Variations of Major Ionic Composition and Salinity of Tigris River within Iraq

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Abstract

Major ions are widely used to identify the hydrochemical and hydrological characteristic of water to assess water quality. Major ions compositions (Ca^{+2}, Mg^{+2}, Na^{+1}, K^{+1}, Cl^{-1}, SO_4^{-2}, $[HCO_3]^{-1}$ and $[CO_3]^{-2}$), pH and salinity (TDS) of water in Tigris river were studied to explore the spatial and temporal variations. Six stations (Fishkhapor, Tikrit, Baghdad, Kut, Emarah and Qurna) along river stretch within Iraq were selected to collect samples of water during the period from January 2011 to December 2012 with one month interval. The major ions in Tigris River showed significant spatial variations ($p < 0.05$), while there is no significant temporal variation. Calcium, sodium and magnesium were the most abundant cations with mean concentrations of 52-95 mg/l, 20-217 mg/l and 22-65 mg/l respectively. Sulfate, bicarbonates and chloride were the most abundant major anions, and its average ranged from 111-432 mg/l, from 151 to 159 mg/l and from 18 to 283 mg/l respectively. Generally, the concentration values of major ions were slightly higher in wet season than those in dry season for the first three stations (Fishkhapor, Tikrit and Baghdad), while the values were far higher for the last three stations (Kut, Emarah and Qurna) due to increasing surface runoff, return irrigation water flow and salinity of soil. Major ions distribution along Tigris River as showed by piper and stiff diagram exhibit different pattern of distributions. The water type changed from calcium- bicarbonate at first two stations (Fishkhapor-Tikrit) into calcium- sulfate at middle two stations (Baghdad-Kut), after that changed into sodium- sulfate at the last two stations (Emarah-Qurna). Changes in water type of the Tigris river indicating the increasing effects of geologic formations downstream direction as well as human activities increasing. Generally, the salinity (TDS) of Tigris water increases downstream where average (TDS) values of the Tigris water at the Turkish Iraqi border (Fishkhapor) is about 300 mg/L and it reaches (as average) more than 1300 mg/L in Basra (Qurna). The variations in salinity exhibit three river sections in terms of salt content (TDS): an upper (northern) section (Fishkhapor-Tikrit), where the initial low salt content is maintained or increased slightly downstream; a middle section (Baghdad-Kut), where the dissolved salt variation is more significant; and a lower (southern) section (Emarah-Qurna), where salt content increased to high levels. The nature of these trends changes is related to the geologic formations that the river passes through, increasing in evaporation rate and increasing human activities.

Key words: Anions, Cations, Hydrochemical composition, Tigris River, Salinity.

1. Introduction

The two Rivers, Tigris and Euphrates are the main water sources of Iraq. High percentages of the water from both of them sourced from Turkey (71%) followed by Iran (6.9%) and Syria (4%). The remain is only 8% which is coming from land internal sources (Al-Ansari, 2013). Tigris River is one of the largest rivers in the Middle East, starching for over 1850 km, of which 1418 km are within Iraq. Tigris River has five tributaries inside Iraq; they are from north to south: Khaboor River which is located near turkey-Iraqi border, Upper Zab at about 50 km downstream Mosul city, Lower Zab at about 220 km upstream Baghdad city, Adhaim River 50 km upstream Baghdad city, and Diyala River at 10 km downstream Baghdad city (Al-Murib, 2014). It drains an area of 473,103 km2 which is shared by Turkey, Syria, Iran and Iraq (Al-Ansari and Knutsson, 2011). At Qurna city, south of Iraq, Tigris meets Euphrates to for Shatt Al-Arab River which eventually drains into the Gulf. Tigris River is an important water source for Iraq, and it serves mainly for drinking water supply, irrigation, fishing, recreation and receiving wastewater. Therefore, its water quality is of great concern.

Tigris basin is characterized by its high mountain ranges (Tauros in turkey) followed by the hilly region in the North of Iraq (Kurdistan) 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 Formation (Buday, 1980). Mineral substances contained in natural waters in the dissolved state are conventionally subdivided into macrocomponents and microcomponents. The macrocomponents comprise the so-called main ions that determine water chemical type and account for the bulk of natural water mineral content (up to 95 % of fresh water). The microcomponents comprise substances occurring only under certain conditions and in very small concentrations (< 1 mg/l) (Philip, 1968).

