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Impact of Climate Changes on the Hydrochemistry of Razaza Lake and Rahaliya – Shithatha Springs – Central Iraq

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Abstract
The climate parameters, rainfall, temperature data for more than forty years for three Iraqi meteorological stations (Baghdad, Basra, and Mosul) were studied .The results show good evidence of climate change indicated by the remarkable decrease of the average means annual rainfall in the studied stations, with the remarkable increase of the average minimum annual temperature. The impact of the climatic change on the hydrochemistry of Razaza lake and Rahaliya – Shithatha springs was obvious in increasing the water salinity as studied for years 1995 and 2013. The average mean annual rainfall for ten years intervals indicate that there were a remarkable decrease in amount of rainfall from 90 mm for the period 1992-2001 to about 71 mm for the period 2002- 2013. The Razzaza lake water has indicated that chloride group and one major family (Chloride-sodium family) is the dominant for years 1995 and 2013 with increase of Mg ions during 2013. The Rahaliya – Shithatha springs' water has showed that the sulphate and chloride groups are dominant for years 1995 and 2013, with increase of sulphate group to 80% during 2013.
Keywords: Climatic changes, hydrochemistry, Razaza lake and Rahaliya – Shithatha springs, Iraq.

1. Introduction:

Water resources systems need to be operated to cope with variability of climate changes, mainly the expected changes in temperature and precipitation. Accordingly, there is great need for an emergency or risk water resources management practices. The current water management practices are very likely to be inadequate to reduce the negative impacts of climate change.

Water resources systems, traditionally, designed on the assumption that the statistical characteristics of the hydro-meteorological processes are almost expected annually and on the long run, but now, it is absolutely necessary taking into account the fact that all these parameters are expected to change accordingly with the effects of the global climate change.

Several studies were submitted concerning the hydraulic characteristics and the hydrochemical properties of the groundwater in Iraq (Al-Ani, 2004, Al-Basrawi 1996, Ali, 1994, Consortium Yugoslavia, 1977) but none deals with the effect of the climatic changes on the future utilization of the groundwater basins in Iraq. The impact of the climatic change on the hydrochemistry of Razaza lake and Rahaliya – Shithatha springs for years 1995 and 2013 was chosen as case study to represent the relationship between the surface water of Razaza lake and the groundwater of Rahaliya – Shithatha springs.

Razaza lake is located west of Karbala , representing the second largest lake in Iraq. The Lake was created in 1969, in order to prevent floods that would take place in South Iraq, by deriving waters coming out of Euphrates River. The salinity level has been increasing for so long; while the water level has been decreasing with each passing day (Othman et al., 2013). The arid climate together with the scarcity of rain and dryness of the springs are the main reasons for decrease in water storage of the lake, consequently a considerable change in the lake water quality is indicated, (Fig. 1 and 2), (Jassim and Al-Zubaidi ,2013; Al- Qaraghuli,2014).

The surface area of Lake Razzaza, is 1621 Km^2 in size, 40 meters in depth, and it conserves 25750 billion m^3 water during 1995. While the Lake has been 5-10 meters in depth with 271 Km^2 in size, that conserves 4300 billion m^3 water during 2013 (Othman et al., 2013).

The existence of the lake occupies an important place in the development of the local fish sector, tourism, and economy in the region. The drying lake and the increasing saline concentration have led to the extinction of the fish species, to the bird species leaving the region, to the fishermen's leaving the region in the course of time, or to their changing their heading towards other jobs. According to the experts, the problems to be caused by the drying lake are not only limited with the extinction of fish and aquatic species, but it is also stated that the region will encounter an environmental destruction as a result of the rising temperature (Othman et al., 2013).

Hydrochemical study is considered as one of most essencial ways to assess the water quality and its suitability for different aspects of life (Todd,1980, Davis and Dewiest,1966).Many types of ionic relations could be used , (Sadashivaiah et al ,2008 and Khodapanah,et al, 2009) . Chemical classification of the dominant cations and anions concentration and their interrelatioships may throws light on the water quality changes within time and the origin of the water (Zaporozee,1972).

The study area is located west of Karbala City between 32º 15` and 32º 45` North and 43º 25` and 44º 00` East (Fig.1). The area is characterized by arid climate of hot dry summer ,cold dry winter with annual rainfall (90 mm) mainly during January to April and annual evaporation (2954 mm) (Table 1) (Al-Qaraghuli,2014). The area is of simple topography, having a gentle slope terrains toward the east (toward Al-Razzaza lake) where the land surface slope is very small and the slope of beds is less than one degree in the direction of east and northeast with elevations of (65- 35) m. above mean sea level (Al- Mehaidi *et al*., 1975).

