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Hydrogeochemical Aspects Of Tigris And Euphrates Rivers Within Iraq: A Comparative Study

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ABSTRACT

The concentration of major cations and anions and the total dissolved salt in Tigris and Euphrates Rivers were measured .The longer river course beside the extent and the lithological diversity of Euphrates River basin caused the Euphrates water to have relatively higher ionic contents than Tigris waters .The ionic concentrations of both rivers increase down stream. No appreciable changes in ionic concentration in Tigris and Euphrates waters were observed .Nevertheless,Ca+2 and SO4=exhibit sharp change in their concentrations, this is attributed to the geologic, Hydrogeologic and irrigation agents. According to the total hardness, the Euphrates may be divided into two groups ; hard at the upper reaches and very hard at the middle and lower reaches whereas Tigris water is hard.

الملامح الهيدروجيوكيميائية لنهري دجلة والفرات في العراق: دراسة مقارنة

الملخص

تم قياس تراكيز الايونات الموجبة والسالبة الرئيسة والاملاح الذائبة الكلية في نهري دجلة والفرات ان طول نهر الفرات وسعة مساحة حوضه وتنوع تركيبه الصخاري ادى هذا التكامل الى زيادة محتواه من الايونات السالبة والموجبة اكثر من نهر دجلة, وعموماً فأن المحتوى الايوني لدجلة والفرات يزداد بأتجاه اسفل النهر. لم يلاحظ وجود زيادة حادة في تراكيز الايونات المقاسة في مياه نهري دجلة والفرات بأستثناء تركيز الكالسيوم والكبريتات اللذين يظهران مثل هذه الزيادة وهذا يعزى الى عوامل جيولوجية هيدروجيولوجية وهيدروكيميائية. طبقاً لقيمة العسرة الكلية فأن مياه نهر الفرات من الممكن تقسيمها الى مجموعتين,الاولى هي المياه العسرة في الاجزاء العليا من النهر والثانية العسرة جداً وسط واسفل النهر, في حين مياه نهر دجلة تعد عسرة فقط .

INTRODUCTION

The Tigris and Euphrates Rivers collect their waters from nearly the same drainage area. Tigris rises on the southern slope of Tauros mountain ranges (inTurkey),and drain toward Iraq, while the northern slopes of the same mountain ranges form a part of the Euphrates River basin.

Tigris flows through Turkey and Iraq; many tributaries flow into the Tigris River inside Iraq. Five major tributaries join Tigris , which are, Khabour River, near the Turkish-Iraqi boarder(Tusan),Greater Zab, at about 50 km down stream Mosul, Lesser Zab at about 220km, upstream Baghdad, Adhaim at about 50km, upstream Baghdad and Dialah River joins the Tigris Rivers about 10km south of Baghdad center (Al-Samak et al.,1985)(Fig. 1).

Fig. 1: Location Map

The Euphrates River has no natural tributaries inside Iraq,except for numerous dry wadies that flow intermittently and for short period during heavy rains ,nevertheless, Euphrates river receives additional water from a reservoir through a recently built artificial canal at Falluja and from Garaf canal at Nasiriya (Fig.1).The total length and the catchement areas of Euphrates and Tigris Rivers and tributaries were listed in table (1).

Table 1:Lengths and catchment area of Rivers and Tributaries in Iraq(Al-Samak et al.,1985).

River		Total length(km)	Length in Iraq(km)	Catchement area (km2)
Euphrates		2330	1200	444000
Tigris		1900	1341	340500
Tigris Tributares	Khabour	-	160	6270
	G.zab	-	392	26470
	L.zab	-	400	22250
	Adhaim	-	230	10700
	Diyala	-	386	32600

Table 2 :Review of the abstracted data.

Author	River	Location	No. of Sample	Abstracted chemical data			
				Cation-ppm	Anion-ppm	other	
Banat &Al-Rawi,1986	Euphrates	Husiba-Qurna	25	Ca,Mg, Na,K	SO4, Cl	TSS	---
Asaad &Hussain,1986,a	Tigris	Tusan-Baghdad	6	Ca,Mg, Na,K	SO4, Cl	TSS	---
Asaad &Hussain,1986,b	Tigris	Baghdad-Qurna	6	Ca,Mg, Na,K	SO4, Cl	TSS	---
Jamil et al.,1990	Tigris	N.Mosul-Qurna	11	Ca,Mg, Na,K	SO4, Cl, HCO3	TSS	---
Ghliem,1997	G.zab L.zab Adhaim Diyala Tharthar	Selected point	5	Ca,Mg, Na,K	SO4, Cl,HCO3	---	---

The climate of Iraq is in general arid to semi – arid and the annual rain-fall exceeds 1000 mm/year in the North ,while it decrease to less than 50 mm/year toward the South (Fig, 2) (Al-Ansari et al., 1981).

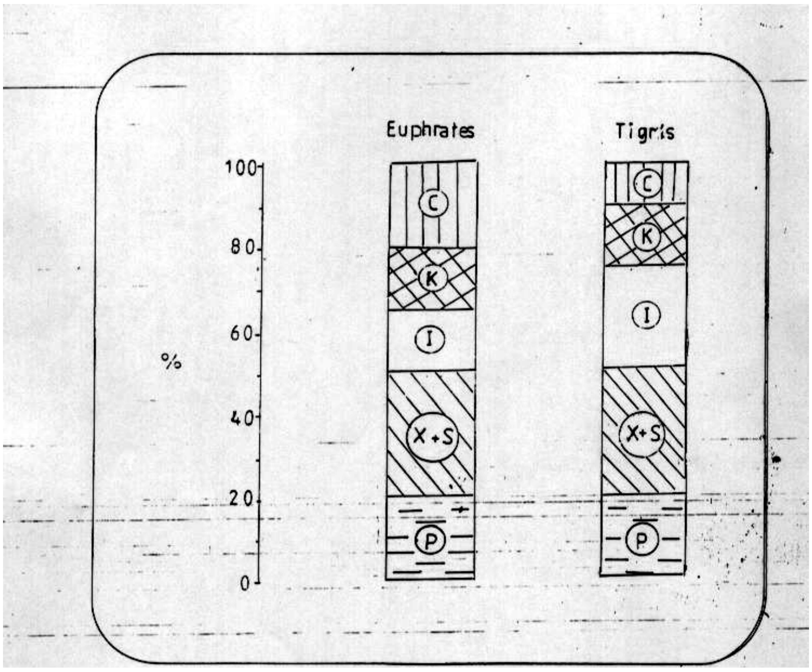

Fig. 2: Clay minerals assemblage of Tigris and Euphrates suspended sediments. P = Palygorskite, X= Mixed layer illite- smectite, S=Smectite, I=Illite, K=Kaolinite, C=Chorite (Aqrawi, 1993).

