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ASSESSMENT OF GROUNDWATER QUALITY FOR DRINKING IN TUZ KHURMATU AREA, SALAHADDEN GOVERNORATE – IRAQ

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ABSTRACT

The results of climatic data that obtained from Tuz Khurmatu meteorological station show actual evidence in the climatic changes, which are indicated by remarkable decreases in the means of annual rainfall, relative humidity percentages and with increases of the means of annual minimum and maximum temperatures. The unconfined aquifer of Adaim river basin is recharged mainly from rain water. Since this source is scarce, the aquifer gains its water slowly in a rate less than the rate of losing by both evaporation and abstraction wells. The water Quality Index (WQI) has been used to assess suitability of groundwater quality for human drinking purpose in Tuz Khurmatu area. Groundwater samples were collected in September (2010) and March (2011) from twenty wells and analyzed for their physicochemical characteristics such as pH, total dissolved solids, Electrical Conductivity, sodium, calcium, magnesium, potassium, bicarbonate, sulphate, chloride and nitrate. Each parameter was compared with its standard permissible limit as prescribed by Iraqi drinking water standards. The results showed that WQI values for the groundwater of the study area ranged from 27.25 to 139.81. Based on the WQI classification majority of the samples are falling under excellent to good water category and suitable for drinking water purpose.

Keywords: Climate, Groundwater, WQI, Tuz Khurmatu, Iraq

INTRODUCTION

The climate of Iraq is characterized by hot-dry summers and cold-rainy winters. Roughly 90% of the annual rainfall occurs between November and April. The temperature in Iraq ranges from 53 °C in July and August to freezing point in January.

Water resources systems need to be operated to cope with variability of climate changes; mainly the expected changes in temperature and precipitation then there are great need for an emergency or risk water resources management practices. Actually, 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 term. However, nowadays, 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 (Al-Dabbas *et al.*, 2016). The impact of the climatic change on the groundwater was obvious in declining the water table as studied in the unconfined aquifer in Tuz Khurmatu area. The Tuz Khurmatu aquifer as case study was chosen to represents the shallow aquifer which recharged mainly from rain water. Since this source is scarce, the aquifer gains its water slowly in a rate less than the rate of losing it by both evaporation and abstraction wells (Rasheed and Al-Kubaisi, 2016). As a result the aquifer is not fully saturated and wide parts are lacking sufficient groundwater. The groundwater in the study during the last two decades had suffered pollution, depletion, bad quality and quantity due to heavy and excessive pumping of groundwater and planting the area, especially during the dry season (April – October) (Rasheed, 2012, and Rasheed and Al-Kubaisi, 2016). Major areas in Iraq are depending on the groundwater, for both domestic and the agricultural sectors. Quantity of groundwater has been badly changes through increasing of total soluble salts. This might be developed due to many new wells, new farms, and heavy population, improperly wells drilling with no previous recommendation and attention (SubbaRao, 2006, and Al-Tamimi, 2007).

In recent decades the groundwater became one of the most important natural resources in Tuz Khurmatu Area, Salahadden Governorate as a result of increasing water demand and decreasing of rainfall amount and surface water supplies. The increase in population and expansion of economic activities undoubtedly leads to increasing demand of water use for various purposes. The degree of severity of groundwater pollution is depends on the types and amount of waste, disposal methods, climate, and hydrologic properties of the aquifer, recharge capacity of the area and rate of pumping out of water (Vigneswaran *et al.*, 2004, SubbaRao, 2006, and Rao *et al.*

2010).WQI is an important technique for demarcating groundwater quality and its suitability for drinking purposes. It is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water for human consumption (Tiwari and Mishra, 1985).

The study area is located in Salahadden governorate between latitudes (34° 50' 00" – 34° 55' 00") and longitudes (44° 33' 00" – 44° 40' 00"). It is a part of Adhaim basin (Fig. 1). The common climate in the area is humid to moist (Rasheed, 2012).

