3.01	3.28	0	15.88
					%epm	40.87	34.23	24.20	0.70	100.00	60.36	18.99	20.65	0	100.00
W9	19.2	6.9	1700	1102.43	ppm	140.3	66.8	94.9	4.43	306.43	481	110	205	0	796
					ppm	7.02	5.57	4.13	0.11	16.82	10.02	3.10	3.36	0	16.48
					%epm	41.70	33.09	24.53	0.88	100.00	60.81	18.80	20.39	0	100.00
W10	21.2	7.3	1510	974.44	ppm	115	57	87.8	5.24	265.04	430	99.4	180	0	709.4
					ppm	5.75	4.75	3.82	0.13	14.45	8.96	2.80	2.95	0	14.71
					%epm	39.79	32.87	26.41	0.93	100.00	60.90	19.04	20.06	0	100.00
W11	21.5	7.1	1410	897	ppm	88	52	86.8	8.27	235.07	412	70	180	0	662
					ppm	4.40	4.33	3.77	0.21	12.72	8.58	1.97	2.95	0	13.51
					%epm	34.59	34.07	29.67	1.67	100.00	63.55	14.60	21.85	0	100.00
W12	21	7.8	1305	841	ppm	80	42.3	76.7	4.02	205.02	380	56	200	0	636
					ppm	4.00	3.53	3.42	0.10	11.05	7.92	1.58	3.28	0	12.77
					%epm	36.20	31.90	30.97	0.93	100.00	61.98	12.35	25.67	0	100.00
W13	21.3	7.11	1050	678.61	ppm	58	31	66.6	3.01	160.61	305	43	170	0	518
					ppm	2.90	2.58	2.98	0.08	8.54	6.35	1.21	2.79	0	10.35
					%epm	33.95	30.24	34.91	0.90	100.00	61.38	11.70	26.92	0	100.00
W14	21.8	6.9	1342	846	ppm	90	33	76.7	3.11	202.81	395	66	201	0	662
					ppm	4.50	2.75	3.33	0.08	10.66	8.23	1.86	3.30	0	13.38
					%epm	42.20	25.79	31.27	0.75	100.00	61.49	13.89	24.62	0	100.00
W15	20.5	6.7	1600	1027.72	ppm	125	65	81.7	4.02	275.72	437	105	210	0	762
					ppm	6.25	5.42	3.55	0.10	15.32	9.10	2.96	3.44	0	15.50
					%epm	40.79	35.35	23.18	0.87	100.00	58.72	19.08	22.20	0	100.00
Max.	21.8	7.8	1700	1102.4	ppm	140.3	66.8	94.9	8.27	306.43	481	110	210	0	796
Min.	18.8	6.7	965	624.7	ppm	55	25	35	1.69	143.4	270	42	150	0	481.3
Average	20.7	7.05	1281.3	830.9	ppm	87.56	44.36	69.1	3.7	180.8	378.3	63.5	184.3	0	618.4

Tc: Degree Centigrade
 Ec: Electrical Conductivity
 TDS: Total Dissolved salts
 epm: Equivalent Per Million

The water analyses are presented in Trilinear (Piper) diagrams in Figure (5), the diagram displays the relations between rock type and water composition and evolution of the composition along its rout (Appelo and Postma, 1999). Using this diagram the water analysis can be classified into two types or hydrochemical facies. For wet season the samples (4,5,6,7,8,10,11,12,13,14,15) are within field No.(9) which means that (cations and anions ratio never exceeds %50) and the water type is (Ca- SO₄). The samples (1,2,3,9) are located in the field No.(6) which means that secondary salinity (non carbonate hardness is excess of %50) and the water type also (Ca- SO₄). For dry season the samples (4,5,6,11,12,13,14) are located in the field No.(9), and samples (1,2,3,7,8,10,15) are located in the field No.(6).