Razaza Lake is surrounded by Tertiary sediments of different ages and types such as Dammam, Euphrates, Nfayil, Injana and Dibdiba formations. Quaternary sediments cover vast area of the lake vicinity represented by gypcrete, inland sabkha, depression fill, flood plain and Aeolian sediments (Figures 1and 2).
The study area is characterized by the existence of:
A-Abu Jir Fault System
B-Imam Ahmad bin Hashim Fault System

These faults are deep (more than 150 m) for a period before Miocene and trends of this system is the northwest - southeast (Al-Sakini, 1984, Brazaniji and Yasi, 1987). It is believed that in the Al-Rahhalia and Shithatha areas through water of springs that appear along the same line, which spread to more than 10 km in width, (Abbas and Al-Khatib, 1982, Al-Sakini, 1984).

Therefore ,it is vital to study the hydrochemical assessment for the lake water quality and its relation with the available springes water in Rahaliya – Shithatha area which is believed to be as important water input to the lake.

The aims of this research are to indicate the evidences of climatic change in Iraq by studying the climate parameters, rainfall, temperature data for more than forty years for three Iraqi meteorological stations (Baghdad, Basra, and Mosul), and to investigate the hydrochemical properties of the Razzaza Lake and springs water in the Al-Rahaliya – Shithatha Area during summer season of years 1995 and 2013.

2. Materials and Methods

A. Climatic parameter analysis in Iraq

Topography plays an essential role in climate. Three representative meteorological stations were chosen in order to analyze the general climatic elements. Mosul meteorological station is chosen to represent the folded belt foothills, and mountain in the north, Baghdad meteorological station to represent the Mesopotamia plain, and flood plain in the center part of Iraq, and Basra meteorological station to represent the coastal area which extends to the south containing marshes in the south, and expresses a coastal environment that lies near the delta of the Arabian Gulf, (Fig. 1). The available data for about 70 years of Mosul , Baghdad and Basra meteorological stations records of the climatic elements were studied (for the years 1938 – 2008) , such as the mean minimum annual temperature, and the mean annual rainfall (Mahmud, et al ,2013)**.**

In this study, the CO_2 level that had been gotten from the Carbon Dioxide Information Analyses Center (CDIAC) was used in comparison with the temperatures of three meteorological stations in Iraq since 1970-2008 for evaluating the local climatic warming and for predicting future warming, (Fig. 3).

B. The hydrochemical analysis

Eight water samples were collected from the area during summer season of year 2013, three from the Razzaza Lake and five from Rahaliya –Shithatha area springs, Figure 1 and compared with water samples collected almost from the same locations during summer season of year 1995 (Al-Basrawi 1996). The analysis of the concentration of cations (K^+, Na^+, Mg^{2+}, Ca^{2+}) and anions (Cl^-,HCO_3^-, SO_4^{2-}) in addition to (Electric conductivity EC, Total dissolved salts TDS and pH) have been done in the chemical laboratory of the General Commission for Groundwater. Major ions, TDS, EC and pH of Razaza lake and Rahaliya – Shithatha springs water samples for years 1995 and 2013 were shown in Tables 1 and 2 respectively.

