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Hydrogeochemistry and Health Risk Assessments of Surface and Groundwater Around Industrial District in Qayarah Area, Northern Iraq

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ABSTRACT

Fourteen samples are selected from surface, ground and springs waters around the city of Qayarah, northern Iraq. Analyses of major components: Ca+2, Mg+2, Na+, K+, Cl-, SO4-2, NO3- and HCO3-, as well as measuring the following properties: pH, TDS and EC are carried out. The mean results for Tigris River samples are (58.2, 16.62, 16.07, 2.15, 16.35, 69.7, 2.75, 137.5,) mg/l respectively. The values of pH, EC and TDS are 8.2, 443.25 µS/cm, and 281.75 mg/l respectively. The average results of both groundwater and sulfur spring analyses are (588.9, 269.1, 1056.3, 7.1, 1281.3, 2843.0, 14.3, 189.1 mg/l) respectively. The values of pH, EC and TDS are (8.2, 7515 µS/cm, and 6491.0 mg/l) respectively. The Piper classification of water reveals that the studied Tigris River samples belong to facies (B), wells [GR5, GR7] belong to (C) facies, wells [GR1, GR2, GR4, GR6, GR3, GR8] belong to the facies (E), well [GR9] and the sulfur spring [SW5] belong to (G) facies. The Water Quality Index (WQI) of the samples show: Tigris River samples are excellent for suitability for drinking, with a rate of (20.81-22.19), sample [GR9] is poor with a value (69.03), samples [GR6, GR7] are of very poor quality with values (95.75) and (85.72) respectively, the samples [GR1, GR2, GR3, GR4, GR5, GR8, SW5] are unsuitable with range values (111.62-341.57). Pollution with heavy elements (As, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Se, and Zn) show low HPI rate (1.18-3.65). The carcinogenic risk calculations show that all samples are under risk; except for (GR3) sample had a significant carcinogenic risk. Non-carcinogenic health risk quotient is under risk. The carcinogenic by ingestion and dermal exposure for adults more than for children, while the non-carcinogenic risk by ingestion and dermal exposure for children is more than for adults.

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هيدروجيوكيميائية وتقدير الخطر الصحي للمياه السطحية والجوفية حول المنطقة الصناعية في منطقة القيارة، شمالي العراق

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الملخص

اختيرت أربعة عشر عينة من المياه السطحية والجوفية والينابيع المحيطة بمدينة القيارة شمالي العراق. حللت المكونات الرئيسية : Ca+2وMg+2وNa+وK+وCl-وSO4-2و NO3-وHCO3-، بالإضافة إلى قياس الخواص التاليةpH :و TDS و .ECكان متوسط النتائج لعينات نهر دجلة: (58.3 و16.62 و16.07 و2.15 و 16.35 و 69.7 و2.75 و137.5) ملغم/لتر على التوالي، وكانت قيم pH و EC و TDS هي 8.2 و 443.25 ميكروسيمنز/سم و281.75 ملغم/لتر. على التوالي. وكان متوسط نتائج تحليل المياه الجوفية والينابيع الكبريتية (588.9 و 269.06 و 1056.3 و 7.1 و 1281.3 و2843 و14.32 و189.1) ملغم/لتر على التوالي. وكانت قيم pH و EC و TDS هي 8.16 و 7515 ميكروسيمنز/سم و6491 ملغم/لتر على التوالي. أظهر تصنيف بايبر للمياه أن عينات نهر دجلة تعود إلى السحنة(B) ، والآبار [GR5, GR7] إلى السحنة (C) ، والآبار [GR1, GR2, GR4, GR6, GR3 ,GR8] الى السحنة (E) والبئر [GR9] والنبع الكبريتي [SW5]إلى السحنة .(G) أظهر مؤشر جودة المياه :(WQI) أن عينات نهر دجلة كانت ممتازة من حيث الصلاحية للشرب، وبمدى (20.81–22.19)، والعينة [GR9] ضعيفة بقيمة (69.03)، والعينات [GR6,GR7] كانت نوعية رديئة جداً بقيم (95.75) و (85.72) على التوالي، والعينات [GR1, GR2, GR3, GR4, GR5, GR8, SW5] غير مناسبة بمدى (111.62–341.57). إن التلوث بالعناصر الثقيلة (As وCd وCr وCu وHg وMo وNi وPb وSe وZn) يُظهر قيمة منخفضة لمعامل التلوث بالعناصر الثقيلة (HPI) ضمن المدى (1.18–3.65). أظهرت حسابات خطر الإصابة بالسرطان أن جميع العينات كانت تحت مستوى خطر الإصابة، باستثناء عينة (GR3) التي تملك خطراً معتبراً للسرطان. وكان حاصل الخطر الصحي غير المسبب للسرطان تحت مستوى الخطر. وكان خطر الإصابة بالسرطان عن طريق الابتلاع والتعرض عن طريق الجلد للبالغين أكبر من الأطفال، في حين أن الخطر غير المسبب للسرطان عن طريق الابتلاع والتعرض عن طريق الجلد للأطفال أكبر من البالغين.