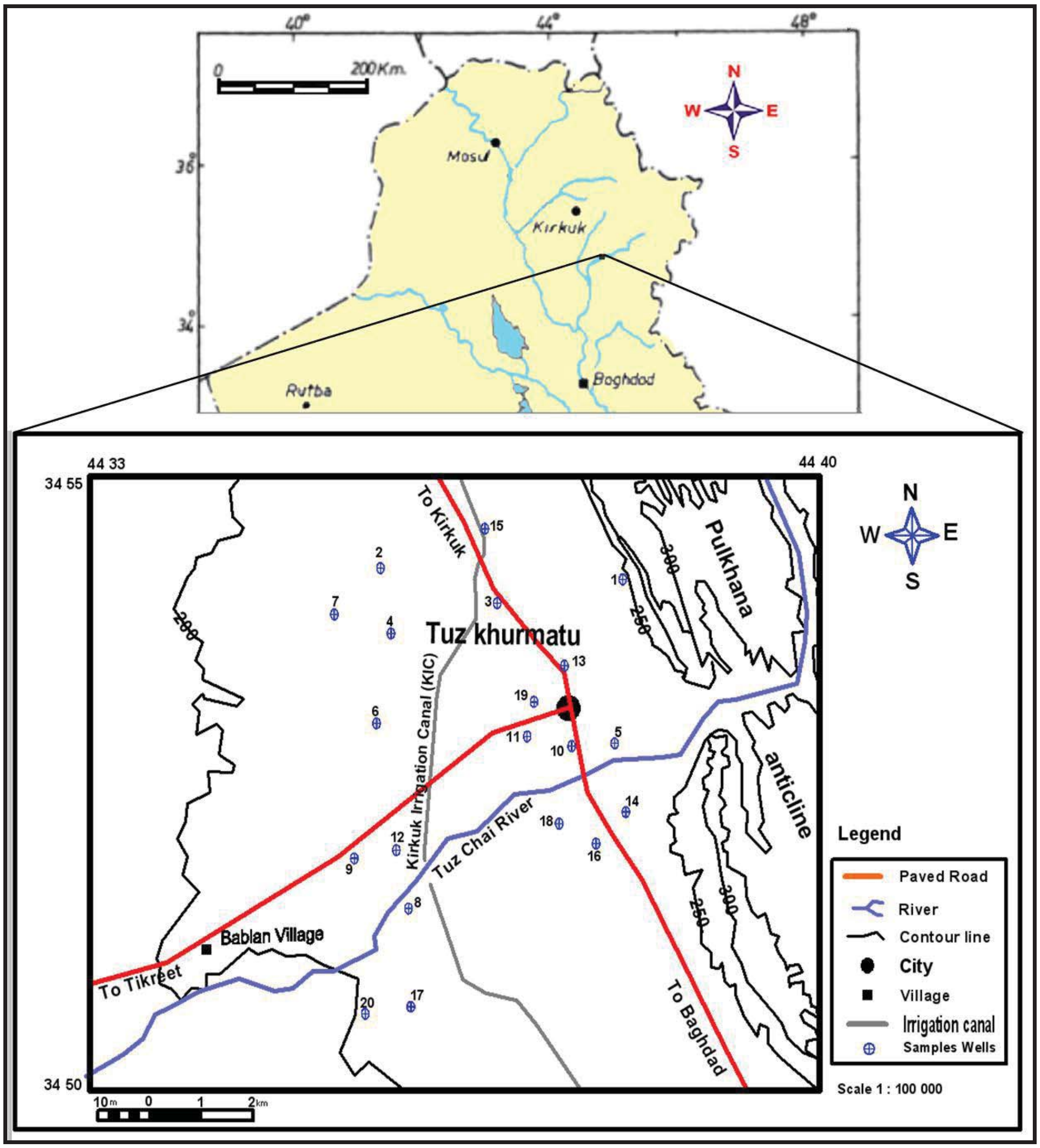

Fig. 1: Study area with samples' locations

The important water bearing formations (aquifers) in the basin consist of Tertiary deposits (Muqdadiya and Bai-Hassan formations) as well as recent Quaternary deposits (Abdul Razaq *et al*., 2007). The major sources of groundwater recharge are precipitation and water infiltration from surface runoff (Tuz chai River) and water losses from irrigation canal (Kirkuk irrigation canal) (Rasheed, 2012). All wells in Tuz Khurmatu area are penetrating Bai-Hassan Formation partially by different depths. Therefore this formation represent the upper and main hydrogeological productive aquifer in the study area . It is considered important aquifer of sandstone and, underlying Mukdadyia formation and the overlying Quaternary deposit gravel (Khudair *et al*., 2000, and Al-Rubaii, 2008). Al-Fat'ha formation (contains evaporates rocks) appears in Pulkhana anticline and affect the groundwater salinity in the area (Mohamed *et al*., 2009, and Stevanovic and Iurkiewicz, 2009). The aims of this research are to indicate the evidences of climatic change by studying the climatic parameters, rainfall, relative humidity percentages and temperature data, also assess suitability of groundwater for human consumption by using (WQI).

MATERIALS AND METHODS

The methodology of this research includes:

A. Climatic Parameter Analysis

Tuz Khurmatu meteorological station was chosen in order to analyze climatic parameters e.g., rainfall, minimum and maximum temperatures and relative humidity % records. The available data for thirty years (1991 to 2010) records of the climatic elements were studied, such as temperature, evaporation and rainfall (Iraqi Meteorological Organization, 2013, and Al-Hashemi, 2013).

B. Evaluation of Groundwater Quality