Water compositions provide a record of natural and anthropogenic processes occurring in an environment. The major ion composition of surface water provides insight to understanding the pattern and linkage between chemical weathering, evaporation, atmospheric deposition and anthropogenic process in a basin (Li and Zhang, 2009; Chen et al, 2002; Gibbs, 1970). The study of chemical composition of river waters is important not only for determining erosion rates, but also to learn about sources of elements to rivers, mineral weathering and elemental mobility. In addition, information on river chemistry is essential to assess water quality for domestic, agricultural and industrial usage (Semwal and Jangwan, 2009). In this study, the variations of major ions (Ca++, Mg++, Na+, K+, Cl-, SO4=, HCO3- and CO3=), salinity (TDS) and pH of Tigris River water were investigated to explore the spatial and temporal variation and classify water according to chemical composition and dominant ions as well as to consider the effect of natural and anthropogenic factors on water quality of stream.

2. Materials and Methods

Surface water samples were collected from six sites in the Tigris River along stretch within Iraq. These sites from northern to southern are Fishkhapor, Tikrit, Baghdad, Kut, Emarah and Qurna. A total of 144 samples were collected at a monthly interval from the six sites during the period from January 2011 to December 2012. The samples were collected in acid-washed polyethylene sample bottles. After rinsing three times with river water, the bottles were immersed at least 30 cm below the water surface, capped to exclude air, and then returned to the laboratory for analysis. Water samples were analyzed in labs of National Center of Water Resources Management according to standard method (APHA, 1999) to determine major ions (Ca, Mg, Na, K, HCO3, SO4, Cl, and CO3) and TDS. The imbalances between positive and negative charged ions were tested (should not exceed 10%) to check the overall precision of the analytical procedures (UNEP/WHO, 1996). Analysis of variance (ANOVA) was performed to analyze the significant (set at $p < 0.05$) spatial and temporal differences.

3. Results and Discussion

3.1. Major ion chemistry of Tigris River

Major ion compositions of Tigris River are given in table (1). River water with a mean pH ranging from 7.5 to 7.9 which indicating that the river water is almost neutral to mildly alkaline in nature. Calcium, sodium and magnesium were the most abundant cations with mean concentrations of 52-95 mg/l, 20-217 mg/l and 22-65 mg/l respectively (table 1). Potassium was the least abundant major cation with mean concentrations ranged from 3.2-6.4 mg/l. Sulfate was the most abundant major anion, and its average ranged from 111-432 mg/l. The second most abundant anion was Bicarbonates ranging from 151 to 159 mg/l. The mean concentrations of chloride ranged from 18 to 283 mg/l. Carbonate was the least abundant major anion with average concentrations ranged from 5 to 8 mg/l.

3.2 Spatial and temporal variations of major ion compositions

The major ions in Tigris River showed significant spatial variations ($p < 0.05$) and different pattern of distribution along Tigris river stretch. Representation of major ions distribution pattern of water samples along Tigris river stretch are shown in figure (1) by using piper diagram for the selected six stations. Piper diagram is the most method used to hydrochemical classify of water samples to determine water type (Walton, 1970). A graphical representation by using stiff pattern diagram (figure 2) was used to enhance understanding ionic composition variations and compare water type in the selected stations. Cations spatial trend, as shown in figure (2) follow a sequence of Ca > Mg > Na+K for the first four sites (Fishkhapor, Tikrit, Baghdad, and Kut) then changed into Na+K > Mg > Ca for the last two sites (Emarah and Qurna). On the other hand, anions spatial trend follow the sequence of HCO3+CO3 > SO4 > Cl for the first two sites (Fishkhapor and Tikrit) then changed into SO4 > HCO3+CO3 > Cl at the third sites (Baghdad), after that it's changed again to follow the sequence SO4 > Cl > HCO3+CO3 in the last three sites (Kut, Emarah and Qurna). As listed in table (2), the water type changed from calcium- bicarbonate at first two sites into calcium- sulfate at middle two sites, after that changed into sodium- sulfate at the last two sites. Changes in water type of the Tigris river indicating the increasing effects of geologic formations downstream direction as well as human activities increasing (Ali & Shaban, 2014).

The variation in the concentration of major ions was not significant at the temporal scale, which indicate that natural factors such as geologic factors can be regarded as the main responsible factors controlling the River Tigris water chemistry for the northern and middle sections of river (Fishkhapor, Tikrit and Baghdad) (Dhannoun & Mahmood, 2014, Ali, 2014). After Baghdad downstream direction, increasing the sodium and chloride ions indicate increasing human activities such as domestic wastewater as well as the natural process (Heath, 1987, Howari & Banat, 2002). Generally, the concentration values of major ions were slightly higher in wet season (precipitation of rain) than those in dry season for the first three stations (Fishkhapor, Tikrit and Baghdad), while the values were far higher in wet season than those in dry season for the last three stations (Kut, Emarah and Qurna) due to increasing human activities, surface runoff, return irrigation water flow and soil salinity (Ahmed, 1999, Ali, 2014, Dhannoun & Mahmood, 2014).