Minor ions:

The concentrations of PO₄³⁻ and NO₃⁻ are given in (Table 4) and the concentration of NO₃⁻ is high in samples (8,9,14,15) because it exceeds (WHO, 2004) and Iraqi standard of (1998) which is (50mg/l), and is high enough to cause pollution. The source of pollution is from infiltrated municipal wastewater into the groundwater since the sewage system of Kifri City is open and exposed to the surface. The agricultural activities, principally irrigation and fertilizer application also causes pollution. The consumption of water with high nitrate concentration causes decrease in oxygen bearing capacity of the blood, this particularly important in the health of young infants (Hudak, 2000, McKenzie, 2001, Esteller, 2005). PO₄³⁻ ions relatively high and the high concentration of PO₄³⁻ in groundwater in the urban area is usually associated with municipal wastewater. The Canadian standard concentration limit of 0.2mg/l has been defined as the acceptable limit for drinking water, therefore all water samples of this study are polluted with PO₄³⁻ ions.

Seasonal changes in groundwater quality:

Several features of the aquifer and some environmental conditions can cause seasonal changes in groundwater quality. These aspects include variations in the input concentration of pollutant; changes in meteorological and hydrological conditions, such as precipitation, evaporation, stream flow, and groundwater recharge; groundwater-level fluctuation; changes in the amount of groundwater abstracted from water wells; and agricultural activities, In the studied area, generally low ionic concentrations occur in wet season, and high concentrations in dry seasons. The greatest pollution, especially of NO₃, PO₄ was measured in dry season. Groundwater recharge is greater in wet months; hence, fresh-water input to the aquifer via precipitation is greater and this is clear from the value of pH which is greater in the wet period, and in these months fertilizer application to the agricultural land is absent. Consequently, the pollution input is low during this season. The degree of fluctuation in groundwater-quality parameters between wet and dry seasons varies among parameters. Water wells that exhibited high seasonal changes of water quality are in the urban area. Seasonal changes of quality parameters of wells outside the urban area were not as great.