Owing to the importance of the Tigris and Euphrates Rivers as a source of waters, each of them has been subjected to various hydrochemical studies. The purpose of the present study is to undergo a comparative reevaluation of the Tigris and Euphrates in the light of the available published hydrochemical , geological , and hydrogeological data ,which are based on 36 water samples collected from 36 stations; twenty- five along Euphrates and eleven stations along Tigris River (Fig,1). All samples were analysed for Ca2+,Mg2+,Na1+,K1+,Cl1-,SO42-,HCO31-, Total Dissolved Salt(T.D.S), and Total Hardness(T.H.) Table(3, 4, and 5).

Table 3 :Minimum, maximum and mean of the measured component in Tigris and Euphrates compared with that of international Rivers, beside the average composition of the river water of the earth.

componenr	Tigris (ppm) Ghliem,1997 Jamil et al.,1990 n=16			Euphrates (ppm) Banat and Al-Rawi,1986 n=25			International Rivers-Faur,1998 (ppm)					Average con. In river water of the earth (Livingston,1963)ppm
	min	max	mean	min	max	mean	Miss.	Color.	Amaz.	Nile	Phili.	
Ca+2	42	119	56.55	43	160	98.16	34	83	5.2	25	31	15
Mg +2	19	61	30.82	20	79	37.84	8.9	24	1.0	7.0	6.6	4.1
Na+2	15.2	158	51.11	34	258	97.68	11.0	95	1.5	1.7	10.4	6.3
K+	1.5	5.8	2.98	3.2	8.5	5.53	2.8	5	0.8	1	1.7	2.3
Cl-	23	259	86.55	6	432	142.36	10.3	87	1.1	7.7	3.9	7.8
SO4=	73	315	158.9	201	1009	561	25.5	270	1.7	9	13	11.2
HCO3-	80	195	150	114	280	151	116	135	20	134	131	58.4
T.D.S	212	1073	444.2	463	2061	1095						
T.H	183	545	268.0	205	673	397						
Sum												105.1

Miss. =Mississippi River
Phili. =Philippine River
Color. =Colorado River
Amaz. =Amazon River
Nile=Nile River

Table 4 :The concentrations of major cations and anions of Tigris River Tributaries and Tharthar lakes ,after Ghliem(1997)

River	Tributary	ppm						
		Ca+2	Mg+2	Na+	K+	Cl-	SO4=	HCO3-
Tigris	G.Zab	47.6	35.5	22.54	1.4	18.08	161.28	178.12
	L.Zab	73.74	34.56	22.08	1.05	17.73	154	177.51
	Adhaim	226.05	83.52	126	1.56	163.34	545.28	189
	Diyala	254.9	231.5	164.2	1.96	234.34	1082	166.5
Euphrates	Tharthar	89.78	118.56	66	2.35	255.3	679.7	85

Note; One sample for each tributary and Tharthar lake.

Table 5 :Chemical analysis results of Tigris River(Ghliem,1997).

Station	Station Name	Ca2+ (ppm)	Mg2+ (ppm)	Na2+ (ppm)	Cl1- (ppm)	SO42- (ppm)	HCO-31- (ppm)	T.D.S (ppm)	T.H (ppm)
1	Tusan	42	19	12	23	132	184	243	183
2	Mosul	48	21	14	27	169	178	260	206
3	Shargat	44	21	13	26	171	80	272	196
4	Tikrit	43	19	14	35	80	140	212	186
5	Samara	42	19	12	32	73	175	230	183
6	Baghdad	53	31	49	95	148	195	479	260
7	Azizya	56	44	65	108	146	160	474	321
8	Kut	57	37	64	111	189	132	544	295
9	Kmait	60	31	77	112	161	134	543	277
10	Amara	58	36	78	124	164	120	557	293
11	Qurna	119	61	174	259	315	122	1073	548

Drainage Basins

Tigris basins is characterized by its high mountain ranges (Tauros).

In the North followed by the hilly region in the North of Iraq and then the plane area in the middle and southern parts of Iraq. Igneous and metamorphic rocks occupy a very small and restricted area in the north part of Tigris basin (Van Bellen et al., 1959).The remainder part is covered by Miocene –Quaternary sediments .The course of the river cuts through Gypsum, Limestone, Shale and Marl of Fat'ha Formation from Mosul to Fat'ha area. South of Fat'ha Quaternary deposits predominate (Buday, 1980).

Greater and lesser Zab Rivers drain the highly folded and faulted igneous and metamorphic rocks of the Nappe zone(Dunnington, 1958), in the extreme northeastern Iraq. Adhaim and Diala Rivers drain the folded zone located south east of the Nappe zone. The folded zone consists mainly of cretaceous –Eocene-Oligocene limestone (Al-Syaab et al., 1982).