3.3. Salinity (TDS) variations

Generally, the water of Tigris deteriorates downstream, the salinity of water increases downstream with a different rate .Salinity increases gradually at the northern part and rapidly at the middle and south parts of Iraq. Average (TDS) values of the Tigris water at the Turkish Iraqi border (Fishkhapor) is about 300 mg/L and it reaches more than 1300 mg/L in Basra (Qurna). The nature of these trends changes is related to the geologic formations that the river passes through, where igneous and metamorphic rocks in the northeast of Iraq, the carbonate in the middle and the Quaternary deposits of clastic nature with some salty sediment are predominant in the southern part. Increasing the rate of evaporation and human activities are additional factor for the TDS increasing at downstream stations (Al-Marsoumi et al. 2006, Ali & Shaban, 2014).

The variations in salinity (TDS) is shown in figure (3) which exhibit three river sections in terms of salt content (TDS) variation along the Tigris River within Iraq: an upper (northern) section (Fishkhapor-Tikrit), where the initial low salt content is maintained or increased slightly downstream due to dilution effect of the Lesser Zab tributary (Assad and Hussain, 1996); a middle section (Baghdad-Kut), where the dissolved salt variation is more significant; and a lower (southern) section (Emarah-Qurna), where salt content increased to high levels. It can be clearly seen from figure (3) that TDS concentrations increase significantly from Baghdad down to Qurna. One of the major reasons for this dramatic increase in TDS in addition to lithologic formations is related to irrigation return flow to the main stream of Tigris River. Also, flow from Tharthar depression (which is heavily saline) to the Tigris is another cause of increasing TDS concentrations in Baghdad and downstream stations (Almurib, 2014). Analysis of variance showed significant spatial variations ($p < 0.05$) in salinity (TDS) values, on the other hand there are no significant temporal variations. The high dissolved solids recorded in wet season belong to increasing surface runoff which has increased the concentration of ions (Rabee et al, 2011).

4. Conclusions

1. The major ions in Tigris River showed significant spatial variations and different pattern of distribution along Tigris river stretch.

2. The variation in the concentration of major ions was not significant at the temporal scale, which indicates that natural factors such as geologic factors can be regarded as the main responsible factors controlling the River Tigris water chemistry.
3. Water type changed from calcium-bicarbonate at first two stations into calcium-sulfate at middle two stations, after that changed into sodium- sulfate at the last two stations.
4. The salinity of Tigris water increases downstream with a different rate .Salinity increases gradually at the northern part and rapidly at the middle and south parts of Iraq.

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التغيرات في تركيب الايونات الرئيسية والملوحة لنهر دجلة في العراق

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الخلاصة :