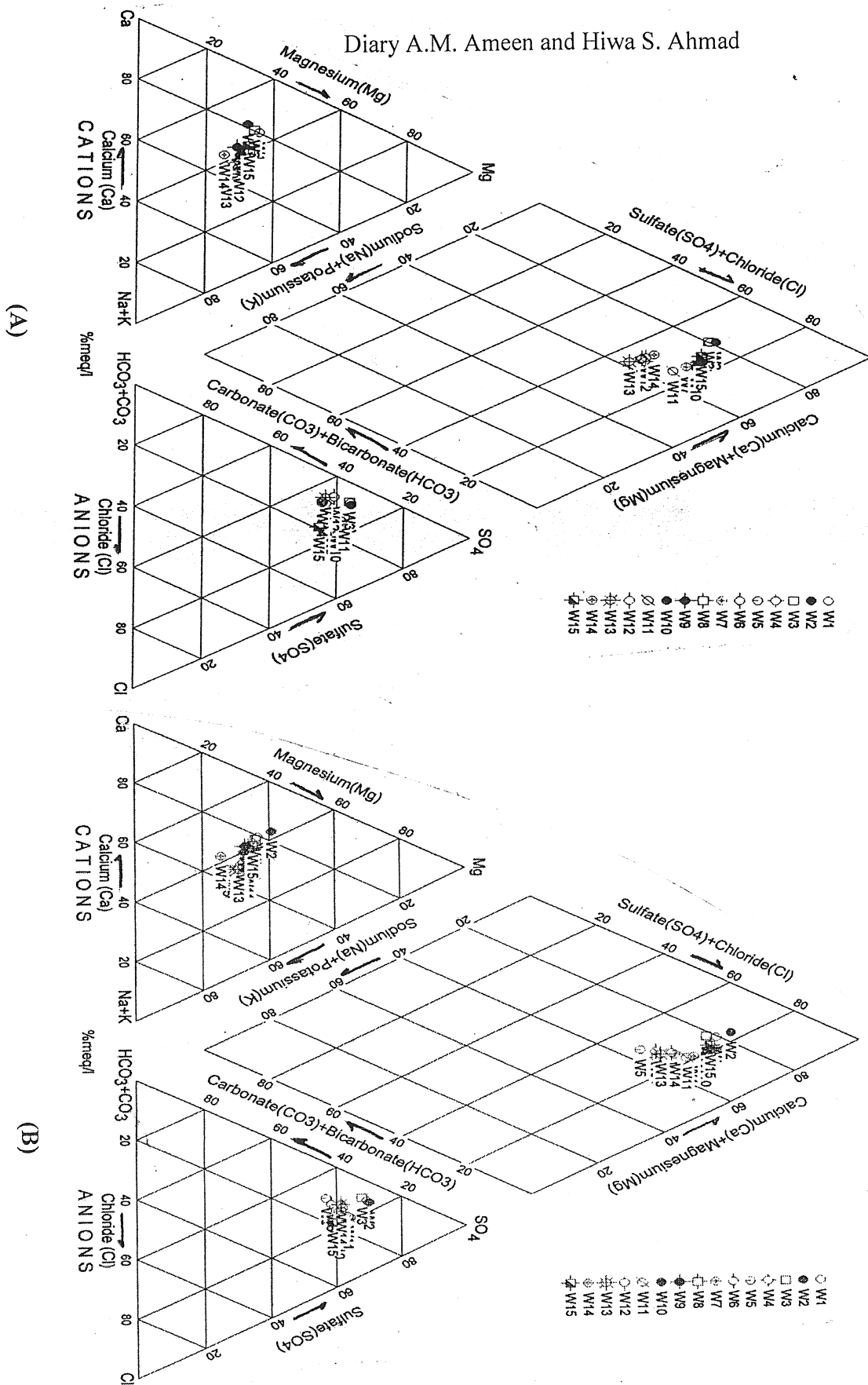


Fig.5: Piper Diagram for Water Samples:(A)Wet Season,(B)Dry Season.

Table 4: Minor Ion Concentrations, SAR, %Na and TH of Water Samples.

No.		PO ₄ ³⁻	NO ₃ ⁻	SAR	Na%	Total Hardness		PO ₄ ³⁻	NO ₃ ⁻	SAR	Na%	Total Hardness
W1	Wet season	0.33	4.4	0.88	19.56	351	Dry season	0.15	8.36	0.97	20.23	402
W2		0.34	8.4	0.79	18.66	331		0.14	11	0.75	16.49	405
W3		0.22	11.9	0.76	19.51	270		0.38	13.6	0.93	21.34	314
W4		0.33	13.6	1.72	35.51	252		0.25	15	1.82	35.65	278
W5		0.29	8.8	1.66	35.44	237		0.33	11	1.68	35.43	240
W6		0.38	12.3	1.61	34.92	235		0.17	17.2	1.62	33.70	266
W7		0.4	28.6	1.66	31.00	359		0.23	26.4	1.67	29.95	398
W8		0.384	44.4	1.56	26.80	476		0.87	49.4	1.51	24.90	548
W9		0.748	67.3	1.70	27.60	524		1.45	67.8	1.65	25.20	625
W10		0.517	40	1.72	29.73	439		0.73	41	1.67	27.34	522
W11		0.649	38	1.86	34.46	348		1.21	39	1.81	31.34	434
W12		0.3	18	1.75	34.06	310		0.82	18.9	1.76	31.90	374
W13		0.47	14	1.78	37.81	225		0.9	18	1.65	33.93	272
W14		0.756	50	1.67	31.93	330		1.95	51	1.75	32.02	361
W15		0.732	53	1.51	25.36	498		1.45	51	1.47	23.86	580

Areal distribution of water-quality parameters:

The greatest values of (Ec) and ion concentrations were observed in the central and southern parts of the city. Because water wells in the urban area are generally near sewage system, and effluents are likely to contribute nitrogen species, phosphate, chloride, and sulphate to groundwater, also the anthropogenic activities are higher in the center, therefore the concentrations of these species in groundwater samples from these wells were higher than in samples from wells in the east and west of city.