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Introduction

Water is the most important for sustaining life and is required in almost all human activities such as drinking, agricultural as well as industrial uses, energy, and generation food production. However, the water quality in many large rivers has deteriorated significantly around the world due to human activities in the past two decades (Kadhem, 2013). Climate change and drought that afflicted most countries in the world as well as the increase in population were a direct cause of the decrease for water and even had effects on the quantity and quality of groundwater (Balachandar *et al.,* 2010). Note that the required quality of groundwater supplies depends on the purpose of its use (Todd, 1980). The quality of water systems is essential for sustainability. In ecosystems, groundwater qualities vary greatly depending on location and environmental factors as well as their sources. Water quality is defined based on its chemical, physical, and biological properties. The quality changes from one season to another as well depend on the geographical region (Opong *et al.,* 2021). The problem of water quality has become more important than the problem of its quantity, and environmental problems are more serious in different parts of the world. The water resource in several places has polluted from its natural sources due to many humans, commercial, industrial and agricultural activities through the misuse of water and land, which directly and indirectly affected the quality of groundwater (Balachandar *et al.*, 2010). Moreover, the quality of groundwater may change either during its exploitation, or by human activities that are not immediately clear, but rather the effect appears over time (Appelo and Postma, 2005). Regular monitoring of water quality is necessary to evaluate water quality in order to maintain the ecosystem. Water quality assessment can be a complex process as many specific factors used in estimating water quality (Poonam *et al.,* 2013).

Evaluating and understanding the sources of heavy metals and their effects as well as physical, chemical and biological parameters of water, are important for effective water management and sources preservation. Therefore, the water quality assessment is a vital tool for water resources management (Opong *et al.,* 2021).

The current study covers Qayarah sub-district, which is located about 60 km to the south of Mosul Governorate as shown in Figure (1). The study area contains many sources of natural and industrial pollution. The natural sources include sulfur springs and tar oil spills, which are distributed in the southeastern part of the city of Qayarah, adjacent to the Tigris River, which passes through the city at the southern plunge of the Qayarah fold forming a floodplain with a width of up to four kilometers on both sides of the river (Alfaris, 2022). The study area is characterized by the presence of structural phenomena such as the Qayarah fold plunge and the faults associated with it. As for the industrial areas, it includes the Qayarah oil field, the Qayarah refinery, and the gas power station, in addition to many other sources such as fuel stations, the city of Qayarah, the main roads, as well as sewage water and landfill areas. The study area is located tectonically in a transformed belt and within the range of low folded zone. The formation of the Fatha (middle Miocene) is revealed in most areas of the current study area, which consists of successive cycles of clay, gypsum, anhydrite and calcareous rocks with layers of marl. It is one of the most densely populated regions in northern Iraq.

The need for more water sources in last decades because of climate exchange, global drought overpopulation, inadequate quantity of surface water; all these reasons prompted the population around Qayarah City to use groundwater in addition to surface water. Additionally, the multiple source (natural and human) and uncontrolled events that took place in last decade led to lack control on many pollutants around Qayarah City. All of the aforementioned caused necessitated for a study of other sources of water, its quality, suitability for uses, the level of pollution of that water, and its environmental and health effects.

