Water quality analysis of the Hemmer and Nau'r aquifer springs in the Snf area, North Jordan

*Kuzey Ürdün Suf sahasında bulunan Hummer ve **Nau'r** akiferleri kaynaklarının su kalitesi analizleri*

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ABSTRACT

In recent, years,, the Suf area, has 'become highly populated, increasing- the demands on water resources for various uses.. This, study aims, to evaluate the water quality of major' springs In the. Suf area.. In this respect. 11 main springs emerging from two different aquifers (Hummer aquifer' A4,, and Nau'r limestone aquifer Al\2) were chemically analyzed... Chemical analyses performed include -TDS,, Ca^{3+}, Mg^{2+}, Na^{+} K^{+}, CT, HCO_3 ; $SO_4^{2"'}$ .and NO_3 as, well as pH, EC and. temperature. Results, show that these springs, have different chemical compositions, which, reflect., to a. large extent, the geological character of the two aquifers. In. addition.,, historical data on. spring chemistry were also used to show the variations and. long term trends in water quality., Generally,» the waters of major springs in the area, are of $HC0'_3$ and. Ca^{2+} type... Chloride ,and sodium ions make the main contribution to- the salinity of spring waters,, while $\$Q^2{}_4$ and $Mg^{2l"'}$ concentrations are moderate. Over all, chemical content of groundwater from various, springs is dominated by NO_3, HCO'_3, Cl",, Na^{+}, and, Ca^{2+}.. Suf, Fawwer,, Um-Faraj, Al-garaj and Nabhan springs show, to some extent, degradation in. the water quality.,

Key Words:: Hummer[1] and Nau'r' aquifers,, Groundwater quality, Jordan, Suf region

ÖZ

*Son yakınla Suf bölgesinin **nüfusu** ile birlikte çeşitli **amaçlarla** kullanılacak suya olan ihtiyacı da artmıştır. Bu çalışma **Suf** sahasında bulunan ana su **kaynaklarının su** kalitesini değerlendirmeyi amaçlar. Bunun için iki ayrı akiferden (Hummer **akiferi** A4 ve **Nau'r** kireçtaşı **akiferi Al/2)** kaynaklanan 11 kaynak suyunun kimyasal analizleri yapılmıştır. Bu analizler,, toplanı çözünmüş madde (TDS) Ca^2\ Mg^2\ **Na**\ C, Ct, HCO'_3$, $SO^2{}'_4$ ve $Nö_3$ ye ilave olarak pH, elektriksel iletkenlik **(EC)** ve **sıcaklıkları** içermektedir.. Sonuçlar bu kaynakların farklı kimyasal içeriklerde ve büyük ölçeklerde bu iki **akiferin** farklı jeolojik karakterde olduğunu göstermiştir., Bunlara ilaveten tarihsel verilerde, uzun bir zaman **içerisinde su kimyalarında** değişiklikler göstermiştir.. Kaynakların çoğu bikarbonat ve kalsiyum **karakterindedir.** Suyun içindeki tuzluluğu **oluşturajı** başlıca iyonlar klor ve sodyum iyonlarıdır, sülfat ve magnezyum oranları orta değerlerdedir., Bütün bu kaynaklardan alınan suların kimyasal analizlerini NO$ **HCO**\ Ct, Na* ve **Cd*** belirlemektedir. **Suf Fawfer,** Um-Faraj, **Al-garaj ve Naphan** kaynakları bir dereceye kadar su kalitelerinde bozulma- **göstermektedir.***

***Anahtar** Kelimeler: Hummer ve **Nau'r akiferleri,** Suf bölgesi, Ürdün, **Yeraltısuyu** kalitesi*

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INTRODUCTION

Water is a natural resource-,, and Jordan **seems** to be among **the** least blessed, areas of the world, with .respect to **its** availability, **Groundwater** has a **geochemical** variability caused by natural processes including groundwater flow, formation through which **the flow** occurs,, chemical chaffges resulting from annual flow fluctuations,» source **recharge** and mixing- with other water types,

Due- to the increasing needs, of local urban and rural areas within the- area, the water is over[1] used. Water of many springs, is used to meet daily needs, of people. This is furtherly strains the water resources and., as **a** result, **some** of the. springs are polluted.,

The study area is located in the central **part** of Jordan and extends between 188-194 North longitude, and 226-234 East latitude (Palestine grid) (Figure 1). **The** area **lies** almost, on. **the** highlands. **Quennell** (1958) has discussed the geology of the region including Jerish and Ajlun areas.

Prevailing geologic **formations** in **the** area, are mainly Naif r **formation of 180 m** thick and. **Hummar** formation of 40-50 **m** thick (Figure 2), They **mainly comprise** a. **sequence** consisting of gray limestone and **dolomitic** limestone **with** intercalation of marl and shale **of lower Cenomanian** age **Olexon,** (1967), and. limestone and dolomitic limestone of upper **Cenomanian** age, Dominant structures, in the study area and **its** vicinity area a major E-W fault system and **NNK-NE** and NW striking faults. Strike slip faults have directions of E-W and. N-S and. consider-