The areal distributions of the mean values of Ec, Ca²⁺SO₄²⁻, NO₃⁻ and PO₄³⁻, concentrations in groundwater are presented in Figures 6,7,8,9 and 10. These maps provide basis for making area-wide generalizations concerning the distributions of water-quality parameters, and they serve to isolate water quality problem areas and their related sources.

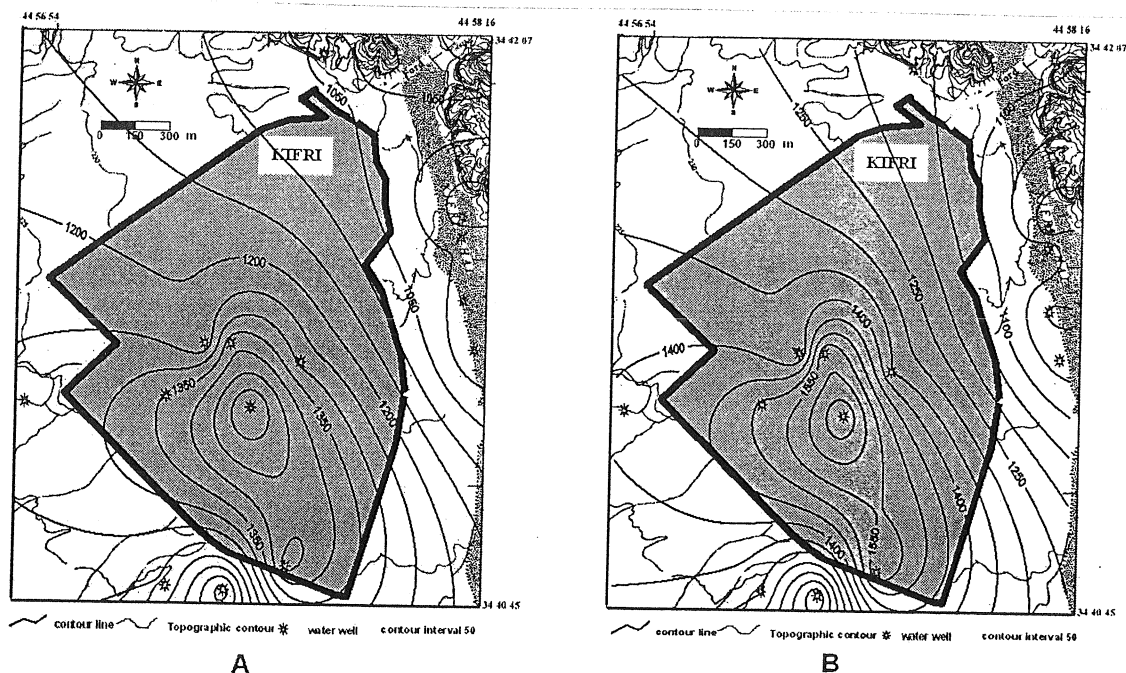


Fig.6: Areal Distribution of Electrical Conductivity: (A) Wet Season, (B) Dry Season.