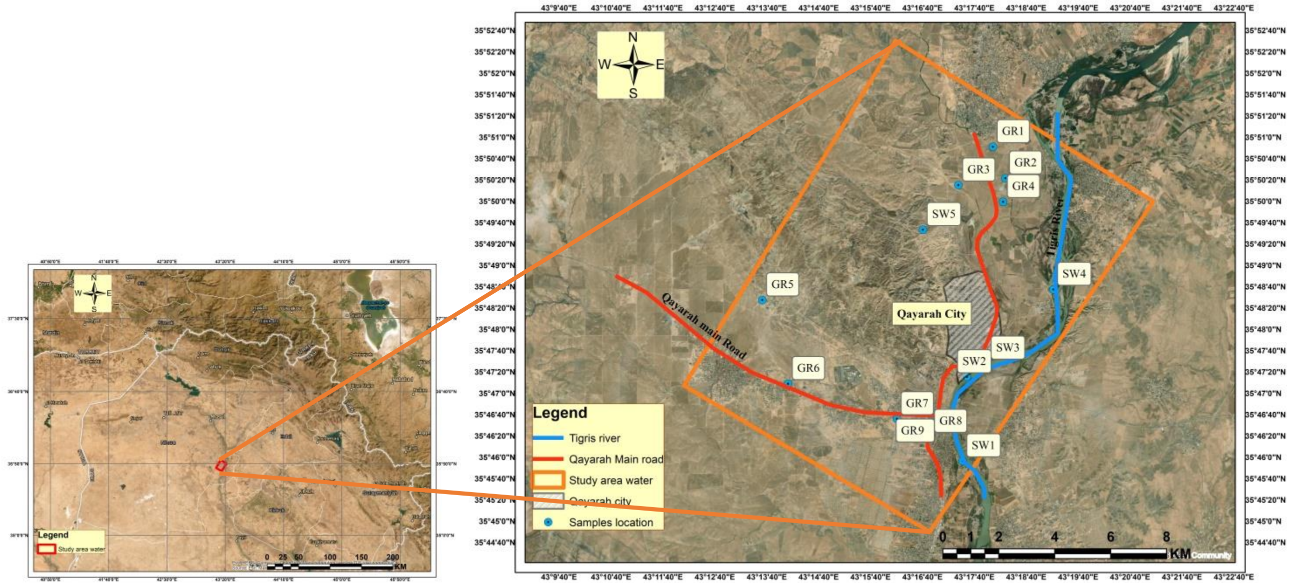

Fig. 1. map of study area and sample's location.

Materials and Methods

Study area and sampling:

Fourteen (14) different sampling sites are selected for this study around of Qayarah district; the study area covers approximately 62.642 square kilometers, and is located in the southern part of Ninawa Governorate, northern Iraq (Fig.1). The study area is situated between
latitude (35° 52' 20" N and 35° 45' 00" N) and between longitudes (43° 12' 20" E and 43° 21' 20" E) as shown in Figure (1). Samples were selected around Qayarah City as follows: [four (4) surface samples from Tigris River (SW1, SW2, SW3 and SW4), one (1) spring sample from sulfide water spring located in the study area (SW5), and nine (9) groundwater samples (GR1, GR2, GR3, GR4, GR5, GR6, GR7, GR8 and GR9)]. About 1 liter of water sample is collected in a clean polyethylene bottle during Jun-September 2022; bottles already have been rinsed out with the same water samples in each case. Physical parameters such as Temperature, pH and EC are determined at the sampling site using digital portable water (PH, EC meter), and (ICP-MS) instrument is used for determining the concentration of cations of the preserved water samples, while anions are determined by digital titration method. All analyses are carried out in accordance with the standard procedures specified in APHA (1998).

Quality control and instrumental analysis

Water facies by Piper and stiff classification:

The measurements of the cations and anions of the collected samples are represented by the main cations (Na^+, K^+, Mg^{+2}, Ca^{+2}) and the main anions (Cl^-, $HCO3^-$, $SO4^{-2}$, $NO3^-$) (Table 1). The type and quality of the water are then calculated, in addition to calculating the risk index in terms of its effect on humans, whether it constitutes a carcinogenic factor or not as well as the PIPER and STIFF charts are used to classify the water hydrofacies and to determine its origin as will be shown later.