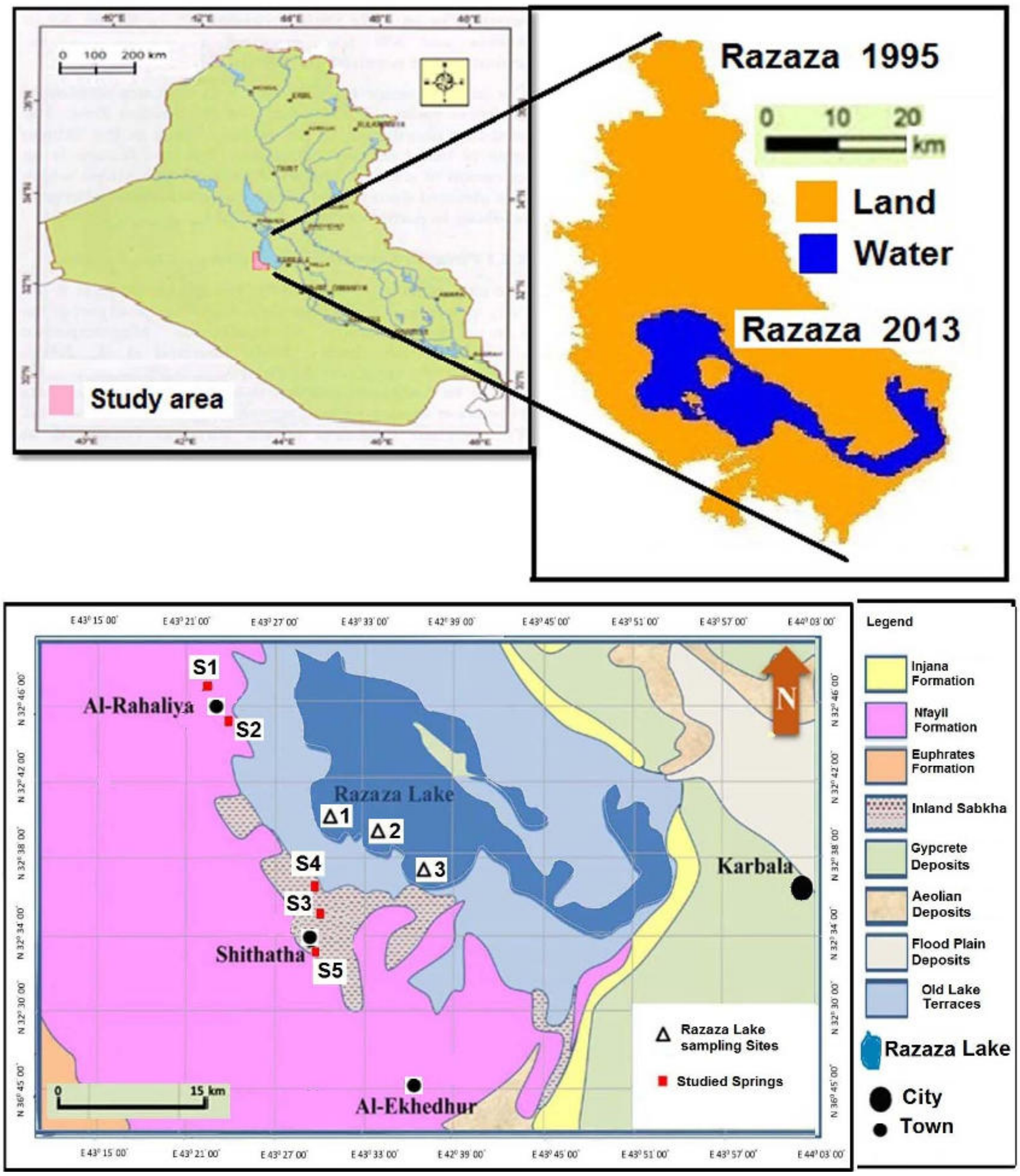


Figure 1: Location and geological map of the study area.

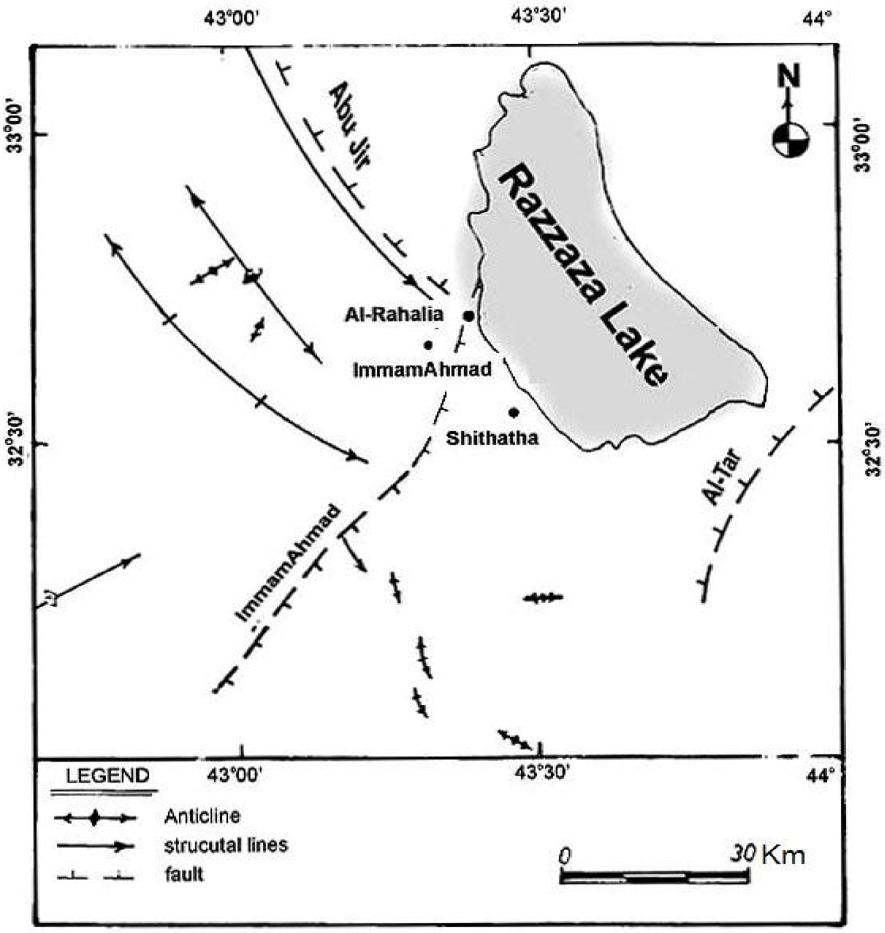


Figure 2: Tectonic map of the study area (modified after Sissakian, et al, 2000).