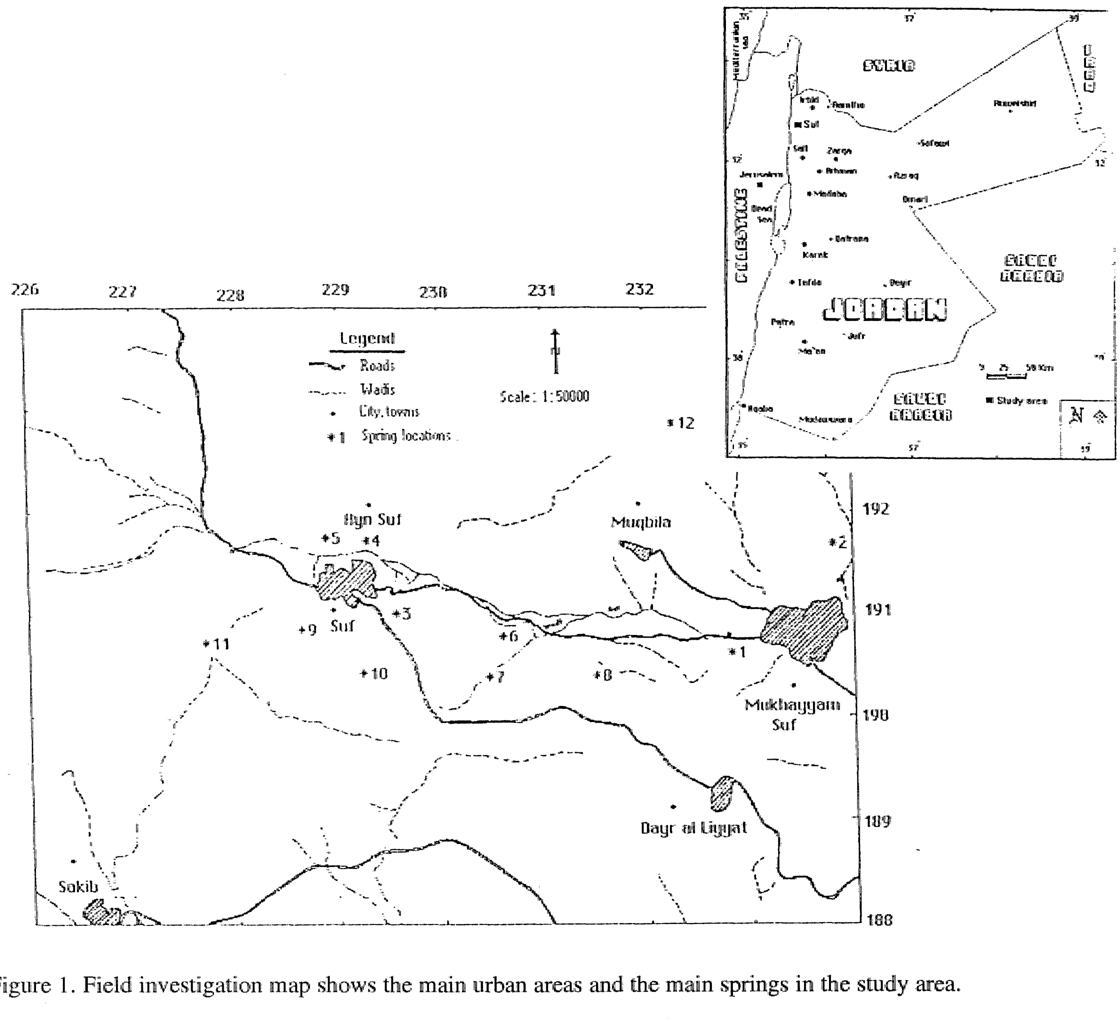


Figure 1. Field investigation map shows the main urban areas and the main springs in the study area.

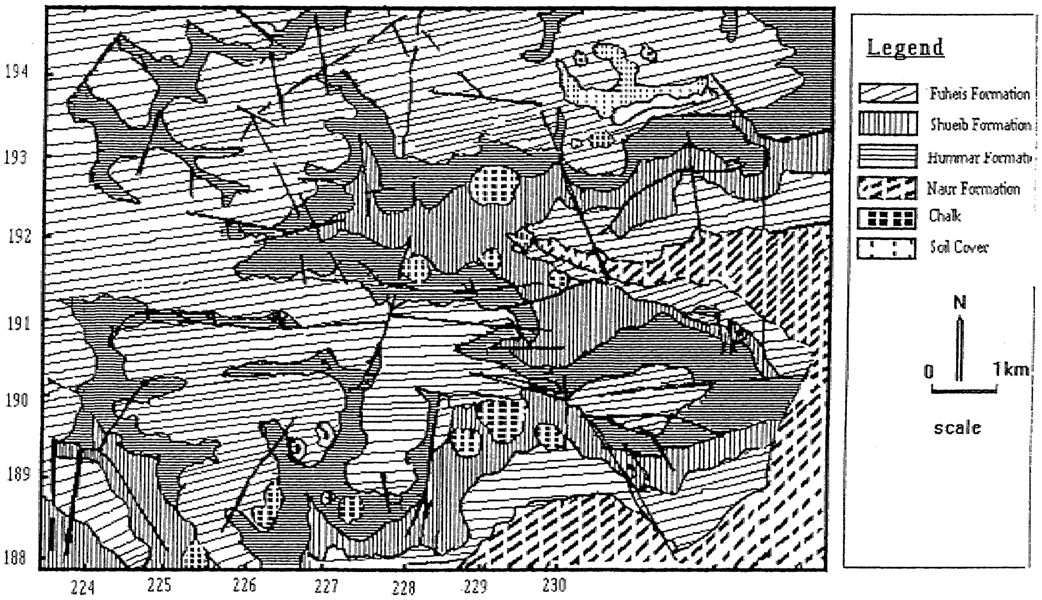


Figure 2.. Geologic map of the study area.,

able down, throw ,are observed along some, other' faults. Majority of the folds are gentle,, subparallel and have trends varying- from. E-NE and. NE to WNW. A number of monoclines, flexures is. associated with major faults, Bender, (1974).

The- climatologie al parameters of the- study area are shown in Table 1,, the area Is chara.cteri.zed by semi-arid climate, the- mean, annual rainfall is 413 mm, while the maximum average temperature is 16.5C\ The springs Investigated within the study area fall within two aquifers, these are the Hummer' aquifer A4, and the Nau'r limestone aquifer Al\2,

Table 1. Selected climatological parameters for the study area

1	Max. Temperature (°C)	39 (August)
2	Max. Average annual Temperature (°C)	16.5
3	Min. Temperature (°C)	-5 (January)
4	Min. Average Temperature(°C)	1.3
5	Max. annual rainfall (mm)	79.5(January)
6	Mean annual rainfall (mm)	413
7	Max. daily rainfall mm	96.4
8	Average annual relative humidity(%)	60
9	Average annual evaporation (mm)	2123.0
10	Wind direction	NW.

(Table 2). The present study aims to evaluate the water quality of these two aquifers, on the basis of their hydiochemical properties and their' relationship to potential deterioration, of the- water' quality in the study area... The water type and quality also classified in the present study.. In addition, historical data are also used to show the variations and long term trends in water quality.

Table 2., Major springs investigated in. the present, study Aquifer types based oo the Water Authority of Jordan technical report. (1989)

Spring name	E Longitudes	N Latitudes	Aquifer type	Flow rate (m^3\h)
1 Bassas Aldub El gurbi	232.7	190.8	A1/2	25.107
2 Bassas El- Room	234.1	191.6	A1/2	30.750
3 Bassas Um-Faraj	229.4	191.4	A4	0.306
4 Ain El-Maghasil	229.3	191.7	A1/2	38.000
5 Ain Suf (ElBalad)	229.	191.6	A4	3.764
6 Ain Fawwar	230.9	190.9	A4	55.087
7 Ain Nabhan	230.6	190.4	A4	1.919
8 Ain El -Karaj	231.5	190.4	A1/2	2.371
9 Ain El kelab	228.7	191.3	A4	0.397
10 Basset Lauzeh	229.2	190.4	A4	0.335
11 Basset Abeid	227.8	191.7	A4	0.172

The: relatively high rainfall, high relief, intensive faulting and solution cavities have lead to the appearance of the major' springs, in the region., According to McDonald (1965), springs in the study area and adja-. cent areas can be classified into four types; these are fault springs., contact springs* fracture springs, and karst springs. ->

The main objectives of 'the present, investigation are as follows:

- To investigate the water quality of the. major springs within Suf area,

- To measure the physical parameters such, as pH, EC, and TDS..

- Water chemistry evaluation for the springs through, the analysis of major and minor ions which includes Ca^{+}\ Mg^{+}\ Na^{+}, K^{+}, CÎ, HCQ"$_3$, SQ_3"^{2}, and NO_3.

- The. classification of the water[1] quality, and to study the correlation coefficient for the various chemicals in water-collected from, the springs in the area.

METHODS

Water of eleven springs issuing from Na.u"'r A1/2 and Hummer A4 aquifers were collected on 11 July 1997 and then analyzed for their chemical compositions... The chemical analysis of the collected spring water samples was conducted out at the laboratories of the Department of Earth, .and Environmental Sciences of the Yarmouk University.. In addition, historical data on waters were-used to determine long term trends in water quality..