Table 1: WHO guidelines of the major physiochemical parameters and heavy metals, and the calculated Si and W_i for each.

Major physiochemical parameters			Heavy metals			
Parameters	WHO (2017) guidelines (S_i)	Unit weight (W_i)	Heavy metal	WHO (2017) guidelines (S_i)	$\frac{1}{S_i}$	Unit weight (W_i)
pH (unity)	6.5 - 8.5	0.004	As	10	0.1	7.74
TDS (mg/L)	200	0.005	Cd	3	0.333	2.32
EC µS/cm	2500	0.0004	Cr	50	0.02	38.72
Hardness (mg/L)	500	0.002	Cu	2000	0.0005	1548.81
Ca^{+2} (mg/L)	150	0.0066	Hg	6	0.166	4.65
Mg^{+2} (mg/L)	100	0.01	Mo	70	0.0142	54.21
Na^{+} (mg/L)	200	0.005	Ni	70	0.0142	54.21
K^{+} (mg/L)	10	0.1	Pb	10	0.1	7.74
Cl^{-} (mg/L)	250	0.004	Se	40	0.025	30.98
HCO_3^{-} (mg/L)	350	0.00285	Zn	3000	0.00033	2323.21
SO_4^{-2} (mg/L)	250	0.004			$\sum\frac{1}{S_i}$=0.77	ΣW_i= 4072.59
NO_3^{-} (mg/L)	50	0.02				
	ΣW_i= 0.1639					

Water quality index (WQI):

The water quality index was developed by (Brown et al. 1972) using the Delphi method by carefully selecting the parameters. The water quality index can be calculated through the specified rating curves and associated weights (Poonam et. al., 2013), where the water quality index (WQI) is calculated using the following equations (1, 2, 3 and 4) (Brown *et al.*, 1972)

$$W_i = \frac{K}{S_i} = \frac{1}{S_i} \dots.(1)$$

$$Q_i = \left(\frac{V_i}{S_i}\right) * 100 \dots.(2)$$

$$Q_{pH} = \left[\left(\left(\frac{V_{pH} - 7}{1.5}\right)\right)\right] * 100 \dots.(3)$$

$$WQI = \frac{\sum(Q_i * W_i)}{\sum W_i} \dots.(4)$$

Where: Wi is the unit weight of the i_{th} parameter. K is a proportionality constant equal to (1). Si is the standard value of the i_{th} parameter published by WHO (2017), [except for pH, the relative weight of chlorides is assumed to be 0.004 as shown in (Aqrawi, 2021)], Qi is the sub-index of the i_{th} parameter table (1), Vi is the value measured in the samples mentioned in table (4). The Water Quality Index (WQI) is rated as quality of Water based on (Al-Hakeem, and Al-Kubaisi, 2022) as follows: WQI < 25 excellent, WQI (25-50) good, WQI (50-75) poor, WQI (75-100) very poor, WQI > 100 unsuitable for drinking purposes.

Heavy metals pollution index (HPI):

Contamination status of water samples was determined using the heavy metal pollution index (HPI). Pollution index was used to determine the combined effect of each heavy metal on the overall water quality and in order to assess the suitability for human consumption. The HPI represents the total quality of water with respect to heavy metals, and it is calculated by assigning a weightage (Wi) for individual parameter which is a value between 0 and 1 reflecting the relative importance of the individual quality consideration. This study used the WHO standards permissible value for drinking water. The HPI was calculated using the following equations (5, 6, 7 and 8):

$$W_i = \frac{K}{S_i} \dots.(5)$$

$$K = \frac{1}{\sum_1^n \frac{1}{S_i}} \ldots.(6)$$

$$Q_i = \sum_{i=1}^{n} \left(\frac{M_i - I_i}{S_i - I_i}\right) * 100 \ldots.(7)$$

$$HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i} \ldots.(8)$$

Where W_i is the unit weight of the *i*th parameter, *Si* the standard value of heavy metals by WHO (2017) table (1) Q_i is the sub index of the *i*th parameter, (Q_i) is the sub index of the parameter. M_i and I_i is the monitored value of metal table (6), (n) number of heavy metals studied. The HPI value of drinking water less than 100 is classified as suitable for drinking (Opong *et al.*, 2021). HPI Pollution Level: HPI <15 Low Pollution, HPI (15-30) Medium Pollution, HPI >30 High Pollution. (Akbar Ali, 2018).