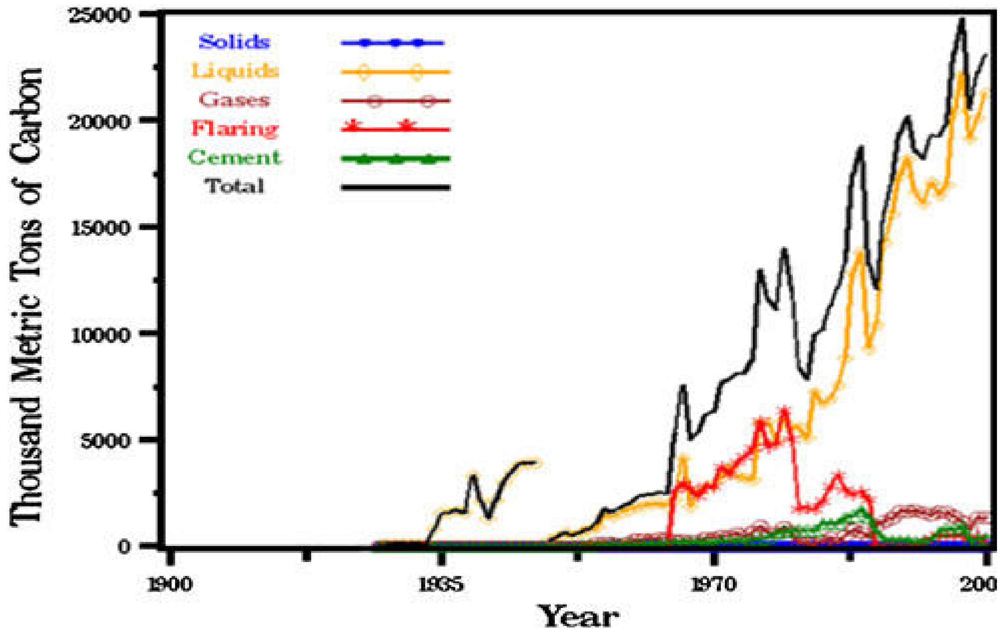


Figure 3: Concentration of carbon dioxide gas in Iraq (from Carbon Dioxide Information Analysis Center, http://cdiac.ornl.gov)

3. Results and discussion

A-Climate

A-1.The Rainfall Analysis:

The average means annual rainfall in mm frequency curves for the years 1938 – 2008, were studied. The relationship between rainfall and time seems negative in Mosul, Baghdad, and Basra (Fig. 4). Remarkable decrease in rainfall amounts were indicating from the general trend line for Baghdad, Basra, and Mosul meteorological stations, (Fig.4).

Moreover, comparison of the annual rainfall distribution maps for the period 1970-1980 and the period 2000-2012 reflect that there was clear upward shifting of the rainfall contour lines, (Fig. 5). The higher average rainfall was in Mosul between 300-400 mm for the periods 1970-1980 and decreased to be between 200-300 mm for the periods 2000-2012. While, the lower average rainfall was in Baghdad and in Basra, between 100-200 mm for the periods 1970-1980 ,whereas the lower average for the period 200-2012 was in Baghdad which decrease to be less than 100 mm (Fig. 5).

B -2. The mean annual temperature:

The average mean annual minimum temperature (°C) frequency curves for the years 1941 – 2009, were studied. The relationship between temperature and time seems positive in Mosul, Baghdad, and Basra (Fig. 6). Remarkable increase in temperature values were indicating from the general trend line for Baghdad, Basra, and Mosul meteorological stations, (Fig. 6).