Groundwater samples were collected from twenty wells from the study area for two periods during September (2010) and March (2011) (Fig. 1). Each of the groundwater samples was analyzed for eleven parameters which are pH, total dissolved solids (TDS), Electrical Conductivity (EC), sodium, calcium, magnesium, potassium, bicarbonate, sulphate, chloride and nitrate using standard procedures recommended by (APHA, 1998).The mean concentrations of parameters of the two periods are shown in Table 1.

Table 1: The mean values of physical and chemical parameters of water samples collected during wet and dry seasons

Well No.	pH	TDS mg/l	EC (µS/cm)	Ca^{+2} mg/l	Mg^{+2} mg/l	Na^{+} mg/l	K^{+} mg/l	HCO_3^- mg/l	SO_4^{-2} mg/l	Cl^- mg/l	NO_3^- mg/l
1	7.7	1551	2379	167.1	83.6	167.2	2	347.8	353	337.3	5.5
2	7.4	1533	2160	159.7	64	213.2	1.36	314.5	374.6	326.5	2.1
3	7.3	2210	3193	179	86.5	329.5	3.4	363	767	314	4.8
4	7.6	701	1046	64.5	21.5	109	1.14	64.5	249.5	130	5
5	7.4	1333	2191	117.5	55	182	1.75	234.5	436.5	200.5	8.5
6	7.6	1251	1993	113	41	198.5	3.1	190	420	196	4.5
7	7.7	1250	1895	120.5	42.5	178	2.95	185	424	187.5	2.1
8	7.7	341	501	33	12.6	55.5	1.91	37	85.2	87	1.8
9	7.6	290	455	29.5	12	42	1.56	36.9	76.6	74.3	1.9
10	7.2	1181	1983	95	44.3	191	0.94	204	353	210	6.1
11	7.8	1404	2174	139.1	60.5	182	3.34	229.1	458	231	4.9
12	7.6	450	787	45.1	20.5	70	2	23	174	96.5	1.7
13	7.9	2327	3411	234.5	121	258.5	2.45	380.5	730.5	463	4.2
14	7.7	971	1443	81	59.2	111.9	0.7	243	277	140.3	7.8
15	7.8	2267	3369	215.5	106	297.5	2.25	445.5	704.5	380	2.1
16	7.6	1177	1778	96	51	179.5	1.85	185.5	390.5	195.5	7
17	7.6	566	790	44	16	105.6	1	55	174.1	139.7	2.4
18	7.3	659	882	57.5	26.9	116.4	2.2	102	188.1	144	2.2
19	7.3	1187	1945	110	60.2	136	0.7	271.5	323.1	210.5	3.6
20	7.6	430	716	38	21.5	54.5	0.9	101.1	87	95.5	1.9