Euphrates River enters Iraq at a few kilometers north Huseiba on the Iraqi-Syrian Borders. In its upper reaches in Iraq, the Euphrates cuts through carbonate bed rocks, having a very narrow strip of flood plain.The lithology of Euphrates River channel then changing to Gypsum, Limestone, green marl from north Hit to Ramadi, (Al-Obeidi, 1983). In the middle and lower reaches the Euphrates River meander over the Mesopotamian alluvial plain. The drainage basin here is underlained by the Injana Formation (formerly Upper Fars)(Upper Miocene)which consists of marls and sandstone at south Ramadi (Banat and Al-Rawi,1986) .At lower reaches ,the Euphrates River flows over fluvitile recent sediments (Ramadi-Diwania),and the Dibdibba Formation(Miocene-Pliocene-Pleistocene) which is consist of clastic sediments basically arkosic arenite , as well as some recent sand dune (Nasiriya) (Al-Rawi and Sadik,1981).

The mineralogical study of Tigris and Euphrates recent fluvitile sediments conducted by Philip(1968), Ali(1977),and Banat and Al-Rawi (1986) showed that the sediments are composed approximately of the same heavy mineral (H.M) species ,The proportion of the identified constituents vary along the Tigris and Euphrates courses. Iron ores, epidote, amphiboles and pyroxene form the dominant H.M recorded.

Whereas, biotite, chlorite, garnet, rutile, zircon, apatite, olivine, tourmaline, muscovite, sphene, staurolite and kyanite range from 0.0 to 4.5% in abundance. The minerals were derived from igneous and metamorphic rocks which form the catchment area of Tigris and Euphrates Rivers (Philip,1968)

Suspended Load

The suspended load of the Euphrates and Tigris consists nearly of the same clay mineral species,Smectite + Illite –Smectite mixed –layered, Illite, Kaolinite and Chlorite (Aqrawi, 1993).The relative abundance of these clay minerals are shown in figure (2).

The identified clay minerals indicate that Tigris and Euphrates Rivers derive their detritus suspended load essentially from metamorphic rocks and to a lesser extent from basic igneous rocks. This conclusion supported by the heavy mineral assemblages recorded in Tigris and Euphrates channel sediments.

Philip (1968) pointed out that these assemblages are characterized by four groups (iron ore, epidote, amphiboles and pyroxene)which make more than 80% of heavy mineral fraction. Moreover, this assemblage results principally from disintegration of metamorphic and basic igneous rocks, cropping out in the Tigris and Euphrates basins in the north western part of Iraq.

RESULT AND DISCUSSIONS

Hydrogeochemistry

The variation in salinity along the course of Tigris and Euphrates Rivers in Iraq is shown in Figure (3), In general the salt content of Tigris and Euphrates is 447 and 1095 ppm respectively (Table 3), i.e. the salinity of Tigris and Euphrates is about four and ten times higher than the avearage T.D.S in the river water of the earth documented by Livingston (1963).

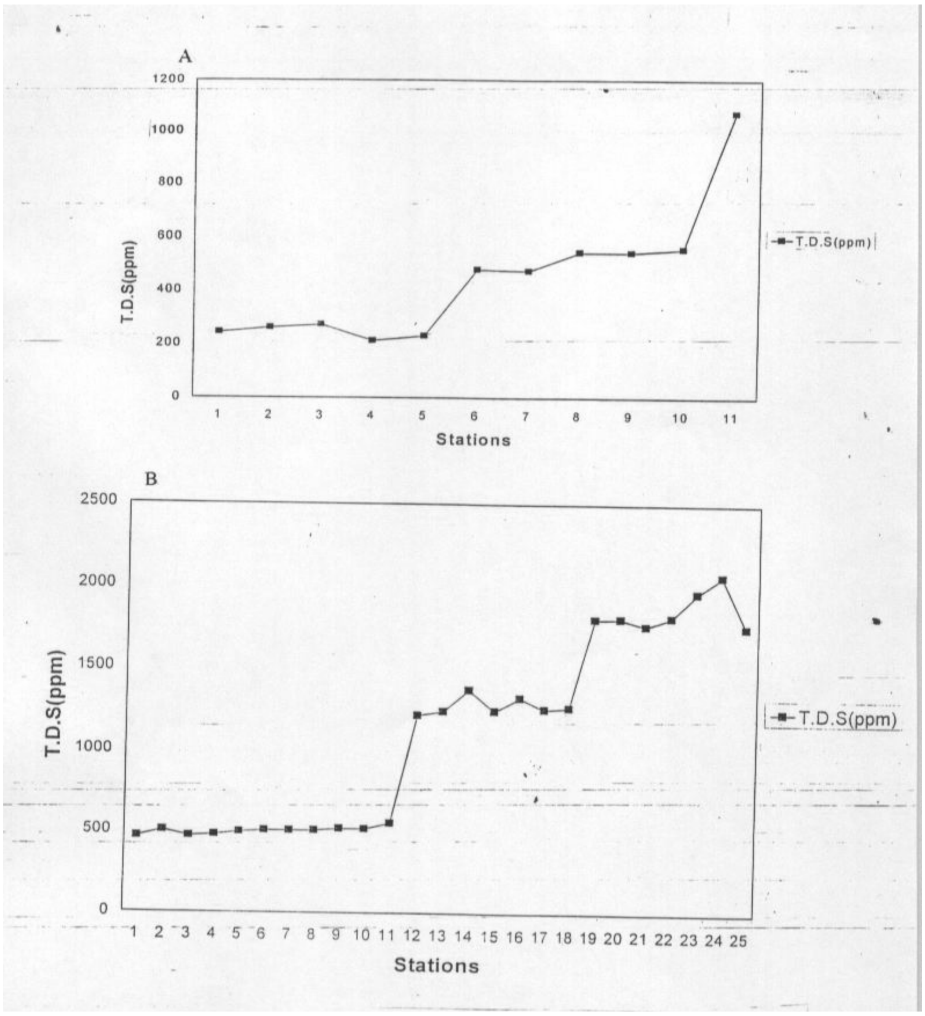

Fig. 3: Change in T.D.S. (ppm) in Tigris River (A) and Euphrates River (ppm) B.