Health risk assessments:

The health impact assessment includes measuring the effect of exposure to heavy metals and estimating the extent of its impact on human health during a specific period. Humans are exposed to heavy metals in water through ingestion and skin absorption. The process includes several steps for diagnosing the risk, which are estimating the human response to doses, estimating the methods of exposure, and finally the nature of the risk that may occur. The non-carcinogenic and potential carcinogenic health risks to human health through the mouth and skin were estimated using elements that have toxicity, as it was calculated. Potential average daily dose (ADD) through the two exposure routes Oral and transdermal based on the approved international standard (U.S. EPA, 1989) Table (2) and the concentrations of heavy metals in table (6) and using equations (9, 10, 11 and 12):

$$ADD_{ing-nc} = \frac{C_{water} * IngR * EF * ED * CF}{BW * AT_{nc}} \ldots\ldots..(9)$$

$$ADD_{dermal-nc} = \frac{C_{water} * SA * K_p * ET * EF * ED * CF}{BW * AT_{nc}} \ldots\ldots..(10)$$

$$THQ = HQ_{ing} + HQ_{dermal} = \frac{ADD_{ing-nc}}{RfD_{ing.}} + \frac{ADD_{dermal-nc}}{RfD_{dermal}} \ldots\ldots..(11)$$

$$HI = \sum THQ \ldots..(12)$$

Where: THQ is the total hazard quotient, HQ_{ing} and HQ_{drmal} were the ingestion and dermal hazard Quotient, respectively, ADD_{ing-nc} and $ADD_{dermal-nc}$ were non-carcinogenic average daily dose through three pathways ingestion (mg/kg-day) and dermal (mg/kg-day), respectively, RfD_{ing} and RfD_{dermal} were Ingestion Reference Dose (mg/ kg-day) and Dermal Reference Dose (RfD_{ing} * Fraction of contaminant absorbed in the skin ($ABSGI$)) (mg/ kg-day), respectively table (3). HI is hazard index, where the value of HI<1 mean there is no non-carcinogenic adverse effects, HI> 1 indicate to potential non-carcinogenic adverse effects on the humans

For carcinogenic:

The carcinogenic risk quotient (CR) for heavy metals used to estimate the probability of carcinogenic danger, it was calculated from the data reveal in table (2) and table (3), the heavy metal concentrations in table (6) based on equations (13, 14, 15, and 16):

$$ADD_{ing-c} = \frac{C_{water} * IngR * EF * ED * CF}{BW * AT_c} \ldots\ldots..(13)$$

$$ADD_{dermal-c} = \frac{C_{water} * SA * K_p * ET * EF * ED * CF}{BW * AT_c} \ldots\ldots..(14)$$

$$Total\ Cancer\ Risk = CR_{ing} + CR_{dermal} \quad .... (15)$$

$$Total\ Cancer\ Risk = (ADDing_{-c} * CSF_{ing}) + (ADD_{dermal}-c * CSF_{derma}) \ldots (16)$$

The acceptable carcinogenic risk values fall within the range (10^{-6} – 10^{-4}) (U.S. EPA, 2004), while values greater than (10^{-4}) have a considered high carcinogenic risk (Yu et. al., 2014).

Table 2: Parameters Used for the Health Risk Assessment of Water for adult and children. (U.S. EPA, 2006; U.S. EPA, 2016).