At each sampling site, water temperature, pH value, and electrical conductivity (EC) were measured using a field the.rmom.eter, a pH-meter and. .an EC-meter. A 500 ml polyethylene bottle was used to store water for chemical analysis (TDS,,, Ca^{2}\ Mg^{2+}, Na\ K\, Cl", HCO3" SO_4^{2}" and NÖ$_3$), Titration method, was used to determine CI" and HCO^ concentration. Spectrophotometer system (SPETRÖMIC 200) was used to estimate NH^{+}_4, SO/" and NO_3 concentration in the samples.. Aflame photometer was used to determine Ca^{2+}, Mg*, Na\ and K.

RESULTS AND DISCUSSION

The present investigation deals with springs, associated with Nau'r (Al/2), and Hummer aquifers (A4), Table 2. Chemical data of the analyzed water samples are presented in Table 3 and Figure- 3, they also includes historical data on variations and long terms •trends in water[1] quality of these springs. Deterioration water quality in. four of the springs can be attributed to either intensive use. of water for domestic and drinking purposes (2.2 MCM/year) or to agriculture (40 MCM/year) and small-scale industries in (4 MCM/year) in the study area, Salameh (1996).

Chemical Characteristics.

A number of inferences, can be drawn from the experimental and historical data obtained, Table 3 and Figure 3. The TDS values, ranges between. 237-1344 ppm. PH values ranges between •6:9-8.2. In all the springs the- data shows variation in the results for the major cations and anions. 'The major cations, Ca^{2+}, Na\ Mg^{2+}, K^{+}, shows range values, between 22-182.5 mg/L, 5.5-115..0 mg/L, 2.7-24.1 mg/L and 0.0-46 mg/L respectively,. The major[1] cations HCO"$_3$, SO^{2}"$_4$, MG^{7}~3, and CÎ show concentration ranges, between 146.4-3562 *mg/L*, 0-56.5 mg/L, 1.8-167 mg/L and 16-500 mg/L respectively. Use of a Piper diagram (Figure4), (Piper 1944) permits the classification of the waters according to Langguth (1966)., This classification, is based on the concentration of the four major[1] anions,,, HCO"$_3$, SO^{2}"$_4$, CÎ and. NO^{2}'$_3$,, and. on the four major cations,. Mg^{24}, Ca^{2}*, Na\ and K^{4}. Based upon this the water' in the study area can be classified as alkaline earth waters of either bicarbonate and. chloride character. This, type of water[1] increases the alkalinity with prevailing bicarbonate and chloride for A3' aquifer, and bicarbonate for A1/2 aquifer.

Carbonate- and bicarbonate anions are considered

Table 3. Chemical data. from, the springs in the study area.(VFor locations and parameters shows increase in concentration)

No	Springs name	Date	EC µs/cm	TDS ppm.	PH	Ca^{2+} mg/L	Mg^{2+} mg/L	Na^{+} mg/L	K^{+} mg/L	Cl^{-} mg/L	HCO^{-}_3▼ mg/L	SO^{2-}_4 mg/L	NO^{2-}_3 mg/L
						Concentration mg/L							
1	Aldub Elgurbi	8/79	651	417.0	7.4	71.7	19.6	29.8	5.9	56	247.7▼	8.6	46.5▼
		7/80	656	420.0	7.5	85.7	19.2	34.4	5.8	48	292.2	22.0	64.1
		3/81	760	486.0	7.3	87.9	16.5	37.7	4.6	51	306.2	18.7	58.4
		5/82	720	460.0	7.0	93.9	16.5	25.2	5.3	54	295.9	21.1	32.3
		1/85	700	408.0	7.4	86.5	20.9	27.5	7.8	53	287.3	21.6	35.4
		4/86	630	416.0	7.8	72.1	21.3	25.2	0.0	37	250.7	9.6	35.7
		9/89	720	461.0	7.3	86.5	22.8	25.2	5.8	49	278.9	30.2	36.5
		6/92	750	452.0	7.6	86.9	23.0	22.9	4.6	66	244.6	28.3	46.9
		8/97	620	353.2	8.1	76.0	7.11	20.0	3.6	70	280.0	39.2	34.0
2	El-Room	7/80	531	340.0	8.0	72.9	21.6	22.9	5.8	37	276.9▼	11.5	27.9▼
		4/81	600	384.0	7.4	64.9	22.6	20.6	0.7	35	266	0.0	29.2
		12/83	680	435.0	7.7	60.1	23.8	34.4	0.0	67	235.5	1.9	34.5
		3/84	570	364.0	7.6	73.9	22.0	16.0	0.0	26	262.3	47.0	17.6
		7/87	580	371.0	7.6	70.1	19.4	18.0	0.0	33	282.4	2.8	16.7
		6/88	570	365.0	7.4	40.4	17.9	16.1	1.9	36	285.5	19.2	16.0
		9/89	590	378.0	7.9	74.7	23.0	17.2	1.9	34	299.5	2.8	17.4
		8/97	712	455.6	8.1	22.0	6.76	19.6	1.5	80	330.0	37.3	19.4
3	Um Faraj	8/79	1034	662.0	7.2	144.2	11.4	54.0	1.5	122	298.9▼	16.3	119.5▼
		4/81	1110	710.0	7.7	158.3	20.6	44.8	1.5	104	314.8	40.3	132.8
		5/82	990	633.0	6.9	148.2	11.6	40.2	0.0	97	309.3	23.0	110.0
		8/89	1110	710.0	7.5	156.1	12.3	50.5	2.7	110	322.7	41.3	102.0
		5/91	1170	650.0	7.4	151.9	13.3	59.5	8.2	128	293.4	31.7	154.0
		9/.92	1150	644.0	7.6	141.6	19.4	63.2	5.8	117	283.7	81.6	135.0
		8/97	440	281.6	7.4	23.0	16.4	42.0	1.5	90	202.0	23.4	-
4	El-Maghasil	2/82	535	342.0	7.2	86.1	8.1	18.1	4.3	16	289.2▼	16.8	14▼
		12/83	560	358.0	7.4	75.1	14.2	11.4	0.0	21	281.8	0.0	11.9
		4/84	550	352.0	7.4	86.3	9.1	11.4	0.0	17	268.4	11.5	13.3
		12/85	540	345.0	7.5	84.7	13.7	11.4	0.0	21	296.5	0.0	13.9
		1/86	580	371.0	7.7	91.9	14.1	11.4	0.0	24	297.7	5.2	17.6
		4/87	570	339.0	7.4	84.1	10.3	11.4	0.0	21	237.9	25.9	20.8
		11/89	560	358.0	7.7	88.9	14.2	11.4	0.0	21	310.5	12.4	13.2
		3/91	580	320.0	7.5	86.1	10.9	20.6	0.7	18	300.0	3.3	17.74
		8/97	583	373.1	7.4	80.0	7.56	19.0	1.5	75	264.0	25.8	4.6
5	Suf ▼	7/80	847▼	542	7.4	130.4▼	13.7	43.6	1.9	88▼	270.2▼	21.1	132.3▼
		1/85	1200	767	7.2	170.7	13.8	50.5	0.0	129	317.2	96.5	63.1
		4/86	750	608	7.5	121.4	19.9	43.5	1.1	109	239.1	38.4	121.0
		8/97	2100	1344	7.3	123.0	18.52	115.0	11	500	192.0	25.8	31.4
6	Fawwar▼	2/82	640	409.0	7.2	90.3▼	12.5	24.5	41	32	290.4▼	19.2	37.5▼
		12/83	620	396.0	7.4	79.9	12.7	20.6	35	34	266.0	12.0	30.9
		10/84	660	358.0	7.3	77.7	15.3	16.0	27	26	248.9	18.7	34.6
		1/86	740	422.0	7.1	92.9	17.1	27.5	40	37	317.2	16.8	43.6
		4/87	570	474.0	7.4	105.4	13.8	27.5	46	47	356.2	12.9	58.7
		2/88	560	365.0	7.6	182.5	11.0	27.5	27	17	264.7	28.8	22.8
		3/91	660	450..0	7.4	89.7	11.5	16.0	28	28	257.4	19.2	26.7
		8 /97	635	406.4	7.6	85.0	12.6	14.0	25	78	300.0	31.8	22.7