The sudden increase in salinity of Euphrates water recorded at Falluja is attributed to the discharge of the high saline water (Table 6) contributed from Tharthar reservoir via recently built artificial canal. Another sharp increase in Euphrates River water was observed at stations 20 and 21(Shanafia area).

Table 6 :Chemical analysis results of Euphrates River (Banat and Al-Rawi, 1986).

Station	Station Name	Ca2+ (ppm)	Mg2+ (ppm)	Na+K (ppm)	Cl1- (ppm)	SO42- (ppm)	HCO31- (ppm)	T.D.S (ppm)	T.H (ppm)
1	Huseiba	48	24	38	6	202	145	463	219
2	Qaim	49	24	41	14	211	163	502	221
3	Karabla	49	20	37	6	201	154	467	205
4	Ubaidy	46	22	43	6	211	149	476	205
5	Anah	46	23	38	40	202	145	495	210
6	W. Haditha	43	25	44	20	211	145	504	210
7	Haditha	45	26	60	43	211	122	504	219
8	Alus	45	24	39	40	211	145	504	261
9	Baghdadi	45	25	42	28	231	145	517	215
10	Hit	50	24	48	37	211	145	515	224
11	Ramadi	53	21	50	48	231	149	552	219
12	Faluja	141	30	84	131	711	119	1216	476
13	Amiryah	130	29	84	165	711	122	1241	444
14	J. Al-Skhar	138	29	85	202	788	127	1369	464
15	Musaib	134	29	78	131	759	114	1245	454
16	Al-Hindiya	143	37	101	128	788	127	1324	509
17	Kufa	134	35	99	116	759	114	1256	479
18	Al-Mundaria	147	31	93	139	740	116	1266	495
19	Shanafia	149	67	194	270	970	149	1799	491
20	Samawa	160	51	180	258	1009	145	1803	609
21	S. Samawa	146	58	172	230	1009	145	1760	603
22	Nasiryah	142	64	198	301	961	145	1811	618
23	Sug Al-Shukh	136	81	267	381	893	202	1960	673
24	Al-mudina	131	79	258	432	893	268	2061	652
25	Qurna	104	68	211	387	701	280	1751	540

This phenomenon is related to the contribution of highly saline sulfurous water discharging from natural springs issued as a result of Abu-Jir deep seated fault (Abbas and Al-Khatib, 1982), in addition to high agricultural activity and increased rate of evaporation(Banat and Al-Rawi,1986).

It is obvious that the salinity of Tigris River generally increases down stream (Fig. 3), except at Tikrit and Samara, due to dilution effect of the Lesser Zab (average T.D.S=180ppm)(Assad and Hussain, 1986,a).

The sharp increase in salinity occurred at Baghdad is mainly due to the combined effect of the drainage systems in the area and the Adhaim River (average T.D.S=1560ppm)(Assad and Hussain, 1986,b). The Tigris River salinity exhibit high rate of increase from Baghdad to Qurna .The value of salinity of Tigris water at Amarah is attributed to the intermittent River Al-Chabab which joins Tigris River at Ali Al-Gharbi and characterized by its high salinity (T.D.S=5568ppm)(Ghliem,1997).At Qurna the T.D.S concentrations were high due to the effect of relatively more salty Euphrates waters which join the Tigris at Qurna.

The concentration of ions in Tigris River from Tusan to Baghdad and in Euphrates River from Al-Qaim to Ramadi show great variations and are of similar pattern of distribution. Nevertheless, the concentration of these ions down stream of Ramadi and Baghdad exhibit a great increase which is attributed to several factors: geologic(change in formation) soil salinity, agricultural activity , irrigation, and domestic use (Table 7,8).

The obtained data (cations and anions) for Tigris and Euphrates River were plotted on triangular diagram (Fig, 4) to show their behavior related to each other.

Table 7 :Hydrochemical formula and water type for Tigris River.

Stations	Hydrochemical formula epm%	Water type
1	Ca> Mg> Na+K,SO4< Cl	Calcium Chloride
2	Ca> Mg> Na+K,SO4< Cl	Calcium Chloride
3	Ca> Mg> Na+K,SO4< Cl	Calcium Chloride
4	Ca> Mg> Na+K,SO4< Cl	Calcium Chloride
5	Ca> Mg> Na+K,SO4< Cl	Calcium Chloride
6	Ca> Mg> Na+K,SO4< Cl	Calcium Chloride
7	Mg> Ca> Na+K,SO4< Cl	Magnesium Chloride
8	Mg> Ca> Na+K,SO4< Cl	Magnesium Chloride
9	Ca> Mg> Na+K,SO4< Cl	Calcium Chloride
10	Mg> Ca> Na+K,SO4< Cl	Magnesium Chloride
11	Ca> Mg> Na+K,SO4< Cl	Calcium Chloride

Table 8 :Hydrochemical formula and water type for Euphrates River.