Parameter	Unit	Adult	Child
Concentration of metals (C_{water})	(mg/l)		
Exposure Duration (ED)	year	30	6
Exposure Frequency (EF)	days/year	350	350
Ingestion Rate (IngR)	l/day	2	1
Body Weight (BW)	kg	70	15
Average Time (AT):	days		
For Non-carcinogenic	ED*365	ED*365	
For Carcinogenic	70*365	70*365	
Conversion Factor (CF)	l/cm3	0.001	0.001
Exposed Skin Area (SA)	cm2	18000	6600
Exposure Time (ET)	h/day	0.58	1
Dermal Permeability Coefficient (KP):	cm/h		

Table 3: Parameters (RfD, CSF, ABSGI and Dermal Permeability Coefficient (KP)) Used for the Non-carcinogenic Hazard and Carcinogenic. Risk Assessment of Water for Adult and Children.

Heavy metals	RfD_{ing}. (mg/kg-day)	RfD_{dermal} (mg/kg-day)	CSF_{ing} (mg/kg/day)	CSF_{dermal} (mg/kg/day)	ABSGI	Dermal Permeability Coefficient (KP) cm/h
As	$3*10^{-4\dagger}$	$3*10^{-4\dagger}$	$1.5^{\dagger}$	$1.5^{\dagger}$	$1^{\dagger}$	$1*10^{-3\dagger\dagger}$
Pb	$3.5*10^{-3\dagger}$	$3.5*10^{-3\dagger}$	$8.5*10^{-3\dagger}$	$8.5*10^{-3\dagger}$	$1^{\dagger}$	$1*10^{-4\dagger\dagger}$
Cd	$5*10^{-4\dagger}$	$2.5*10^{-5\dagger}$	$0.38^{\ddagger}$	$25.6^{\ddagger\ddagger}$	0.05	$1*10^{-3\dagger\dagger}$
Cr	$3*10^{-3\dagger}$	$7.5*10^{-5\dagger}$	$5*10^{-1\dagger}$	$38.5^{\ddagger\ddagger}$	$0.025^{\dagger}$	$2*10^{-3\dagger\dagger}$
Co	$3*10^{-4\dagger}$	$3*10^{-4\dagger}$	-	-	$1^{\dagger}$	$4*10^{-4\dagger\dagger}$
Cu	$4*10^{-2\dagger}$	$4*10^{-2\dagger}$	-	-	$1^{\dagger}$	$1*10^{-3\dagger\dagger}$
Ni	$2*10^{-2\dagger}$	$8*10^{-4\dagger}$	$0.084^{\ddagger\ddagger}$	$2.1^{\ddagger\ddagger}$	$0.04^{\dagger}$	$2*10^{-4\dagger\dagger}$
Zn	$3*10^{-1\dagger}$	$3*10^{-1\dagger}$	-	-	$1^{\dagger}$	$6*10^{-4\dagger\dagger}$

(†). (U.S. EPA, 2017), (††) (U.S. EPA, 2006; U.S. EPA, 2016), (‡) Nduka J.K. et al. 2019 (‡‡) Caceres D.D. et al. 202

Table 4: Concentrations of major Chemical compositions, physiochemical properties and water quality classification.