Table 3. (contid)

7	Nabhan	8/79	635	406	7.6	84.9	11.1	24.1	0.3	57	179.3▼	25.9	63.7▼
		7./80	561	359	7.6	87.9	10.0	20.6	1.1	49	186.0	4.8	105.0
		5./82	650	416	7.4	93.9	9.4	22.9	0.0	53	207.7	20.1	74.9
		1/85	680	435	8.0	91.7	13.1	27.5	0.0	64	169.6	9.1	131.0
		4/86	740	474	8.2	107.0	15.3	25.2	1.9	62	206.2	40.8	107.0
		9/89	890	570	7.8	113.6	12.7	41.3	1.9	81	219.6	45.1	113.0
		6/92	840	566	7.4	112.6	13.3	34.9	1.5	74	231.8	36.0	110.0
		8/97	450	288	8.0	97.0	7.92	28.0	0.7	90	186.0	15.5	112.0
8	El-karaj	8/79	439	281.0	7.8	63.8	7.5	14.9	0.3	26	205.7▼	0.0	17.7▼
		7/80	491	314.0	7.4	87.5	7.0	25.2	1.5	25	259.9	16.8	51.4
		5/82	550	352.0	7.3	94.1	5.1	11.4	0.0	25	273.9	1.9	9.4
		10/83	600	320.0	7.4	56.5	18.8	16.0	0.0	26	247.9	0.0	23.9
		1/85	510	326.0	7.9	85.5	7.6	13.7	0.0	25	234.8	19.0	22.7
		4/88	460	274.0	7.8	74.1	6.5	8.3	4.6	41	170.3	25.9	26.2
		9/89	600	384.0	7.5	96.7	7.1	13.7	1.5	33	261.1	19.2	28.5
		8/97	638	408.3	7.6	79.0	8.6	18.0	5.0	89	252.0	17.2	67.0
9	El-keelab	8/79	541	329	7.9	53.7	11.1	33.3	2.7	49	146.4▼	22.0	54.9▼
		7/80	576	369	7.5	79.9	10.9	34.4	3.9	57	189.1	8.6	93.4
		4/81	690	441	7.4	90.1	10.2	26.4	3.9	51	231.8	13.4	75.2
		5/82	655	419	7.7	85.7	15.3	28.7	3.9	57	229.4	23.0	59.5
		10/83	660	422	7.5	74.1	12.1	34.4	3.9	65	192.1	9.6	65.0
		1/85	650	422	7.7	76.6	15.3	32.1	0.0	57	237.9	28.0	63.8
		4/86	616	390	7.8	77.3	14.5	29.8	3.1	56	189.1	13.4	84.0
		9/89	105	672	7.4	107.8	24.1	50.5	3.9	82	237.3	33.1	167.0
		5/91	108	620	7.5	127.4	20.6	51.9	8.2	106	255.0	23.0	45.0
		6/92	990	611	7.2	125.6	18.2	45.5	3.9	91	280.6	34.5	130.0
		8/97	997	638	8.0	87.0	9.2	9.2	3.6	20	222.0	18.3	111.0
10	Basset Lauzeh	8/97	485	310.0	7.7	80.5	6.5	11.4	0.3	21	266▼	0.0	4.3▼
		7/80	460	269.0	7.7	77.9	5.1	16.0	0.3	18	247.7	0.0	4.5
		4/81	400	294.0	7.9	76.1	3.6	11.4	0.3	24	229.4	0.0	10.6
		6/83	420	256.0	7.9	73.7	3.6	18.3	0.0	21	196.4	0.0	7.5
		1/85	370	268.0	7.8	65.7	2.7	9.19	0.0	21	209.2	9.6	7.3
		4/86	420	237.0	7.9	70.5	5.2	6.8	0.0	16	206.2	9.6	6.1
		1/88	500	269.0	7.4	84.1	4.8	11.4	0.0	18	215.3	6.7	4.8
		9/89	0.440	320.0	7.8	74.7	3.9	9.1	1.1	21	269.6	9.1	4.6
		5/91	0.450	312.0	7.6	86.3	4.8	7.5	5.8	33	225.1	9.6	6.0
		4/92	0.504	315.0	7.6	54.4	6.0	7.3	0.0	20	236.7	0.0	8.8
		8/97	-	322.5	8.2	46.0	4.8	19.0	0.3	62	254.0	14.7	17.0
11	Basset Abeid▼	8/79	0.461	295.0	7.9	69.3	8.9	11.4	0.7	222▼	222▼	14.4	10.8▼
		7/80	0.485	310.0	7.7	84.5	11.3	20.6	1.5	263	263.5	21.6	21.7
		5/82	0.542	346.0	7.9	84.9	11.9	12.6	0.0	273	273.9	23.0	10.6
		6/83	0.510	326.0	7.7	52.1	23.0	9.1	0.0	256	256.8	0.0	9.1
		1/85	0.510	826.0	7.8	80.3	11.5	9.1	0.0	255	255.0	28.8	9.3
		4/86	0.460	294.0	7.2	76.1	13.3	6.8	0.0	244	244.0	25.9	8.0
		1/88	0.570	365.0	7.6	92.1	15.1	13.7	0.3	294	294.6	17.7	1.8
		9/89	0.530	339.0	7.2	84.9	8.5	9.1	1.5	266	266.0	24.0	8.1
		5/91	0.510	312.0	7.8	83.7	10.9	8.7	5.8	265	265.4	18.7	9.9
		6/92	0.510	312.0	7.5	83.3	12.1	5.5	0.3	262	262.9	25.9	8.1
		8/97	0.509	325.7	7.2	74.0	8.4	12.0	0.7	150	264.0	15.5	33.0

to be the most important anions io natural waters. They Me related to and control the pH and. alkalinity of water. In A4 aquifer the correlation between bicarbonate (HCO"$_3$) and. TDS shows a strong correlation between Um-Faraj, Nabhan, Elkelab, aed Lauzeh springs and r ranges between 0.5-0.9. While in springs emerged from aquifer A1/2, and. El Karaj spring show a correlation between HCO"$_3$ and TDS that's r = 0.5. This is attributed to the increasing of bicarbonate, content in the water,. The bicarbonate present in the water is derived mostly from carbon dioxide that has been extracted from the air and liberated in the soil through, natural weathering and biochemical activity., In addition, anthropogenic activities in the area mainly domestic sewage from septic tanks .and wastewater from treatment plants in the >area contribute to the increase in bicarbonate.