Stations	Hydrochemical formula epm%	Water type
1	Ca> Mg> Na> K , Cl< HCO3< SO4	Calcium Sulphate
2	Ca> Mg> Na> K , Cl< HCO3< SO4	Calcium Sulphate
3	Ca> Mg> Na> K , Cl< HCO3< SO4	Calcium Sulphate
4	Ca> Mg> Na> K , Cl< HCO3< SO4	Calcium Sulphate
5	Ca> Mg> Na> K , Cl< HCO3< SO4	Calcium Sulphate
6	Ca> Mg> Na> K , Cl< HCO3< SO4	Calcium Sulphate
7	Ca> Mg> Na> K , Cl< HCO3< SO4	Calcium Sulphate
8	Ca> Mg> Na> K , Cl< HCO3< SO4	Calcium Sulphate
9	Ca> Mg> Na> K , Cl< HCO3< SO4	Calcium Sulphate
10	Ca> Mg> Na> K , Cl< HCO3< SO4	Calcium Sulphate
11	Ca> Mg> Na> K , Cl< HCO3< SO4	Calcium Sulphate
12	Ca> Mg> Na> K , HCO3< Cl< SO4	Calcium Sulphate
13	Ca> Mg> Na> K , HCO3< Cl< SO4	Calcium Sulphate
14	Ca> Mg> Na> K , HCO3< Cl< SO4	Calcium Sulphate
15	Ca> Mg> Na> K , HCO3< Cl< SO4	Calcium Sulphate
16	Ca> Mg> Na> K , HCO3< Cl< SO4	Calcium Sulphate
17	Ca> Mg> Na> K , HCO3< Cl< SO4	Calcium Sulphate
18	Ca> Mg> Na> K , HCO3< Cl< SO4	Calcium Sulphate
19	Ca> Mg> Na> K , HCO3< Cl< SO4	Calcium Sulphate
20	Ca> Mg> Na> K , HCO3< Cl< SO4	Calcium Sulphate
21	Ca> Mg> Na> K , HCO3< Cl< SO4	Calcium Sulphate
22	Ca> Mg> Na> K , HCO3< Cl< SO4	Calcium Sulphate
23	Ca> Mg> Na> K , HCO3< Cl< SO4	Calcium Sulphate
24	Ca> Mg> Na> K , HCO3< Cl< SO4	Calcium Sulphate
25	Mg> Ca> Na> K , HCO3< Cl< SO4	Magnesium Sulphate

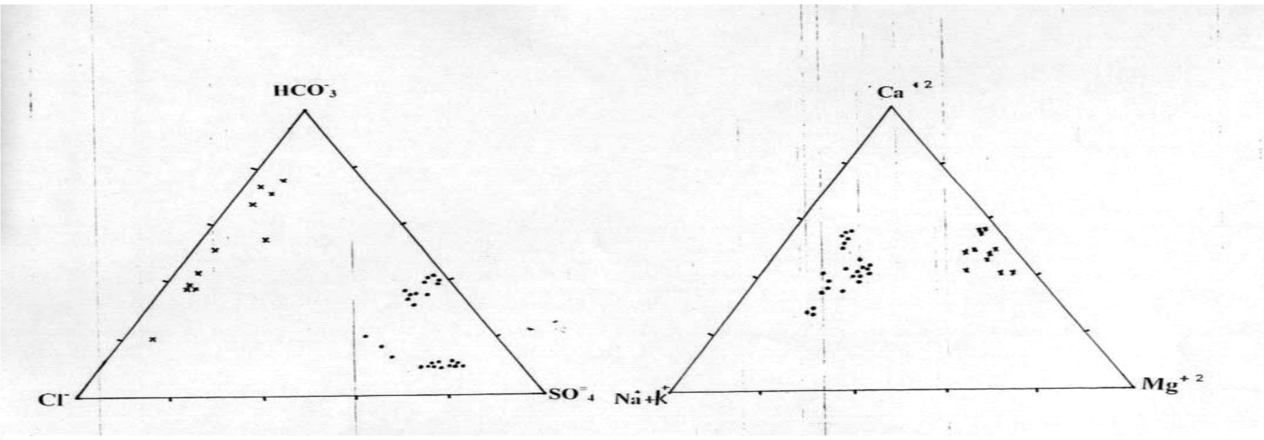

Fig. 4: Triangular diagram showing the distribution of Tigris and Euphrates water samples.
-for Euphrates. x -for Tigris.

The cations of Tigris River revealed a single magnesium – calcium group (Fig. 5), which infers that there is no serious change in Ca and Mg concentrations along this river. On the other hand , the cations of Euphrates River exhibit two distinct groups (Fig. 6), as previously mentioned by Banat and Al- Rawi, (1986) .

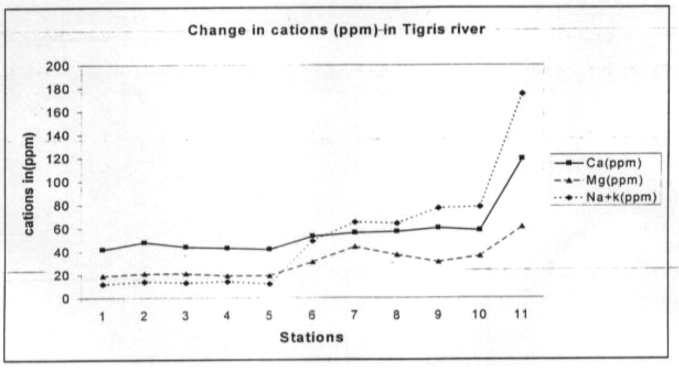

Fig. 5: Cgange in cations (ppm) in Tigris river.

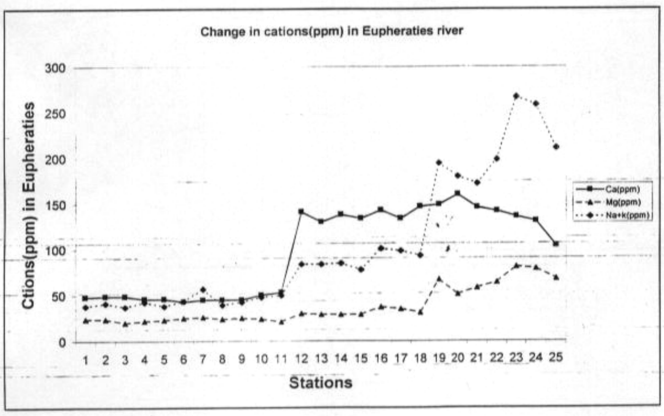

Fig. 6: Cgange in cations (ppm) in Euphrates river.

The anions of Tigris River showed no distinct grouping in the sample distribution (Fig, 7),while Euphrates River anions showed two distinct water groups; sulfate bicarbonate from Al- Qaim to Ramadi , and sulfate chloride down stream of Ramadi (Fig, 8).

ased on Todd (1980), Euphrates waters can be classifies as hard at its upper reaches and very hard water at its middle and lower reaches, whereas, Tigris waters is consider as hard water along its course. Generally speaking the total hardness (T.H) of both Euphrates and Tigris Rivers increases down stream and this is attributed to the increase in salt contributed to Tigris and Euphrates Rivers Via natural tributaries, intermittent wadies, smaller stream and irrigation projects. Nevertheless the T.H of Tigris River decreases at Tikrit and Samara, respectively as demonstrated by its low sulfate contents (Ghliem, 1997).