	sample	Ca	Mg	Na	K	Cl	SO_4	NO_3	HCO_3	TH	pH	TDS	EC	WQI	Water Quality (Al-Hakeem and Al-Kubaisi,2022)
		(mg/l)									unity	(mg/l)	uS/cm		
Ground water and spring samples	GR1	601	315	557	11.1	486	3000	13.6	209	559.38	8.3	5260	5650	175.5	Unsuitable for drinking purpose
	GR2	499	298	536	9.02	392	2810	7.78	193	494.45	8.3	4390	5240	150.96	Unsuitable for drinking purpose
	GR4	622	543	1470	9.59	1590	4330	8.75	273	757.52	8.3	8830	10300	231.35	Unsuitable for drinking purpose
	GR3	589	667	1940	9.94	1770	5560	25.7	216	843.09	8.3	10900	12200	272.49	Unsuitable for drinking purpose
	GR5	607	136.5	195.5	6.92	147	2030	33.6	99	415.48	8	3360	3580	117.07	Unsuitable for drinking purpose
	GR6	554	148	280	3.48	132	2200	23.3	85	398.47	8	3480	3710	95.75	Very poor
	GR7	585	120.5	166.5	3.42	140	1890	8.81	158	391.32	8.2	3100	3250	85.72	Very poor
	GR8	609	172.5	440	4.06	395	2360	20.1	154	446.1	8.2	4210	4690	111.62	Unsuitable for drinking purpose
	GR9	213	81.1	598	3.28	511	1010	1.65	312	173.12	8.1	2680	3630	69.03	Poor
	SW5	1010	209	4380	10.25	7250	3240	-	192	676.4	7.9	18700	22900	341.57	Unsuitable for drinking purpose
	Min	213	81.1	166.5	3.28	132	1010	1.65	85	173.12	7.9	2680	3250	69.03	
	Max	1010	667	4380	11.1	7250	5560	33.6	312	843.09	8.3	18700	22900	341.57	
	Mean	588.9	269.06	1056.3	7.106	1281.3	2843	15.92	189.1	515.53	8.16	6491	7515	165.11	
Tigris River samples	SW1	57.8	17.1	17.25	2.27	16.3	70.9	0.59	144	42.94	8.3	276	436	21.94	Excellent
	SW2	57.7	17.25	15.3	2.24	14.5	67.6	0.58	144	43.01	8.3	271	427	21.67	Excellent
	SW3	58.5	17.35	16.8	2.3	16.3	69.9	0.64	146	43.49	8.3	282	440	22.19	Excellent
	SW4	59.2	14.8	14.95	1.8	18.3	70.4	9.2	116	41.74	8.2	298	470	20.81	Excellent
	Min	57.7	14.8	14.95	1.8	14.5	67.6	0.58	116	41.74	8.2	271	427	20.81	
	Max	59.2	17.35	17.25	2.3	18.3	70.9	9.2	146	43.49	8.3	298	470	22.19	
	Mean	58.3	16.625	16.075	2.153	16.35	69.7	2.753	137.5	42.795	8.28	281.75	443.25	21.653	