Figure 5 and Table 4 show the correlation and

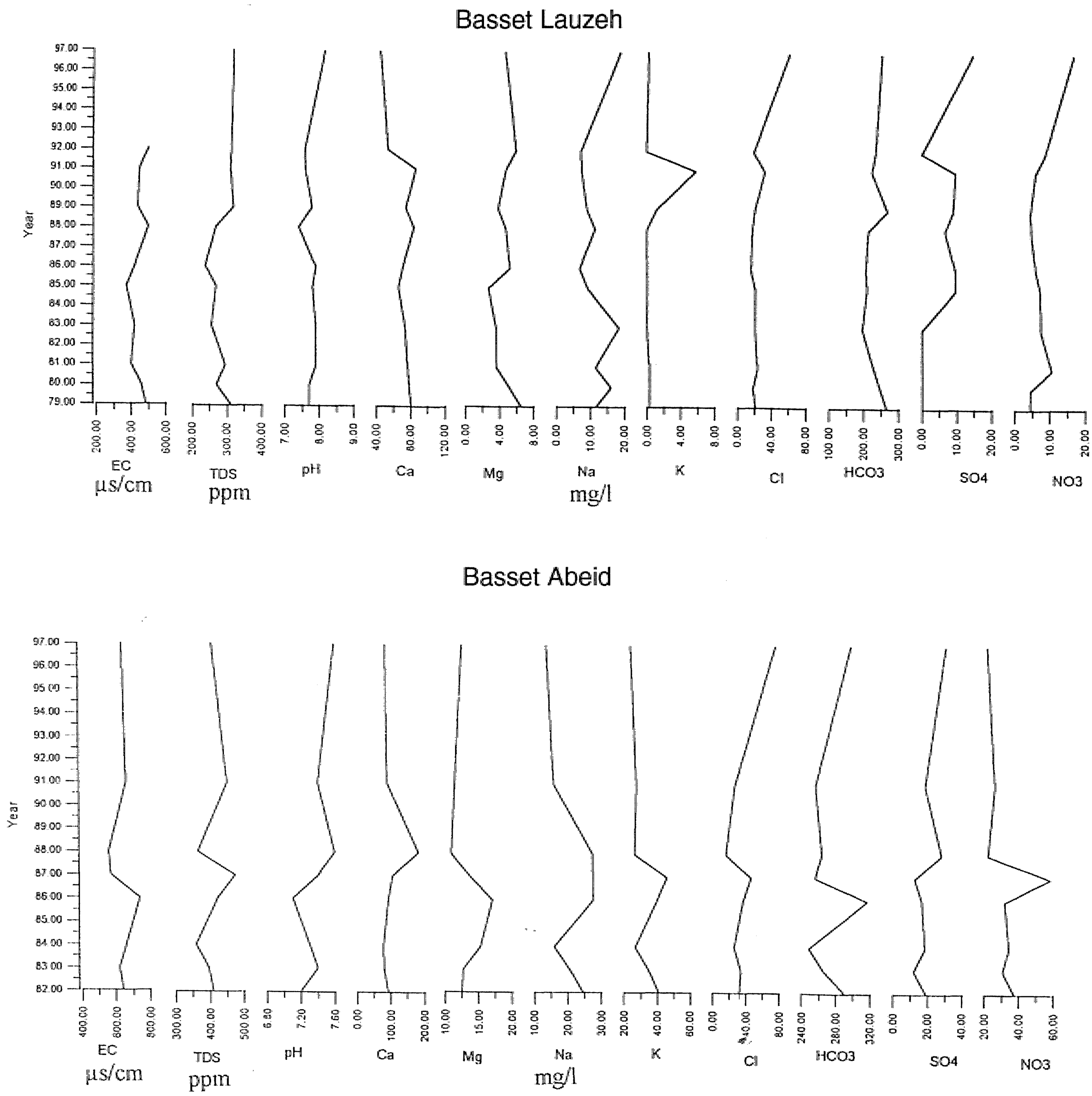
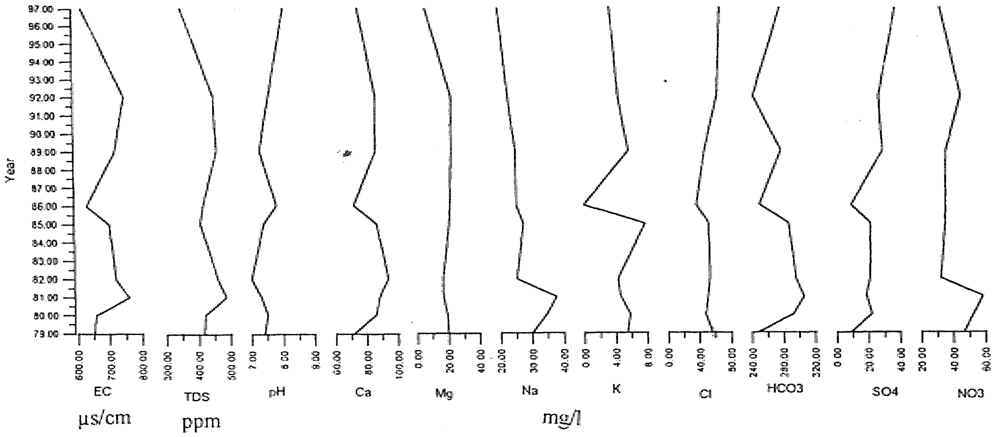
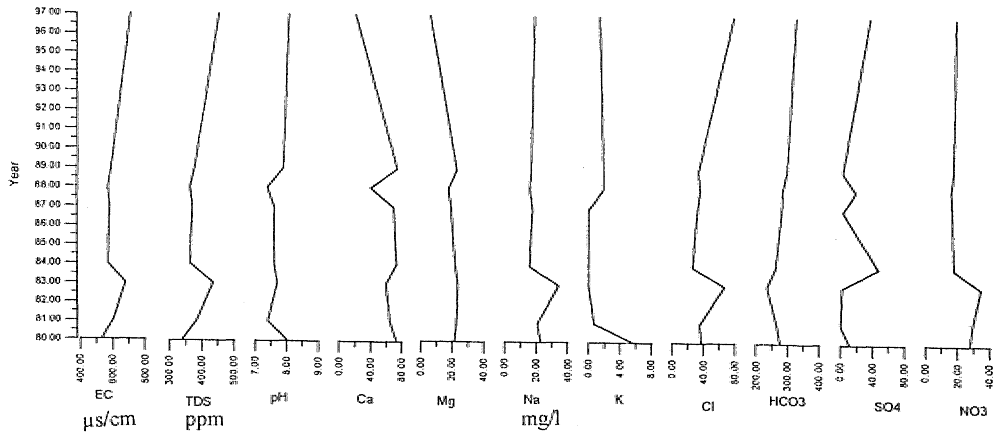


Figure 3. Various variables concentration in collected water samples of study area.