Statistical Treatments

Autocorrelation and cross correlation were employed in this study with ultimate aim of checking whether there is a similarity in hydrochemical conditions or not between Tigris and Euphrates Rivers. All the mathematical calculations in such statistical treatment were carried out according to Davis (1973).Autocorrelation results (Fig 9-12) illustrate the stability of various conditions related to the concentrations of ionic composition of Tigris and Euphrates waters except for Ca+2 and SO4= which survive variation in their behaviors along Tigris River.

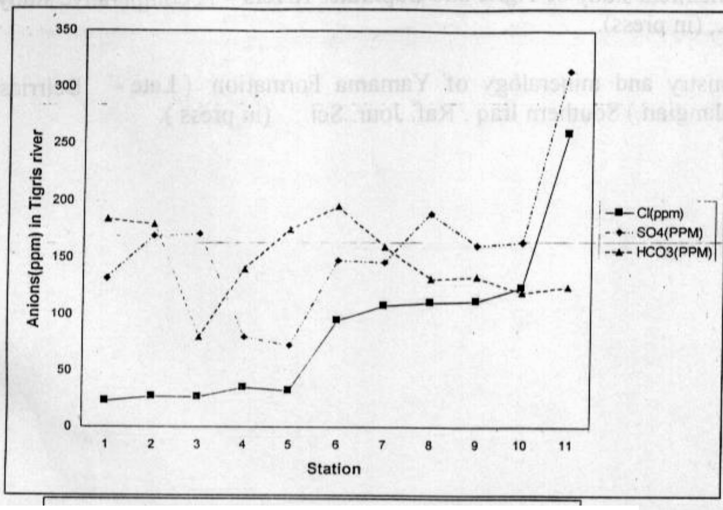

Fig. 7: Cgange in anions (ppm) in Tigris river.

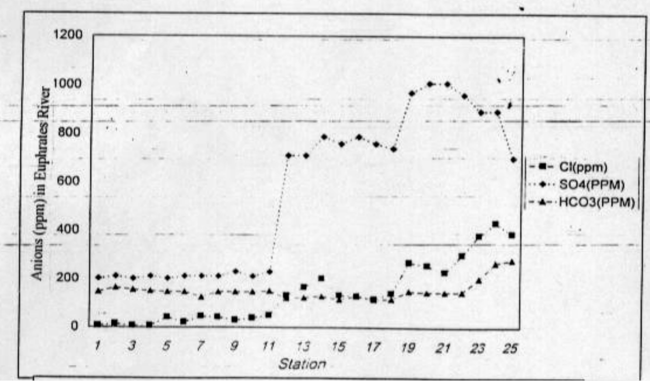

Fig. 8: Cgange in anions (ppm) in Euphrates river.

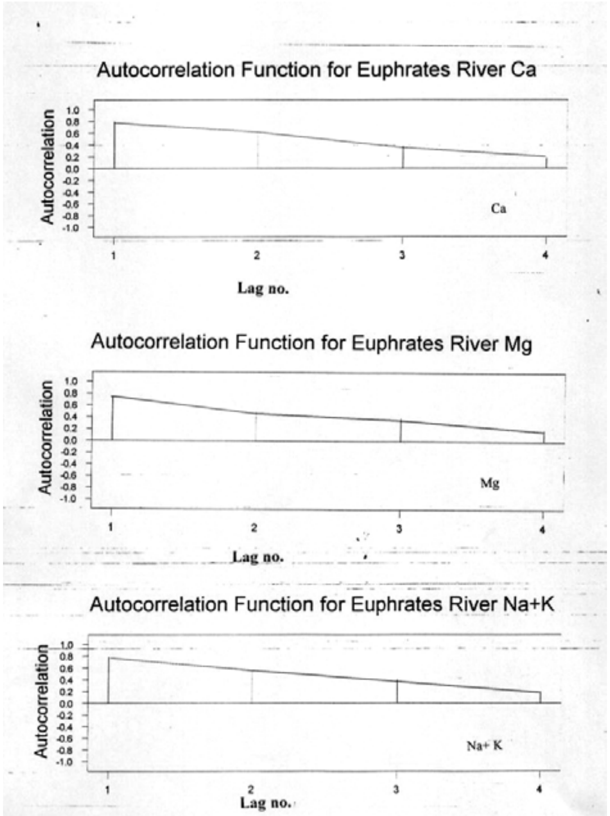

Fig. 10: Variation in Ca,Mg,and Na+K-concentrations alonge Euphrates river course.

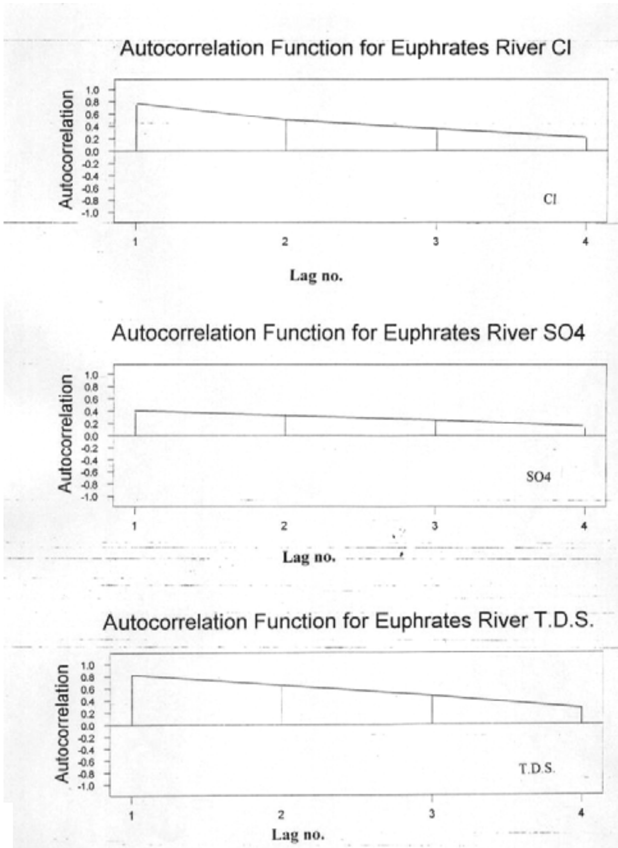

Fig. 9: Variation in Cl,So_4,and T.D.S-concentrations alonge Euphrates river course.