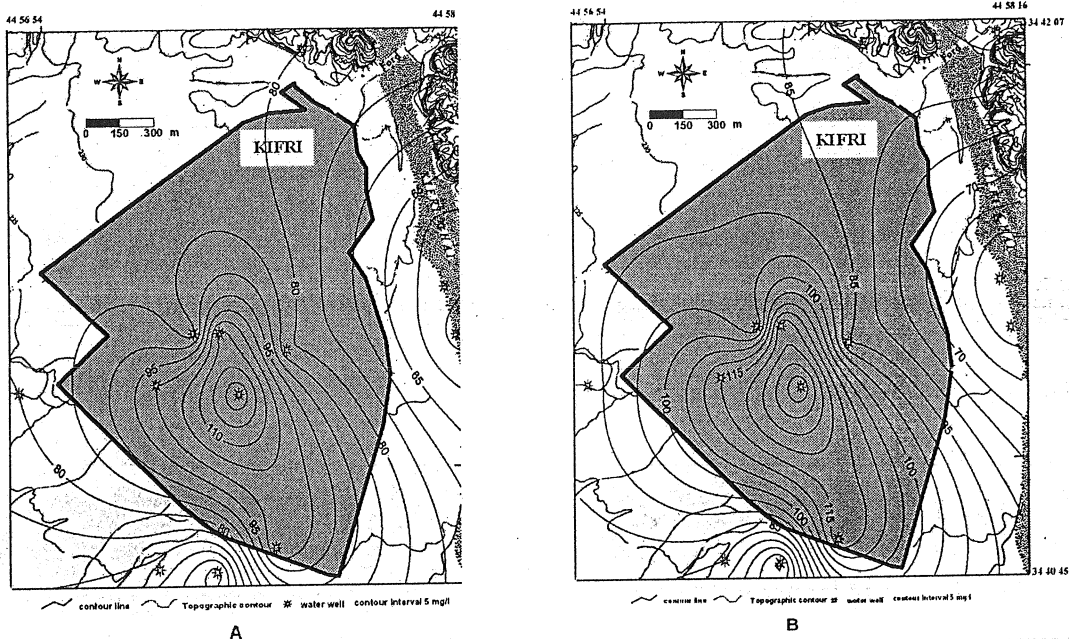


Fig.7: Areal Distribution of Calcium Ion: (A) Wet Season, (B) Dry Season.

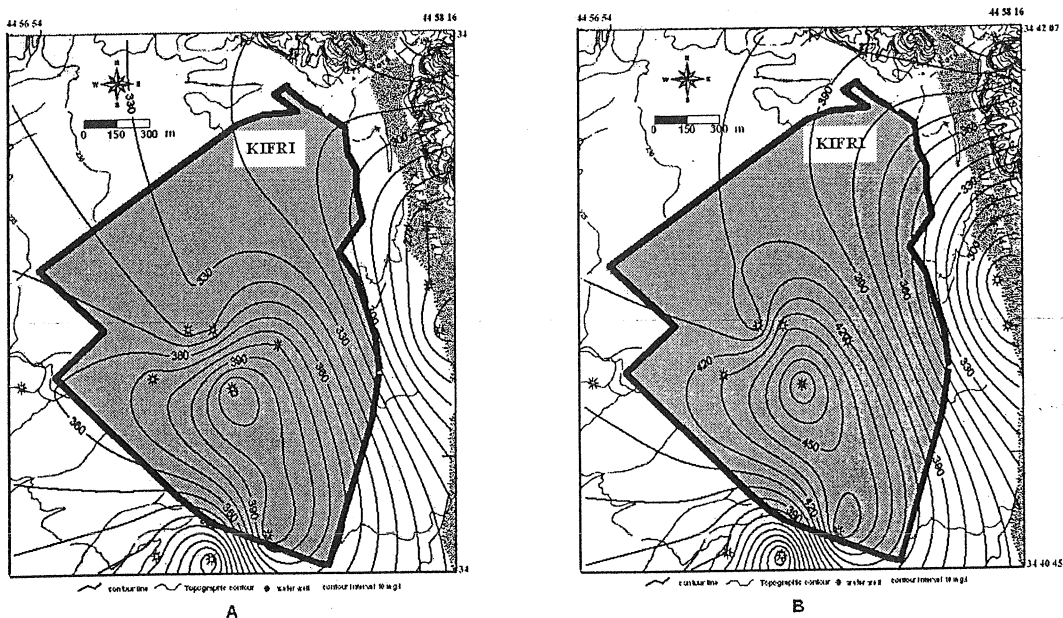


Fig.8: Areal Distribution of Sulfate Ion: (A) Wet Season, (B) Dry Season.