Bassas Aldub Elgurbi



Bassas El-Room



Bassas Um-Faraj

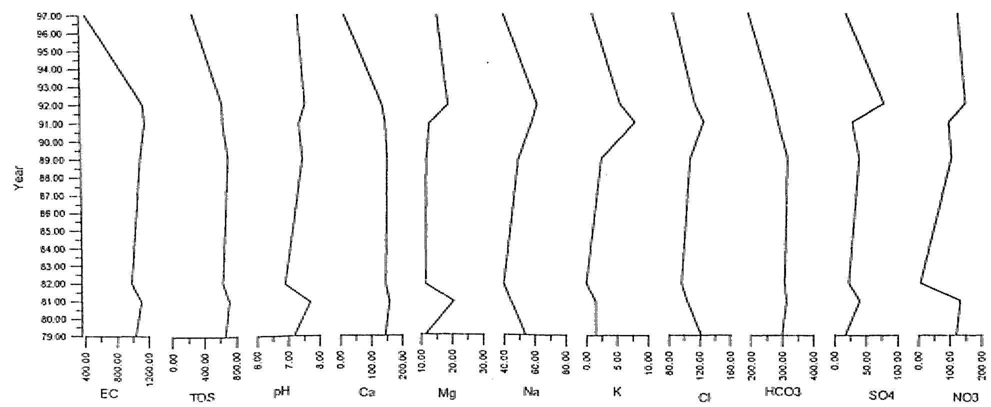


Figure 3 (cont'd)

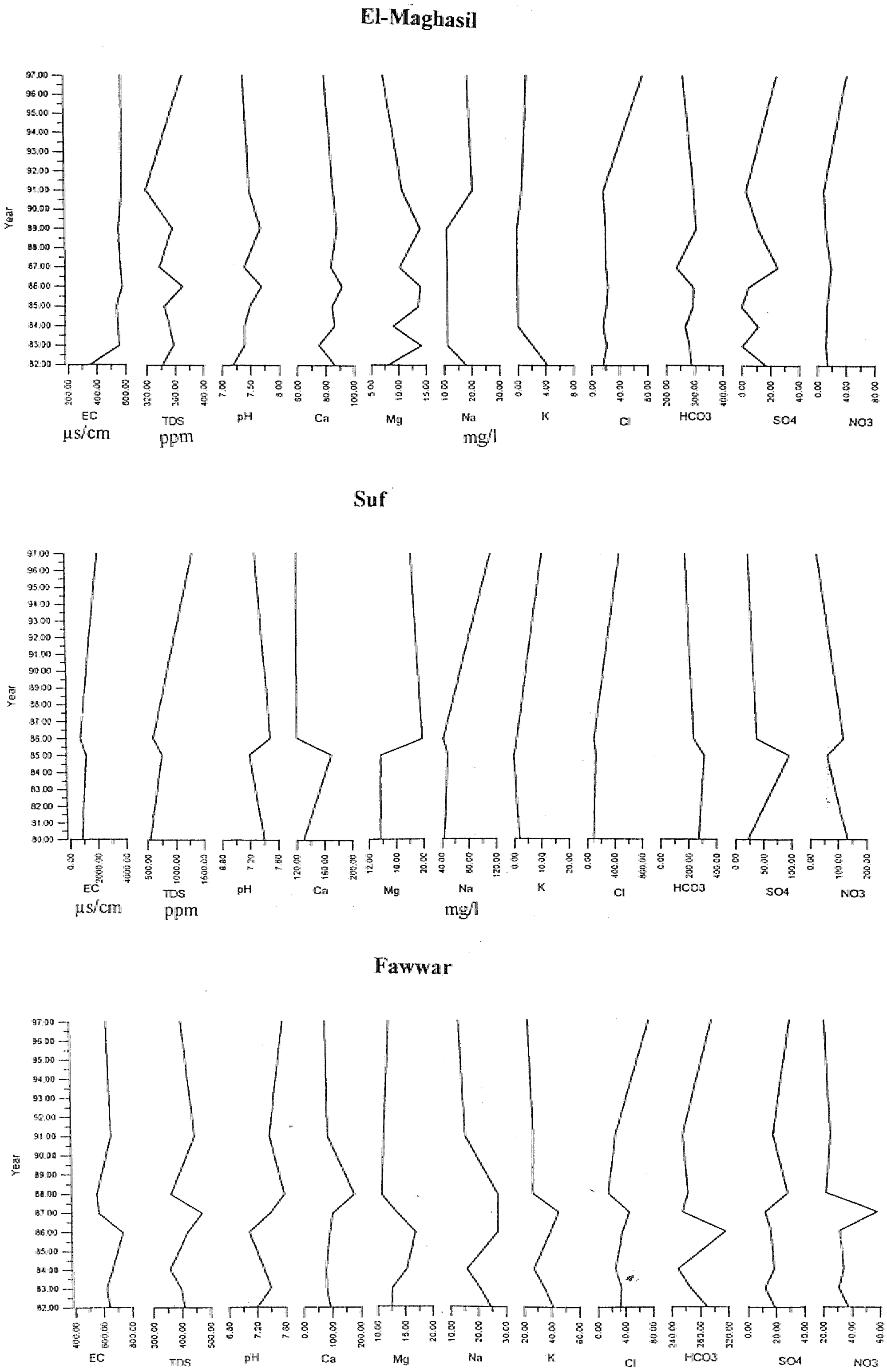
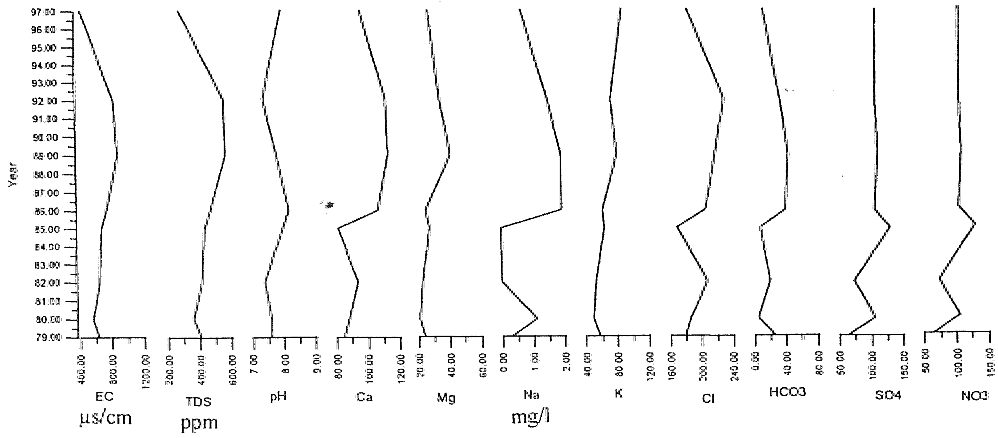
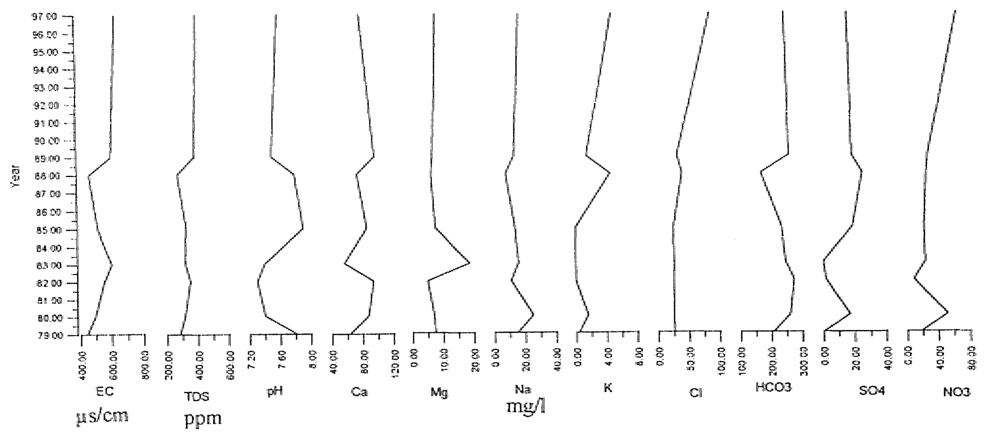