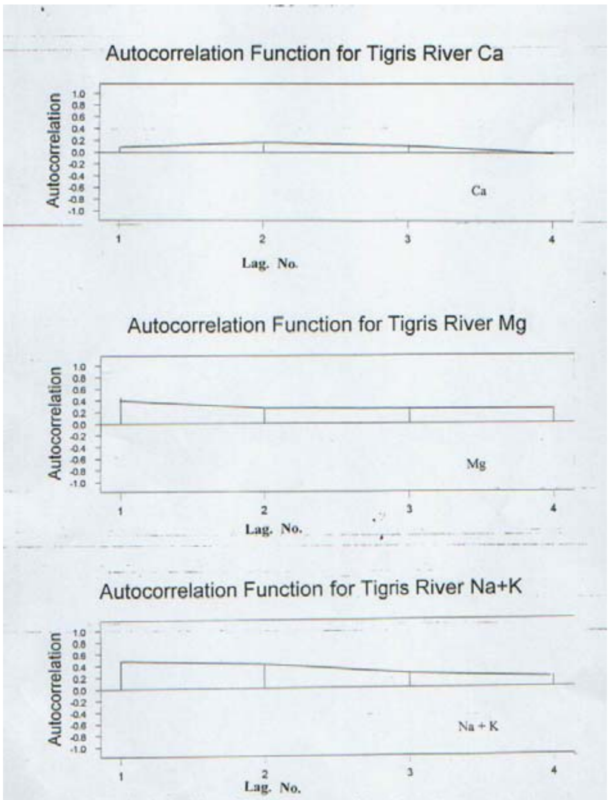

Fig. 12: Variation in Ca,Mg,and Na+K-concentrations alonge Tigris river course.

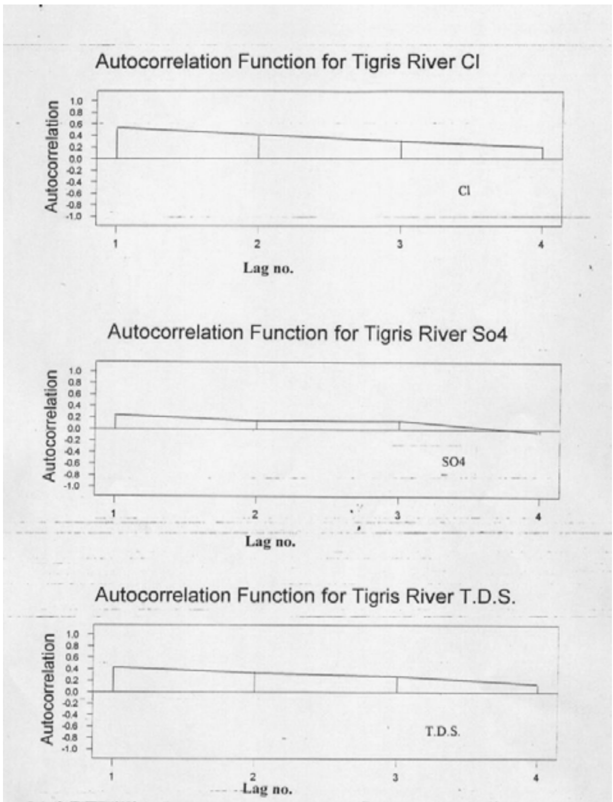

Fig. 11: Variation in Ca,Mg,and Na+K-concentrations alonge Tigris river course.

Cross correlation usually carried out between two groups of equal sample number (Davis, 1973). The total number of the analysed samples of Tigris and Euphrates Rivers are unequal, so to solve this problem eleven samples out of 25 samples were selected from Euphrates River, taking in consideration the long separating distance, the appreciable change in chemical composition, and the coverage of the Euphrates River, the selected stations are Qaim, Anah, Hit, Ramadi, Faluja, Al- Hindiya, Kufa, Samawa, Nasirah, Sug Al-Shukh, and Qurna. This statistical technique showed that the similarity in distribution sequence along both Tigris and Euphrates Rivers is (high matching of their chains).Moreover ,the area of positive matching (Fig 13-15)is larger than the negative one except for sulfate in $SO4=$ in both rivers which reflects the multisources of sulfate contribution. Evaporite sediment – gypsum(Fat'ha Formation), natural sulfurs spring; irrigation and industrial and domestic wastes.

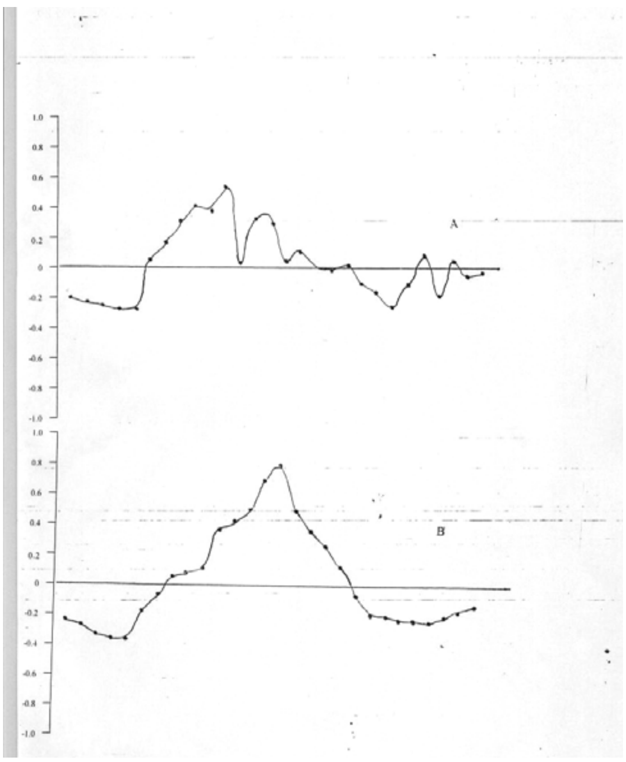

Fig. 14: Cross correlation diagram for Cl and So_4 in Tigris (A) and Euphrates (B) river.