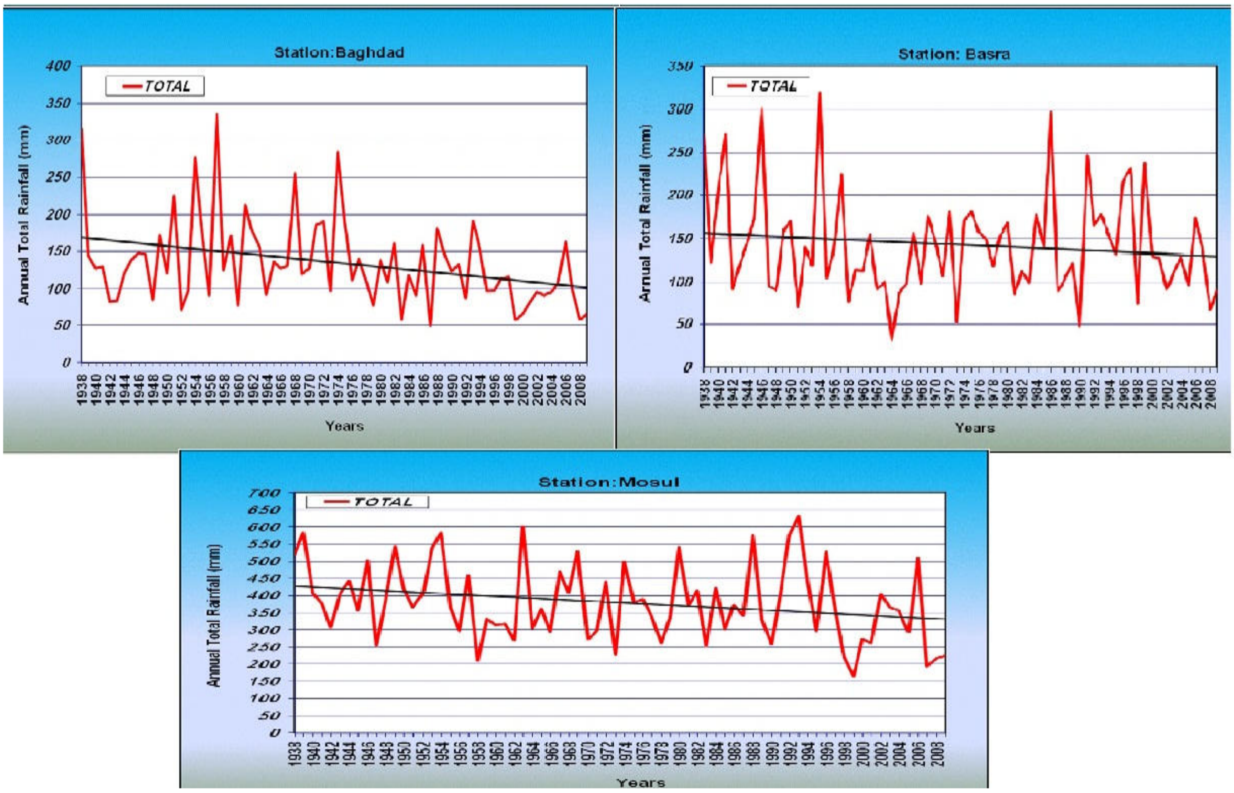
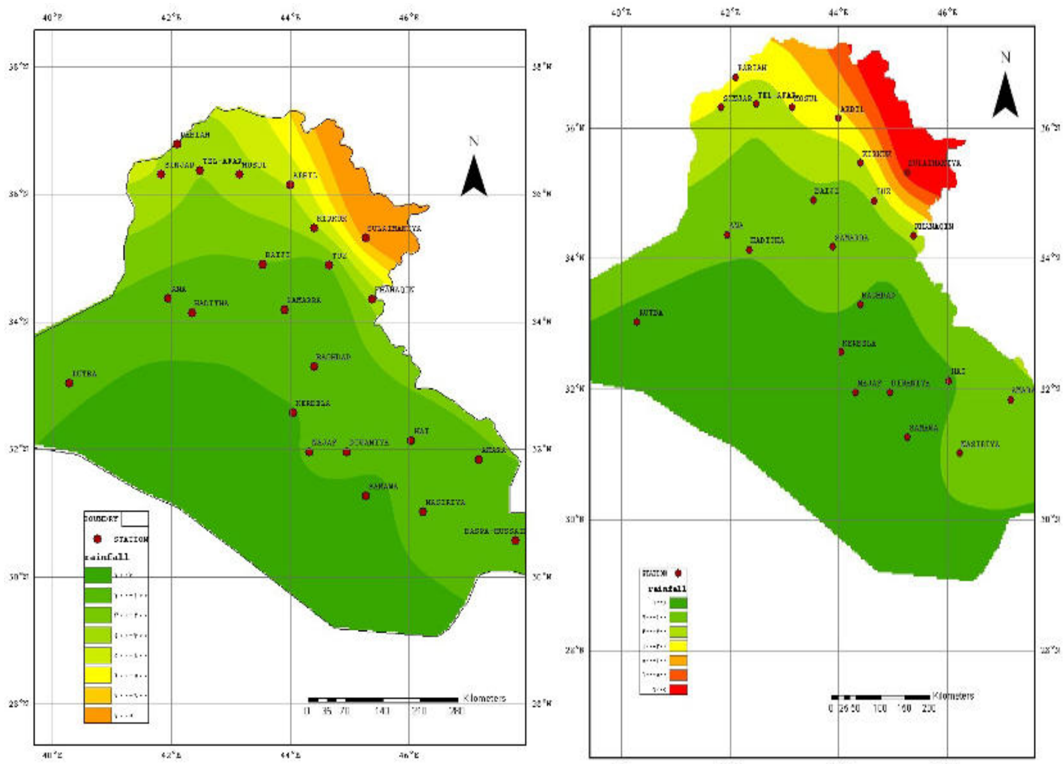


Figure 4: The average mean annual rainfall (mm) frequency curves of Baghdad ,Basra and Mosul meteorological stations for years 1938-2008.



(A) (B)

Figure 5 : The average mean annual rainfall (mm) for the years 1970-1980 and for the years 2000-2012 (B).