ان الايونات الرئيسية تستعمل بشكل واسع لتحديد الخصائص الهايدروكيميائية والهايدروجيولوجية لتقييم نوعية المياه . تم دراسة تركيب من مياه نهر دجلة من الايونات الرئيسة (ايونات الكالسيوم ؛ الصوديوم ؛ المغنسيوم ؛ البوتاسيوم ؛ الكلوريد ؛ الكبريتات ؛ البيكاربونات والكربونات) والدالة الحامضية والملوحة (TDS) لاستكشاف التغيرات المكانية والزمانية الحاصلة . ستة مواقع للنمذجة تم اختيارها على طول مجرى النهر داخل العراق (فيشخابور - تكريت - بغداد - كوت - عمارة والقرنة) وفحصت النماذج للفترة من كانون ثاني 2011 لغاية كانون اول 2012 بمعدل نموذج شهريا لكل محطة . الايونات الرئيسية اظهرت تغيرات مكانية (على طول مجرى النهر) مؤثرة (لمستوى دلالة > 0.05) بينما لم تظهر تغير زمني مؤثر . ايونات الكالسيوم والمغنسيوم والصوديوم كانت الاكثر وفرة للايونات الموجبة وبمعدل تركيز تراوح بين 52- 95 ملغم/لتر ؛ 22- 65 ملغم/لتر و 20- 217 ملغم/لتر على التوالي . ايونات الكبريتات والبيكاربونات والكلوريد كانت الاكثرة وفرة بين الايونات السالبة وبمعدل تراكيز تراوحت بين 111- 432 ملغم/لتر ؛ 151- 159 ملغم/لتر و 18- 283 ملغم/لتر على التوالي . بصورة عامة ترتفع تراكيز الايونات الرئيسية بشكل قليل في موسم الشتاء عنها في موسم الصيف بالنسبة للمواقع الثلاثة الاولى بينما ترتفع بشكل كبير بالنسبة للمواقع الثلاثة الاخرى اسفل النهر نتيجة لزيادة الجريان السطحي (surface runoff) ومياه الري الراجعة للنهر وارتفاع ملوحة الارض . نموذج بايبر واشكال ستف استعملت لمعرفة انماط توزيع التركيب الايوني وتحديد نوعية المياه . النتائج اظهرت تغير نوعية مياه النهر من النوع (كالسيوم-بيكاربونات) في اول محطتين (فيشخابور-تكريت) الى النوع (كالسيوم- كبريتات) في المحطات الوسطى (بغداد-كوت) ثم يعود ليتغير الى النوع (صوديوم-كبريتات) في المحطتين الاخيرتين (عمارة- قرنة) . وهذه التغيرات تعكس تأثير التغير في التكوينات الجيولوجية وزيادة الانشطة البشرية على نوعية المياه في مجرى النهر . بصورة عامة تزداد ملوحة النهر مع مجرى النهر باتجاه المصب حيث كان معدل التركيزللاملاح عند الحدود التركية العراقية (فيشخابور) بحدود 300 ملغم/لتر ووصل معدله الى 1300 ملغم/لتر في القرنة (البصرة) . التغير في تركيز الاملاح اظهر ثلاث مقاطع للنهر ، المقطع الاول المتمثل باعلى النهر (فيشخابور-تكريت) ويتميز بالمحتوى الواطيء من الاملاح مع المحافظة على هذا المحتوى او الزيادة بشكل طفيف مع المجرى باتجاه الجنوب في هذا المقطع ؛ اما المقطع الوسطي بعد تكريت الى شمال الكوت فيلحظ زيادة مؤثرة في مستوى الاملاح ؛ اما المقطع الثالث الجنوبي (عمارة-قرنة) فان مستوى الاملاح يرتفع بشكل كبير ومؤثر . ان طبيعة الاتجاه في التغير لمستوى تراكيز الاملاح يرتبط بالتكوينات الجيولوجية التي يمر خلالها النهر وارتفاع معدلات التبخر والزيادة في تاثير الانشطة البشرية .

الكلمات المفتاحية : الايونات ، الموجبة ، الايونات السالبة ، التركيب الهايدروكيميائي ، نهر دجلة ، الملوحة .

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Table (1) : hydrochemical composition of six locations in Tigris River within Iraq from Jan. 2011 to Dec. 2012 (units mg/l* except pH) (Researcher).

		Fishkhapor	Tikrit	Baghdad	Kut	Emarah	Qurna
	Min.	32	38	24	46	40	60
Ca	Mean	55	52	76	88	87	95
	Max.	68	63	136	150	152	120
	Min.	9	10	29	31	41	36
Mg	Mean	22	24	41	53	65	62
	Max.	34	40	52	99	103	101
	Min.	12	16	21	67	120	130
Na	Mean	20	24	67	84	211	217
	Max.	24	32	99	99	375	381
	Min.	1.5	2.5	2.5	3.0	4.0	4.0
k	Mean	3.2	3.3	3.7	4.8	5.9	6.4
	Max.	5.5	4.5	5.0	5.8	7.3	8.0
	Min.	11	14	50	70	163	178
Cl	Mean	18	22	61	98	274	283
	Max.	25	43	117	128	417	426
	Min.	58	86	135	250	230	288
SO4	Mean	111	114	351	344	414	432
	Max.	173	167	489	518	518	672
	Min.	134	128	104	98	122	134
HCO3	Mean	155	153	151	152	154	159
	Max.	183	183	201	177	189	183
	Min.	0	1	1	1	0	1
CO3	Mean	5	5	6	6	7	8
	Max.	12	12	14	18	17	18
	Min.	220	234	422	582	812	930
TDS	Mean	320	331	583	772	1248	1374
	Max.	380	462	848	1183	1678	1847
	Min.	7.0	7.0	7.1	7.2	7.1	7.3
Ph	Mean	7.6	7.5	7.8	7.7	7.8	7.9
	Max.	8.1	8.2	8.4	8.3	8.2	8.4

*Note: To convert from mg/l to meq/l, multiply by conversion factor for each ion (0.0499 for Ca, 0.0823 for Mg, 0.0435 for Na, 0.0256 for K, 0.0282 for Cl, 0.0208 for SO4, 0.0164 for HCO3, 0.0333 for CO3)

Table (2) : Hydrochemical formula and water type for Tigris River (Researcher).