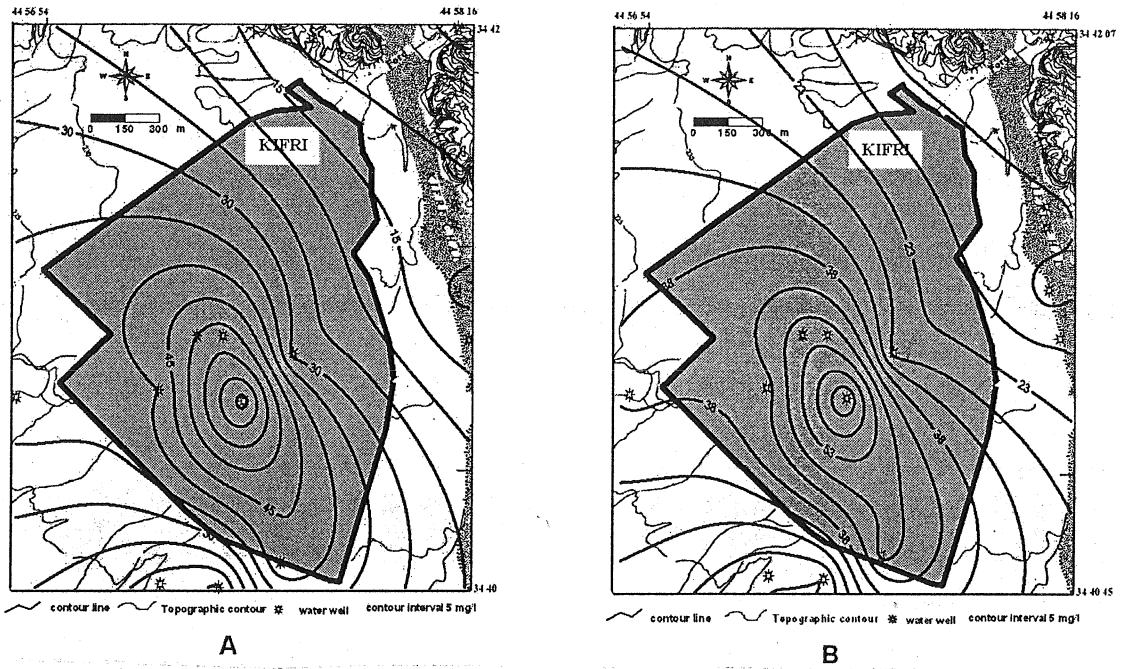


Fig.9: Areal distribution of Nitrate Ion: (A) Wet Season, (B) Dry Season.