(WQI) is used in this research, which is defined as the rating that reflects the composite influence of the different parameters. Water Quality Index (WQI) is a mathematical tool to integrate the complex water quality data into a numerical score that describes the overall water quality status (Ramakrishnaiah *et al*., 2009). Quality index is an important tool for getting an idea about the quality of water for drinking purpose. Indices are the most effective ways to communicate information regarding water quality trends to policy makers and the general public or citizens (Dwivedi and Pathak, 2007). The quality index does not show exact degree of pollution, rather it is used to assess water quality trends for the management purpose (Mishra *et al*., 2008). The eleven parameters which were pH, total dissolved solids, Electrical Conductivity, sodium, calcium, magnesium potassium, bicarbonate, sulphate, chloride and nitrate were used for the calculation of WQI. To calculate the WQI, the weight has been assigned for the parameters according to the parameters relative importance in the overall quality of water for drinking water purposes. The assigned weight ranges from 1 to 5 as shown in Table 2. The maximum weight of 5 has been assigned for nitrate and TDS, 4 for pH, EC, SO_4, 3 for HCO_3 and Cl, 2 for Ca, Na and K and weight 1 assigned for magnesium

(Vasanthavigar *et al.*, 2010). The relative weight is computed from the following equation:

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \quad \text{.............................. 1}$$

Where:

Wi is the relative weight

wi is the weight of each parameter

n is the number of parameters

The quality rating scale for each parameter is calculated by dividing its concentration in each water sample by its respective standards (IQS, 2009) as shown in Table 2 and multiplying the results by 100.

$$q_i = \left\{\frac{C_i - C_o}{S_i - C_o}\right\} * 100 \quad \text{............................ 2}$$

Where:

qi is the quality rating

Ci is the concentration of each parameter in each water sample

Si is the Iraqi drinking water standards for each parameter

For computing the final stage of WQI, the SI is first determined for each parameter. The sum of SI values gives the WQI for each sample.

$$SIi = Wi \times qi \quad \text{............................... 3}$$

$$WQI = \sum_{i=1}^{n} SIi \quad \text{............................ 4}$$

Where:

SIi is the sub-index of i^{th} parameter

Qi is the rating based on concentration of i^{th} parameter

n is the number of parameters

On the basis of the WQI, the quality of the water is categorized into fivestatuses from unfit for drinking purpose to excellent (APHA, 2005, and Vasanthavigar *et al.*, 2010) (Table 3).

Table 2: Relative weight of physico-chemical parameters

Chemical parameters	Iraqi Standard 2009	Weight (wi)	Relative weight (Wi)
pH	8.5	4	0.114
TDS	1000	5	0.142
EC	1500	4	0.114
Ca^{+2}	150	2	0.057
Mg^{+2}	100	1	0.028
Na^{+}	200	2	0.057
K^{+}	12	2	0.057
SO_4^{-2}	400	4	0.114
Cl^{-}	350	3	0.085
NO_3^{-}	50	5	0.142
		Σwi = 32	

Table 3: Water quality classification based on WQI values

WQI range	Type of water
< 50	Excellent water
50 – 100	Good water
100 – 200	Poor water
200 – 300	Very poor water
> 300	Unfit for drinking

RESULTS AND DISCUSSION

1. Climate

According to Hashim, 2009 procedure the average monthly data of the atmospheric variables such as rainfall (mm), maximum, minimum air temperature (°C) and relative humidity (%) have been selected for four months (mid-season months) to represents the four season, such as January represents Winter, April for Spring, July for Summer and October represents Autumn season(Al-Hashemi, 2013). These variables are used to draw general trends directions which are the most important factors to identify the effects of climatic changes. Therefore, the average monthly values of these factors were analyzed for Tuz meteorological station for the period from 1991 – 2010 for January, April, July, and October (Iraqi Meteorological Organization, 2013, and Al-Hashemi, 2013).

Rainfall analysis: The mean monthly rainfall (mm) for January, April and October month's frequency curves for the years 1991-2010 were evaluated for available data of Tuz meteorological station. The relationship between rainfall and time seems negative. Remarkable decrease in the rainfall amounts was indicating from the general trend line for all the three months (Fig. 2).

Temperature analysis: The mean monthly minimum and maximum temperatures (°C) of January, April, July and October (for the years 1991 – 2010) frequency curves were evaluated for available data of Tuz meteorological station. The relationship between temperature and time seems to be positive in the area with remarkable increases in temperature as indicated from the general trend line of the studied months (Figs. 3 and 4).