Figure 3. (cont'd)

Nabhan



El-Karaj



El-Kelab

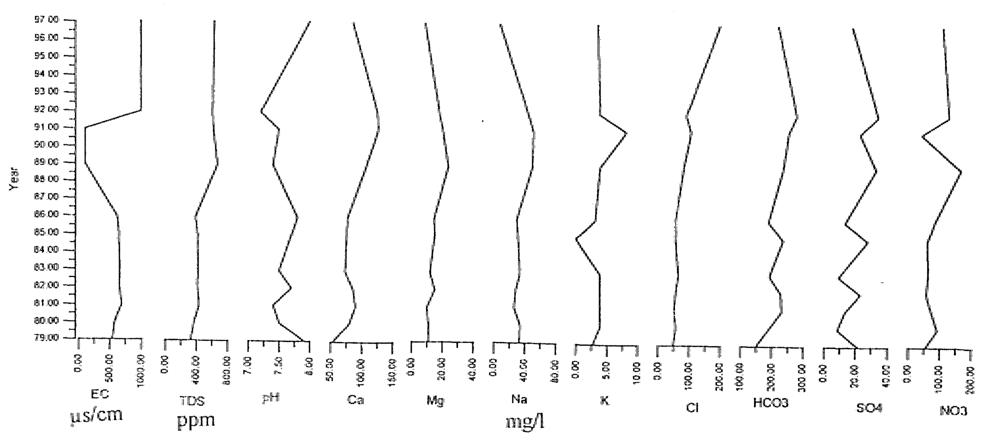


Figure 3. (cont'd)

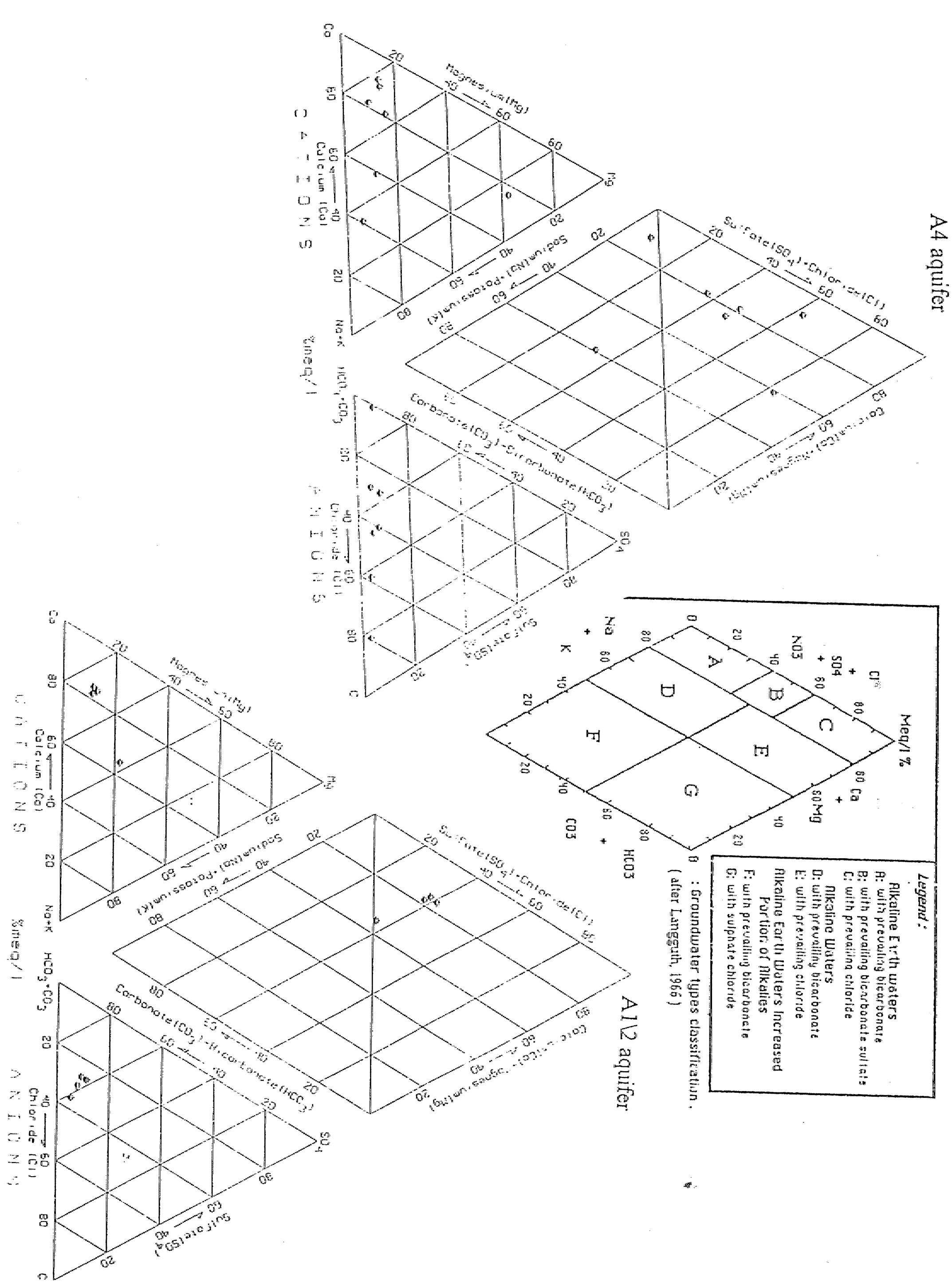
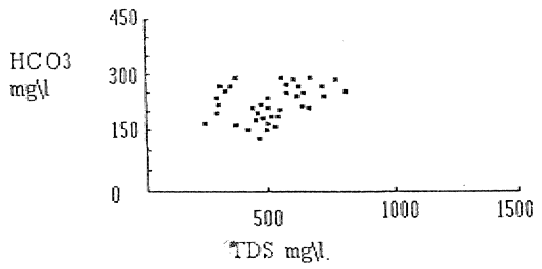
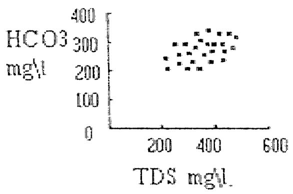