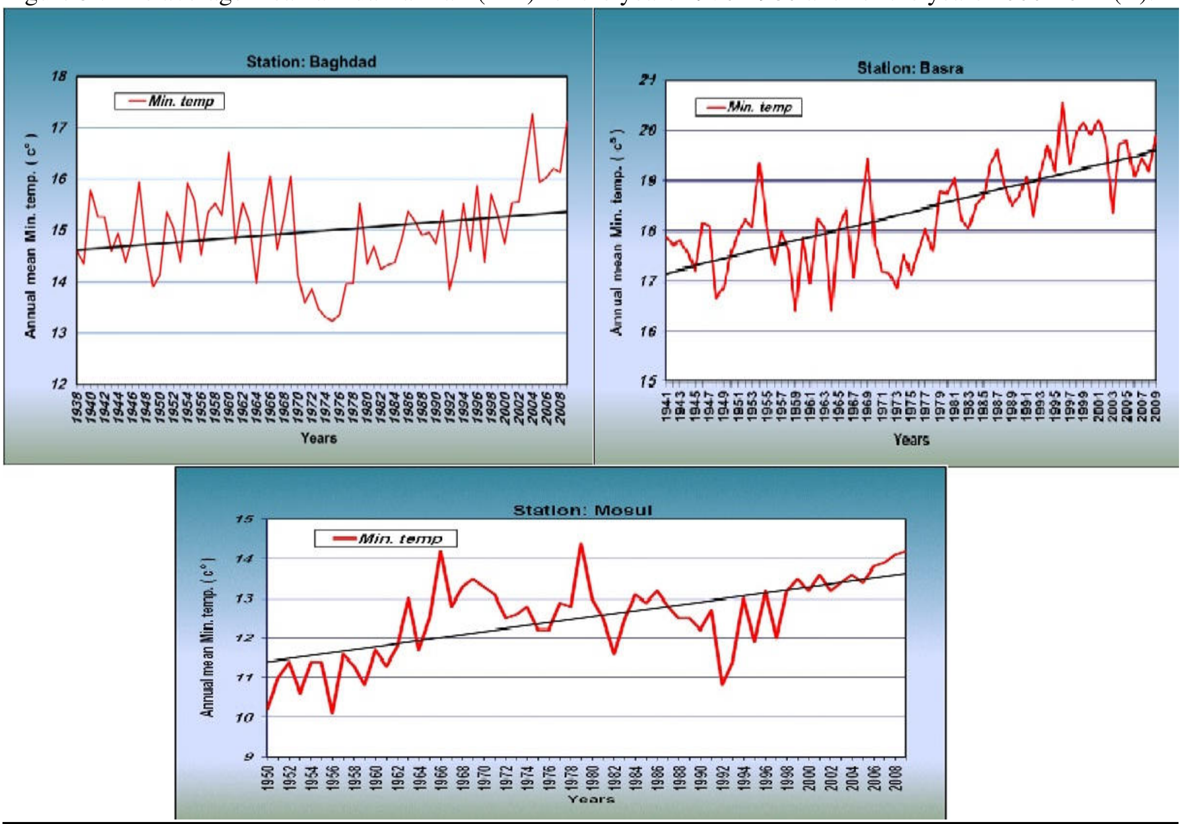


Figure 6 : The average mean annual minimum temperature (°C) frequency curves of Baghdad ,Basra and Mosul meteorological stations for years 1938-2008

B-The effect of carbon dioxide in Iraq

The geosphere plays a role in the regulation and variation of global climate, to a greater or lesser extent, over varying time scales (Buchdahl 1999, Bridgman and Oliver 2006).

The global climate system was influenced, primarily by increasing the Earth's natural greenhouse effect as indicated by the increase of the global mean temperature at the surface of the Earth by approximately 0.5°C between years 1850 and 1990 (Lean and Rind 1996, Buchdahl 1999). During the same period, the amount of carbon dioxide measured in the Earth's atmosphere increased by about 25%. This raises the possibility that the two trends are directly connected, and the climate system responds to human activities (Lean and Rind 1996).

Currently, there are 359 parts per million by volume (ppmv) of CO_2 in the atmosphere, a concentration which is continuing to rise due to anthropogenic (man-made) emissions from the burning of fossil fuels and forests (Schimel et al. 1995). There is a strong correlation between carbon dioxide content in the atmosphere and temperature (Petit and Jousel 1999).

Level and source of carbon dioxide in Iraq is emitted from many sources, such as fossil fuel burning (solid, liquid, and gas), flaring and the cement industry (Blasing, 2013). The war in March 2003 is responsible for at least 141 million metric tons of carbon dioxide. Between March 2003 and October 2007, the US military in Iraq purchased more than 4 billion gallons of fuel from the Defense Energy Support Center (DESC). The agency is responsible for procuring and supplying petroleum products to the Department of Defense. Burning these fuels has directly produced nearly 39 million metric tons of CO_2 (Reisch and Kretzmann 2008). Generally, a considerable increase in CO_2 level since 1950 to 2007 in Iraq had been obviously detected (CDIAC). Figure 2 displays the increase of temperature during the period extending between 1970 and 2008. This refers to the CO_2 role in climatic warming.

The influence of the Arabian Gulf on the climate of Iraq is very limited but appears to be clear on Basra climate.