Relative humidity percentages analysis: The mean monthly Relative humidity (%) for January, April and October month's frequency curves for the years 1991 – 2010 were evaluated for available data of Tuz meteorological station. The relationship between Relative humidity and time seems negative. Remarkable decrease in the Relative humidity percentages was indicating from the general trend line for all the four months (Fig. 5).

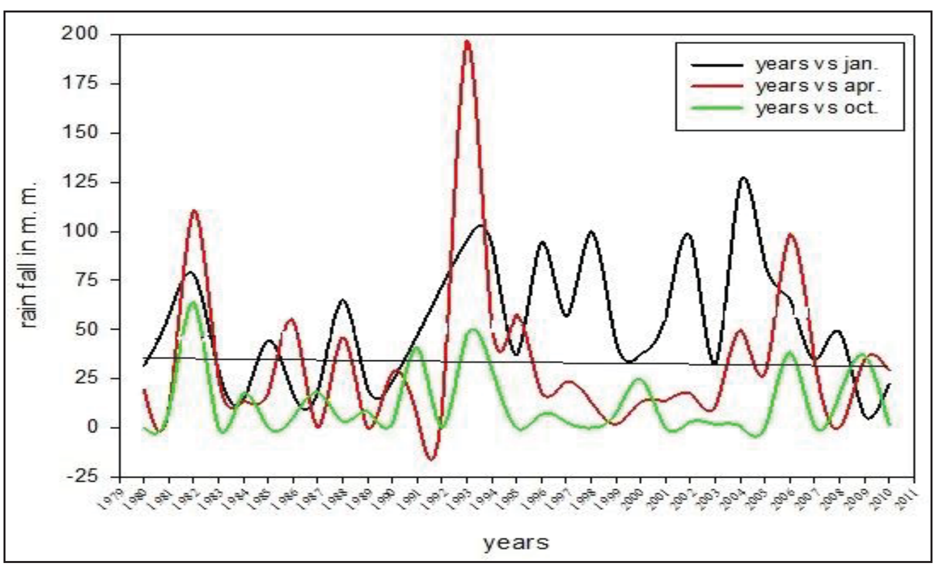

Fig. 2: The annual rainfall from 1991 to 2010 and trend direction for January, April and Octoberrelationship for Tuz Khurmatu meteorological station (Al-Hashemi, 2013)

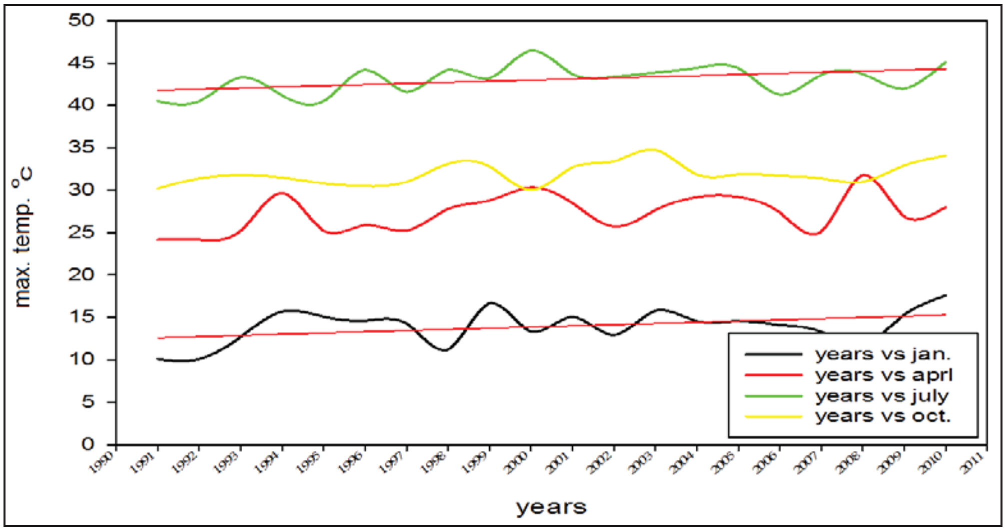

Fig. 3: The maximum temperature from 199 – 2010 and trend direction for January, April, July and October relationship for Tuz Khurmatu meteorological station (Al-Hashemi, 2013)