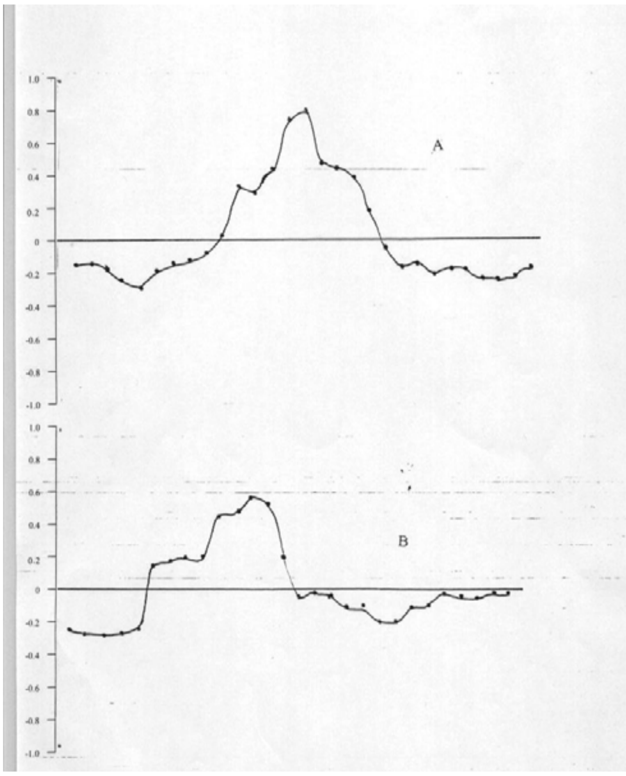

Fig. 13: Cross correlation diagram for Ca and Mg in Tigris and Euphrates waters(A,B) .

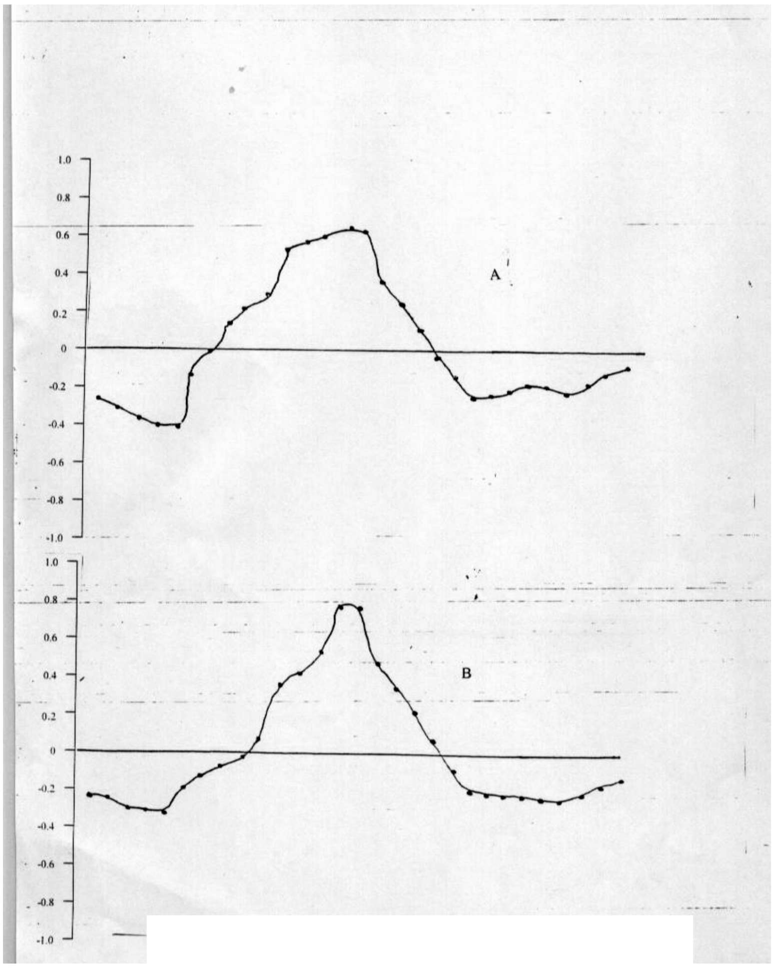

Fig. 15: Cross correlation diagram for Na+K and T.D.S. in Tigris (A) and Euphrates (B) river.

CONCLUSIONS

The average ionic concentration in Tigris and Euphrates waters are greater than that reported in international rivers, this fact could be attributed to lithologic diversity of drainage basin ; igneous and metamorphic rocks in southeast Turkey and northeast Iraq, carbonate and evaporates in the middle part of Iraq ,and saline soil as well as alluvial sediments at the southern part of Iraq. Generally speaking, the water of Tigris and Euphrates deteriorate down stream, the salinity of water increases down stream, but at different rate .Salinity increases gradually at the northern part and rapidly at the middle and south parts of Iraq. Autocorrelation statistical techniques showed the stability of various conditions controlling the ionic contents of Tigris and Euphrates waters except for Ca+2 and SO4= as variation in their concentration along Tigris and Euphrates course were occurred.

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