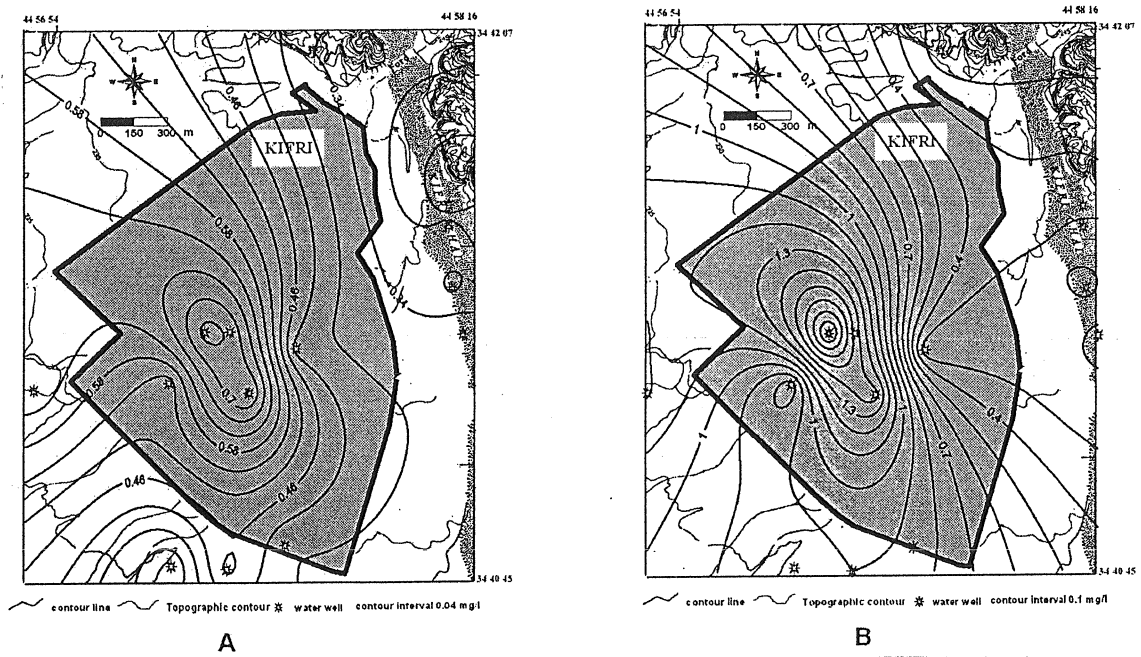


Fig.10: Areal Distribution of Phosphate Ion: (A) Wet Season, (B) Dry Season.

Evaluation in terms of the drinking, Irrigation and industrial water quality:

The water analyses were classified with regard to the hardness using Todd (1980) and Detay (1997) classification water samples are considered to be hard to very hard (Table 4).

In Iraqi Drinking Water Standards (IDWS) the recommended limit for hardness is 500 mg/l as CaCO₃, and for the sulfate ion the recommended limit is 250 mg/l. Regarding these limits, samples (8,9,10,15) for dry season and sample (9) for wet season are not suitable for drinking with respect to total hardness and all samples are not suitable for drinking with respect to sulfate. The recommended limit for calcium ion in IDWS is 50 mg /l, therefore all samples are not suitable.

From the point of irrigation water quality, the main concerns are the increase of the salinity of the soil and presence of elements toxic to plants. The drainage characteristics of the soil are equally as important as the water chemistry (Mather, 1997). Irrigation water classification of water samples using Don (1995) classification is presented in table (5). Using this method all water samples are permissible for irrigation.

The quality requirements of waters used in different industrial processes range widely, and almost every industrial application has its own standards (Hem, 1985). Salinity, hardness, and dissolved silica are three parameters that usually are important for industrial water (Todd, 1980). The standards represent maximum values permitted in the water at the point of use. Comparison of the water quality data with the standards (Hem, 1985) reveals that, SO₄ concentrations of water samples in Kifri City exceed maximum permitted values therefore they are not suitable for drinking but could be used for textile, chemical pulp and paper industry.

Table 5: Classification of Water Samples According to Don (1995).

Water Quality	pH	SAR	%Na	T.D.S	Ec μmohs/cm
Excellent	6.5	3	20	175	250
Good	6.5-6.8	3-5	20-40	175-525	250-750
Permissible	6.8-7	5-10	40-60	525-1400	750-2000
Doubtful	7-8	10-15	60-80	1400-2100	2000-3000
Unsuitable	>8	>15	>80	>2100	>3000
Water samples (Range)	First season	0.76-1.86	18.66-37.81	571-1008	910-1560
	Second season	0.75-1.82	16.49-35.43	624-1102	965-1700

CONCLUSIONS

The main conclusions of this study are:

- 1- There is a seasonal variation of groundwater quality due to excess rainfall in the wet period.
- 2- Fat'ha formation has a great effect on enriching groundwater with sulfate ion.
- 3- Some wells are polluted with nitrate and phosphate due to impact of urbanization.
- 4- The hydrochemical study showed that the water type is Ca-SO₄ type.
- 5- The areal distribution of ions showed that the center and the south of the city have a high value of ions.
- 6- The water samples are not suitable for drinking because they exceed permissible limit but could be used for agricultural use (Don, 1995) classification and also suitable for textile, chemical pulp and paper industry.

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