C-The hydrochemistry of the Razzaza Lake and Rahaliya – Shithatha springs

The Razzaza lake water is characterized by their wide variation in TDS (ranging from 14000 to 16640 ppm during 1995 while during 2013 ranging from 21400 to 24960 ppm) and EC (ranging from 18510 to 21000 µs/cm during 1995 while during 2013 ranging from 26000 to 42910µs/cm) with pH values ranging from 7.5 to 7.6 during 1995 while during 2013 ranging from 7.2 to 7.4 . The springs' water of Rahaliya – Shithatha Area is characterized by their variation in TDS (ranging from 2030 to 2230 ppm during 1995 while during 2013 ranging from 2135 to 2371 ppm) and EC(ranging from 2100 to 2700µs/cm during 1995 while during 2013 ranging from 2400 to 3310 µs/cm) with pH values ranging from 7.2 to 7.6 during 1995 while during 2013 ranging from 7.2-7.8 . Appling Detay, 1997 relationship between electrical conductivity (EC µS/cm) and water mineralization. It can be concluded that the type of spring and Razzaza lake water indicate excessively mineralized water. Comparison of TDS values for both periods with three classifications of water (Altoviski,1962; Drever,1997 and Todd,2007), it is clear that the groundwater in the studied area is classified as slightly-brackish water for the spring water and as brackish water for the Razzaza lake water, accordingly all the water samples were not useful for drinking .

Appling Sulin's 1946 classification, the Razaza lake and spring's water samples fall in the zone of A< 1 that represent marine water in semi confined aquifer and in the zone of B<1 that represent meteoric origin of Na+K - Sulphate . While according to Piper's 1944 classification the water samples fall in e -class which represents earth alkaline water with increase portion of alkali with prevailing sulphate and chloride,and some of these samples fall in g - class which represents alkaline water with prevailing sulphate and chloride. The application of Piper's diagram 1944 shows that all water samples have non carbonate hardness (secondary salinity)>50% . Moreover, all the water samples have total hardness value > 300 and according to Todd's classification 1980 all the water samples were not useful for drinking.

The result of using Hassan, et al, 1988, method to classify the Razzaza Lake and springs' water of Rahaliya – Shithatha Area during 1995 and during 2013, and identifying their water types are shown in Tables 1, 2, 3 and 4.

The Razzaza lake water has clearly indicated that chloride ions are the dominant ions during 1995 and during 2013. The chloride group in year 1995 contains one major family (Chloride-sodium family) and one water type which is rNa>.rCa>rMg; rCl>SO4. While, during the year 2013, the chloride group contains the same major family, (Chloride-sodium family) and two water types which is rNa>.rCa>rMg; rCl>SO4 and rNa>rMg> rCa; rCl>SO4.

The Rahaliya – Shithatha springs' water has clearly indicated that the sulphate and chloride groups are dominant during 1995 and during 2013. The sulphate group with two families (sulphate -sodium and sulphate-magnesium) the first family with two water types rNa>.rCa>rMg; SO4> rCl and rNa>rMg> rCa; rSO4> rCl, while the second family with only one major water type rMg> rCa> rNa; rSO4> rCl during 1995 and rMg> rNa >rCa; rSO4> rCl water type during 2013. The chloride group contains one major family (chloride -sodium family) and one water type which is rNa>.rCa>rMg; rCl>rSO4 during 1995 and rNa >rMg> rCa; rCl>rSO4 water type during 2013.

This variation can be attributed to the lithological and mineralogical contents of the geological formation or to the spatial variation in controlling factors that are responsible for sedimentation and dissolution of different minerals. The springs' water samples in the study area are divided into two types, the first is marine water and the second is meteoric water. Marine origin was gathered through sedimentation under marine conditions at the late of Miocene age or this water came from a deep origin because of existence of a different pressure caused to make a vertical flow of groundwater. So that continental water is considered as a conveying factor to the water of marine origin. According to Hassan, et al, 1988, it is clearly appeared that sulphate and chloride ions are the dominant ions in the study area. Al-Basrawi, 1996, concluded that the main groundwater recharge sources at the west and south west of Razaza lake are from the subsurface water flow from the west and south west catchment of the studied area which flow through fractures and subsurface channels that affected by the fault systems of the area represented by Abu Jeir and emam Ahmad faults (Fig.2). Moreover, the spring water and razaza lake water are similar to the deep groundwater of Tayarat aquifer of Chloride group with Chloride-Sodium family that affected the Dammam and Euphrates aquifers of Sulphate group with Sulphate-Sodium and Sulphate- Magnesium families.

The rainfall represent water availability element which is vital for the water surplus occurred in the study area and it is the most important climate elements in the water balance and aquifer recharge. The increase precipitation has an impact on the groundwater and transmission of material from the upper parts to the lower parts. The average means annual rainfall in mm for ten years intervals indicate that there were a remarkable decrease in amount of rainfall for years (1992-2013) that reflected the regional climatic change as shown for Karbala meteorological station, the average mean annual rainfall in mm for ten years intervals decrease from 90 mm for the period (1992-2001) to about 71 mm for the period (2002- 2013) (Al- Qaraghuli, 2014).

Table 1: Physical and Chemical properties of the Razaza Lake water samples for years 1995 and 2013.