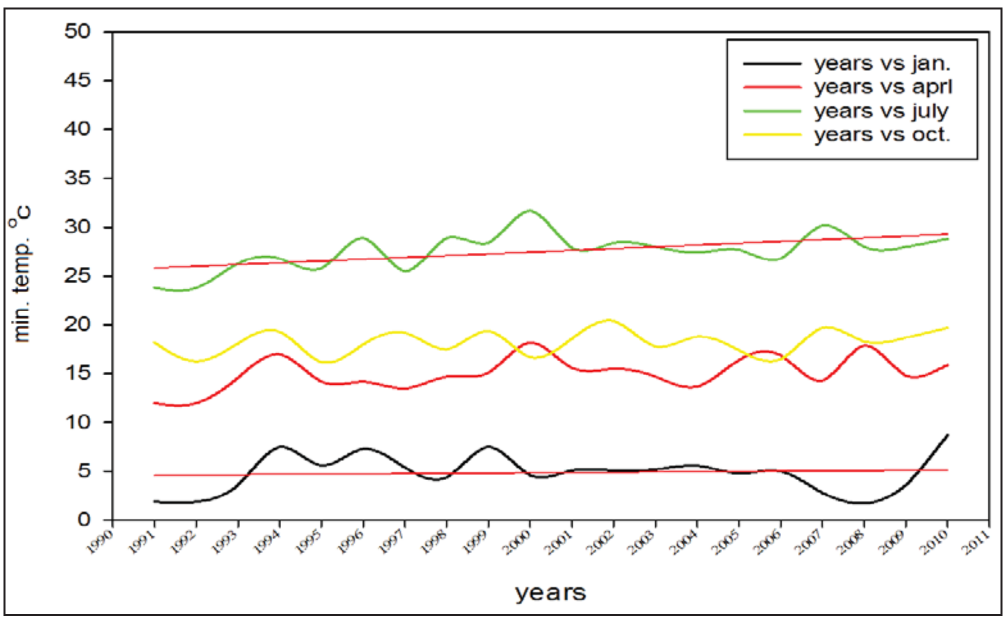

Fig. 4: The minimum temperature from 199 1– 2010 and trend direction for January, April, July and October relationship for Tuz Khurmatu meteorological station (Al-Hashemi, 2013)

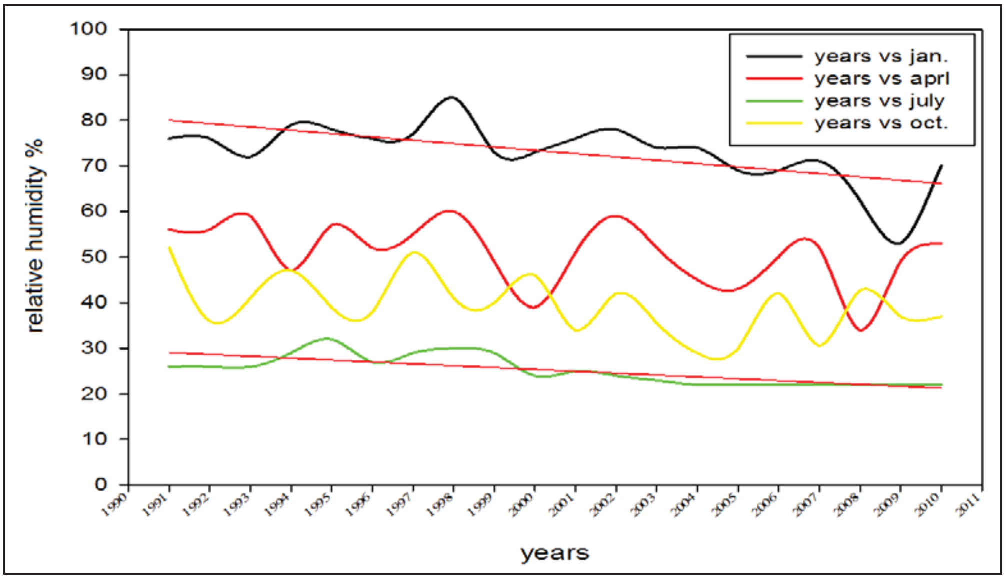

Fig. 5: The relative humidity% from 1991 – 2010 and trend direction for January, April, July and October relationship for Tuz Khurmatu meteorological station (Al-Hashemi, 2013)