Sites	Hydrochemical formula	water type
Fishkhapor	Ca > Mg > Na+K, Cl < SO4 < HCO3+CO3	calcium bicharbonate
Tikrit	Ca > Mg > Na+K, Cl < SO4 < HCO3+CO3	calcium bicharbonate
Baghdad	Ca > Mg > Na+K, Cl < HCO3+CO3 < SO4	calcium sulfate
Kut	Ca > Mg > Na+K , HCO3+CO3 < Cl < SO4	calcium sulfate
Emarah	Na+K > Mg > Ca, HCO3+CO3 < Cl < SO4	sodiume sulfate
Qurna	Na+K > Mg > Ca, HCO3+CO3 < Cl < SO4	sodiume sulfate

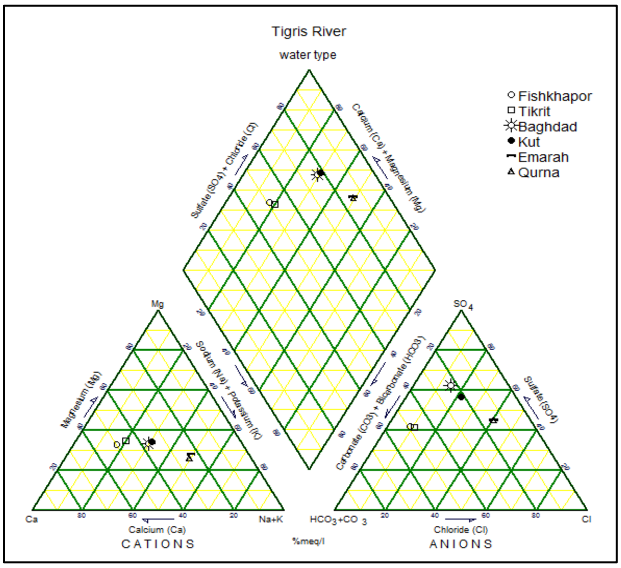

Figure (1) : Piper diagram showing cation and anion compositions of Tigris river water (Researcher).

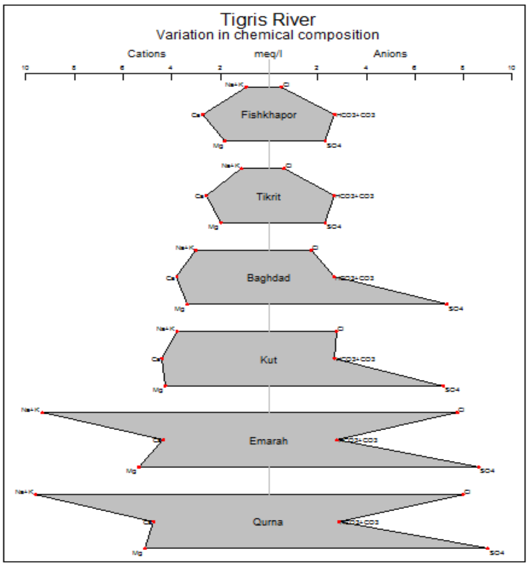

Figure (2) : Stiff diagram showing spatial variation in composition of major ions along Tigris river (Researcher).

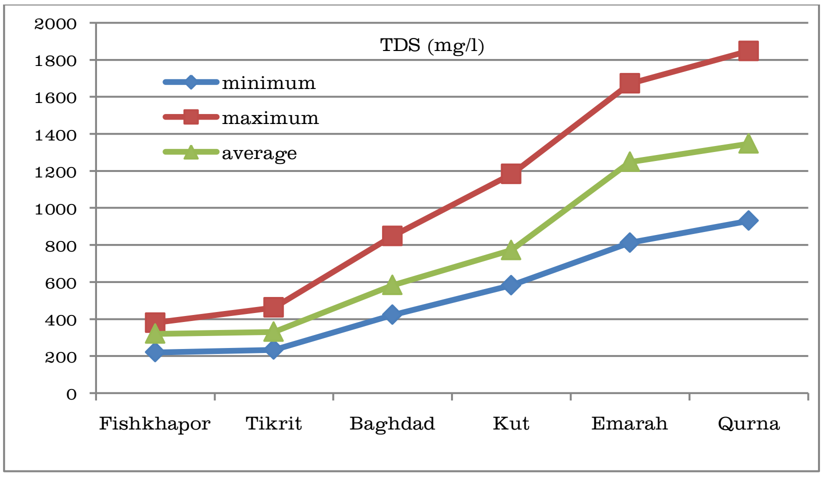

Figure (3): Variation of salinity (TDS) along Tigris River (Researcher).