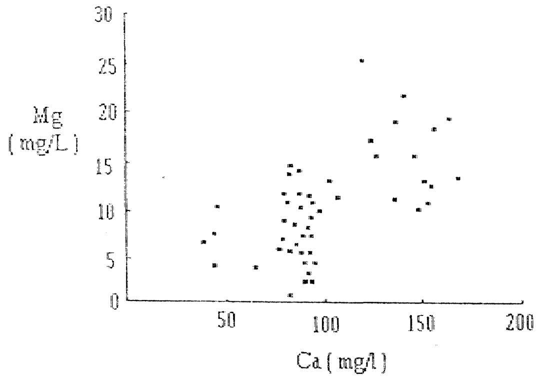
Figure 4. Trilinear diagram of major ions of water samples in the study area for A4 and A1/2 aquifers.



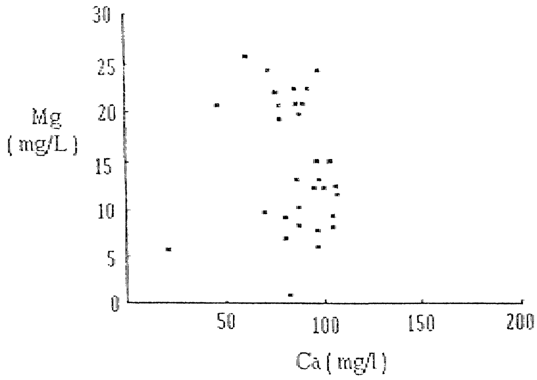
Correlation of bicarbonate with total dissolved solid for A4 aquifer .



Correlation of bicarbonate with total dissolved solid for A1\2 aquifer.



Calcium Vs magnisum for the A4 aquifers.



Calcium Vs magnisum for the A1\2 aquifers.

Figure 5. Correlation between various elements of the studied water samples.

correlation coefficient, between the various chemicals in the Hummer aquifer (A4). There is a slight. correlation between Mg^{2+} and Ca^{2+} in Suf and Nabhan springs., r is 0.5 and 0,5 respectively, while for Al/2 in El-Room' and El Karaj springs, there is a strong correlation between Mg^{2+} and Ca^{2+}, Here the presence of dolomite limestone and pure limestone as the aquifer formation reflect, a good correlation.

Water Quality

According to Hem. (1971), EC is the ability of substance to conduct electric current., The measure of the conductance is used to approximate the total, concentration of ionic .species, present. Generally., EC is less than 1500 ms/cm. None of the springs has higher ^concentration than recommended by WHO, except Suf spring with 2100 ms/cm Table 3,,, in the August 1997.. Um Fara] shows range from 440-1170 ms/cm, which is within the permissible limits, but indicate the possibilities of increase in the future. The increase in the concentration, of EC reflects that, these springs emerge from a shallow aquifer (A4) and. are consequently more affected by wastewater from the authopogenic activities within the- area... The TDS values, in. all the springs for the various 'years' ranges between 237-1344 ppni Table 3. The international guideline (WHD) indicates the permissible level between 500-1000 mg/L. Only Suf springs shows higher' concentrations, exceeding the permissible limits (1344 mg/L), Table 3, and to some extent Um-Faraj springs, the values ranges between 281.6-710mg/L, this falls within the permissible limits, but. is an indication of possible increases in the .future. The Ca^{2+} shows elevated values in Suf (170.2 mg/L) and Fawwar springs (182.5 mg/L), Table 3. The WHO permissible limits for Ca^{2+} is 75-200 mg/L, The: increase in the Ca^{2+} concentration is due to the release, of Ca^{2}* front sedimentär}[7] carbonate rocks and. soils into the springs. Most of the springs included, in. the present study, shows increased concentration of HCO''_3, especially Suf (192-317.2 mg/L) El. Room. (235..5-330 mg/L), Aldub Elgurbi (244.6-306.2 mg/L), Fawwar (248.9-317.5), Table 3, the permissible limits (WHO) is 125-360 mg/L The pH low values in the study area contribute to the increase in the bicarbonate., The permissible limits for chloride Cl" are 250 mg/L as stated by 'the WHO. The highest CÎ values are found in Suf spring (88-500 mg/L) and Basset Abeid spring (150-294 mg/L), Table 3. This increase in Cl" concentration can. be attributed to municipal waste from the septic tanks .and the local effluent from, domestic and agricultural water use.

There, is fluctuation in the in. the NO_3' concentration from one year to the next (Table 3). Kolenhander (1977) indicated that there are several processes affecting the quantity of nitrate in groundwater, including nitrification., denitrification,,, amm.onifi.cation, assimilation, and oxidation. The data presented in Table- 3 show higher concentrations in NO_3" in almost all the springs included, in the- present: study exceeding the permissible guidelines of the "WHD'50 mg/L. Nitrate concentration, in the Al/2 aquifer springs ranges from 9.4 mg/L- (El Karaj springs) to 67 mg/L (El karaj spring) Aldoub Elgarbi, El Room and. El Karaj shows concentration values exceeding the- permissible limits, Table 3. Nitrate concentration in. the A4- -aquifer ranges from 4.3 mg/L (Basset Lauzeh springs) to 154 mg/L, (Um-Faraj spring). The distribution of nitrate in spring; 'water in the study .area suggests that, the human waste sources of nitrate have entered the aquifers at more than one location. The- source of nitrate in the shallow aquifer (A4) originates from, non-point leakage of municipal waste- from different sites in the- stndy .area. The relatively low levels of nitrate in some springs such -as Magasil, Fawwar, Lauzeh and Bussat Abeid can be perhaps attributed to two conflicting trends.

- The spring water is not affected, by any source of nitrate, either from domestic waste or fertilizers,,

- Denitrification. of nitrates decreasing its level by special, types of psedomonas. The first, trend, is likely to be- more favorite-, because the chemical of different ions is 'within the natural levels- in these springs.

CÖNCOJMON

The geocheinical conditions, of groundwater contamination in spriog: of the Suf region were investigated. Based on the chemical data, the value of TDS is the highest in Suf springs (1.344 mg/1), which exceeds the permissible limits.. Degradation in water quality is seen in Fawwar, Um-faraj, 'Ël-Karaj, .and Nabhan springs with respect, to certain chemicals.. Ca"$^{+}$, Ma" and Mg^{+} reaches to 123, 115 and 500 mg/1, respectively, which exceed 'the permissible WHO limits. The Um-faraj springs show-increasing values of **NO3.** Local people attribute this increase in 'the value of the various chemicals to the natural, .and anthropogenic that's the aquifers rock formation, .and the use of water for various purposes. The water in the study area is classified as alkaline earth waters of prevailing bicarbonate and chloride character for A4 aquifers, and .alkaline earth water, with prevailing bicarbonate character for Al/2 aquifer.

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