2. Water Quality Index

In order to determine the water quality index (WQI), physical and chemical properties for twenty groundwater samples from the study area were analyzed for different parameters (Table 1). The statistical parameters like minimum, maximum and mean concentration of physico-chemical parameters and their comparison with Iraqi drinking water standards are tabulated in Table 4.

The pH values of the study area groundwater ranged from (7.21 to 7.91) indicating the low alkaline nature of the groundwater. The pH values are found to be within the permissible limit. The TDS and EC values are ranged from (290 to 2327.5 mg/l) and (454.5 to 3411 μs/cm), respectively. The mean concentrations of TDS and EC exceeded the permissible limits for drinking water. Increasing in TDS and EC concentrations may be attributed to the gypsum and anhydrite rocks dissolution from Al-Fat'ha Formation in Pulkhana anticline (Rasheed, 2012).

The ranges of Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} were (29.50 to 234.5 mg/l), (12.05 to 121 mg/l), (42.04 to 329.5 mg/l) and (0.7 to 3.4 mg/l), respectively. High concentrations of Calcium, Magnesium and Sodium ions are observed for groundwater samples in 10% of

Ca, 10% of Mg and 20% of Na that exceeded the permissible limits for drinking water, while the potassium concentration was within the permissible limits. The ranges of (HCO_3^-), (SO_4^{-2}) and (Cl^-) were (23 to 445.5 mg/l), (76.6 to 767 mg/l) and (74.35 to 463 mg/l), respectively. About 35% of HCO_3^-, 35% of SO_4 and 5% of Cl in water samples have concentrations that exceeded the permissible limits for drinking water. The nitrate values ranged from (1.7 to 8.5 mg/l), the nitrate concentration was within the permissible limits.

The calculation of water quality index WQI results for individual groundwater samples shows that the WQI values ranged from (27.25 to 139.81) (Table 5). About 35% of water supply can be classified as excellent water, while 50% of water supply are classified as good water, the remaining 15% can be classified as poor water.

Table 4: Minimum, maximum and mean concentration of parameters and their comparison with Iraqi drinking water standards

Parameters	Minimum	Maximum	Mean	Iraqi Standard 2009
pH	7.21	7.91	7.56	6.5 – 8.5
TDS	290	2326.5	1153.7	1000
EC	454.5	3411	1754.3	1500
Ca	29.50	234.5	106.98	150
Mg	12.05	121	50.29	100
Na	42.04	329.5	158.88	200
K	0.7	3.4	1.87	12
SO_4	76.6	767	352.31	400
Cl	74.35	463	207.95	350
NO_3	1.7	8.5	4.04	50

Table5: Water quality index (WQI) classification for individual water samples

Well No.	WQI	Water classification	Well No.	WQI	Water classification
1	99.39	Good water	11	90.4	Good water
2	95.23	Good water	12	36.55	Excellent water
3	131.97	Poor water	13	139.81	Poor water
4	49.25	Excellent water	14	67.15	Good water
5	87.26	Good water	15	137.74	Poor water
6	81.79	Good water	16	77.21	Good water
7	79.79	Good water	17	41.14	Excellent water
8	29.65	Excellent water	18	46.9	Excellent water
9	27.25	Excellent water	19	78.41	Good water
10	77.81	Good water	20	35.42	Excellent water

CONCLUSIONS

The climatic parameters (rainfall, relative humidity % and minimum and maximum temperature) show actual evidences in the climatic changes. The mean annual rainfall and the relative humidity percentages from 1991 to 2010 trend direction for January, April and October relationship are indicated by remarkable decrease with increases of the mean annual minimum and maximum temperatures.

Based on the WQI classification majority of the samples are falling under excellent water (35%), good water (50%) and suitable for drinking water purposes in respect to major elements while 15% showed poor water unsuitable for drinking.

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