S. years	pH	TDS (ppm)	(Ec) (µs/cm)	Ca^{+2} ppm	Ca^{+2} epm	Mg^{+2} ppm	Mg^{+2} epm	Na^{+} ppm	Na^{+} epm	K^{+} ppm	K^{+} epm	Cl^{-} ppm	Cl^{-} epm	SO_4^{-2} ppm	SO_4^{-2} epm	HCO_3^{-} ppm	HCO_3^{-} epm
West Razaza lake 1995	7.5	16640	21000	980	49	516	43	3289	143	195	5	5460	156	3264	68	120	2
	7.6	14995	20100	900	45	432	36	2990	130	195	5	4900	140	3120	65	126	2.1
	7.6	14000	18510	840	42	444	37	2852	124	187	4.8	4550	130	3024	63	126	2.1
West Razaza lake 2013	7.4	21400	26000	1180	59	648	54	4278	186	265	6.8	6965	199	4368	91	122	2
	7.3	24960	42910	2100	106	1060	88	5300	230	380	9.6	8800	258	4800	100	143	2.3
	7.2	23220	42890	1300	66	850	70	4900	214	360	9.2	6320	180	5488	114	143	2.3

Table 2: Physical and Chemical properties of the Rahaliya – Shithatha area springs water samples for years 1995 and 2013.

Spr. No.		pH	TDS (ppm)	(Ec) (µs/cm)	Ca^{+2} ppm	Ca^{+2} epm	Mg^{+2} ppm	Mg^{+2} epm	Na^{+} ppm	Na^{+} epm	K^{+} ppm	K^{+} epm	Cl^{-} ppm	Cl^{-} epm	SO_4^{-2} ppm	SO_4^{-2} epm	HCO_3^{-} ppm	HCO_3^{-} epm
S1	1995	7.6	2082	2100	162	8.1	88	7.2	301	13.1	35.3	0.9	561	15.9	516	10.7	159	2.6
S2		7.2	2090	2200	184	9.2	140	11.5	196	8.5	43.1	1.1	509	14.4	710	14.7	233	3.8
S3		7.2	2030	2540	156	7.8	93	7.6	306	13.3	35.3	0.9	547	15.5	525	10.9	135	2.2
S4		7.4	2139	2658	125	6.23	84	6.9	130	15	10	0.26	415	11.7	572	11.9	129	2.1
S5		7.4	2230	2700	160	7.97	91	7.48	256	11.1	7	0.18	389	11.0	545	11.3	210	3.4
SS1	2013	7.2	2155	2400	150	7.5	104	8.5	288	12.5	74.5	1.9	332	9.4	429	8.9	141	2.3
SS2		7.8	2270	2830	162	8.1	131	10.7	228	9.9	39.2	1.0	487	13.8	677	14	165	2.7
SS3		7.2	2135	2650	180	9.0	69.5	5.7	317	13.8	47	1.2	490	13.9	690	14.3	129	2.1
SS4		7.2	2205	2760	156	7.8	116	9.5	331	14.4	55	1.4	466	13.2	646	13.4	153	2.5
SS5		7.3	2371	3310	126	6.28	83	6.82	135	15.9	12	0.31	442	12.5	620	12.9	202	3.3

Table 3: Schoeller- Sulin's 1981 classification of the Rahaliya – Shithatha springs' water of during 1995.

	Family	Group	Index	Water type	Spring No.	%
1	Sulphate- Sodium	Sulphate	13; 32	rNa>rMg> rCa; rSO4>Cl	S4,	20%
2			23; 32	rNa>.rCa>rMg ; rSO4 >rCl	S5	20%
3	Sulphate- Magnesium		53; 32	rMg>rCa> rNa; rSO4>Cl	S2	20%
4	Chloride-Sodium	Chloride	23;12	rNa>.rCa>rMg; rCl>SO4	S1,S3,	40%

Table 4: Schoeller- Sulin's 1981 classification of the Rahaliya – Shithatha springs' water of during 2013.

	Family	Group	Index	Water type	Spring No.	%
1	Sulphate- Sodium	Sulphate	13; 32	rNa>rMg> rCa; rSO4>Cl	SS4, SS5	40%
2			23; 32	rNa>.rCa>rMg ; rSO4 >rCl	SS3	20%
3	Sulphate- Magnesium		33; 32	rMg> rNa >rCa; rSO4>Cl	SS2	20%
4	Chloride-Sodium	Chloride	13;12	rNa>rMg> rCa; rCl>SO4	SS1	20%

4. Conclusion

a- The analysis of climate parameters for three Iraqi meteorological stations (Baghdad, Basra, and Mosul) show remarkable increase of the average minimum annual temperature with remarkable decrease of the average means annual rainfall from 90 mm for the period 1992-2001 to about 71 mm for the period 2002- 2013.
b- The impact of the climatic change on the hydrochemistry of Razaza lake and Rahaliya – Shithatha springs was obvious in increasing the water salinity as studied for years 1995 and 2013.
c- The Razzaza lake water has indicated that chloride group and one major family (Chloride-sodium family) is the dominant for years 1995 and 2013 with increase of Mg ions during 2013.
d- The Rahaliya – Shithatha springs' water has showed that the sulphate and chloride groups are dominant for years 1995 and 2013, with increase of sulphate group to 80% during 2013.

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