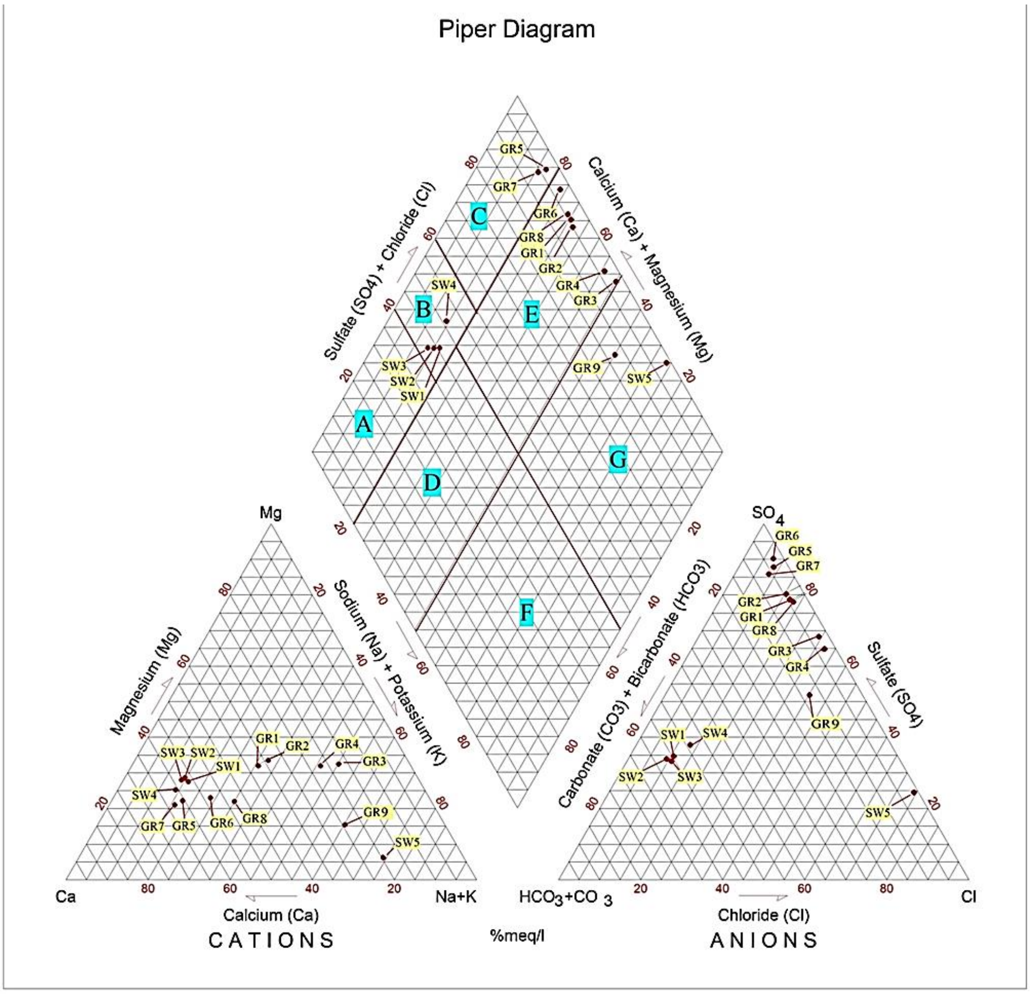

Fig. 2. Piper diagram and Main hydrochemical facies classification

Table 5: Main hydrochemical facies by Piper classification.

	Hydro-chemical facies	Samples
A	Normal earth alkaline water with prevailing bicarbonate	
B	Normal earth alkaline water with prevailing bicarbonate and sulphate or chloride	SW1, SW2, SW3, SW4
C	Normal earth alkaline water with prevailing sulphate or chloride	GR5, GR7
D	Earth alkaline water with increase portion of alkali with prevailing bicarbonate	
E	Earth alkaline water with increase portion of alkali with prevailing sulphate and chloride	GR1, GR2, GR4, GR6, GR3, GR8
F	Alkaline water with prevailing bicarbonate	
G	Alkaline water with prevailing with prevailing sulphate and chloride	GR9, SW5

Table 6: heavy metal concentration and Heavy metal pollution index (HPI)

Heavy metals	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Se	Zn	HPI
Samples						(µg/l)					
GR1	0.60	0.02	2.5	0.9	-	9.08	9.1	-	3.03	1.6	1.91
GR2	0.74	-	1.7	0.2	-	12.4	2.4	0.15	2.19	2.0	1.80
GR4	1.02	0.04	2.1	0.8	-	14.6	4.3	0.14	3.82	2.1	2.99
GR3	0.99	-	16.8	0.8	-	20.1	3.5	0.07	9.76	4.1	3.65
GR5	0.80	0.01	3.4	0.6	0.05	7.45	3.4	-	3.57	13.1	2.11
GR6	0.41	-	24.5	0.5	0.12	19.65	3.1	-	5.45	3.2	3.26
GR7	0.41	0.01	7.5	0.8	-	3.6	1.9	0.25	1.17	3.5	1.62
GR8	0.50	0.01	10.6	0.8	0.05	4.3	2.8	0.10	2.87	3.8	2.06
GR9	1.04	0.06	2.9	0.7	0.08	13.4	5.5	0.10	0.82	2.7	3.33
SW1	1.35	0.01	0.5	0.7	-	3.4	2.9	0.13	0.34	5.5	2.27
SW2	1.72	-	0.5	0.3	-	3.01	3.5	-	0.54	4.2	2.46
SW3	1.62	0.02	0.6	0.5	-	3.01	3.2	0.05	0.39	3.6	2.67
SW4	1.46	0.01	-	0.4	-	3.07	1.5	0.19	0.18	2.9	2.41
SW5	0.59	0.01	0.7	0.1	-	0.12	2.8	0.07	0.83	0.7	1.18
Mean	0.95	0.02	5.72	0.58	0.08	8.37	3.56	0.13	2.50	3.79	2.41
Max.	1.72	0.06	24.5	0.9	0.12	20.1	9.1	0.25	9.76	13.1	3.65
Min.	0.41	0.01	0.5	0.1	0.05	0.12	1.5	0.05	0.18	0.7	1.18

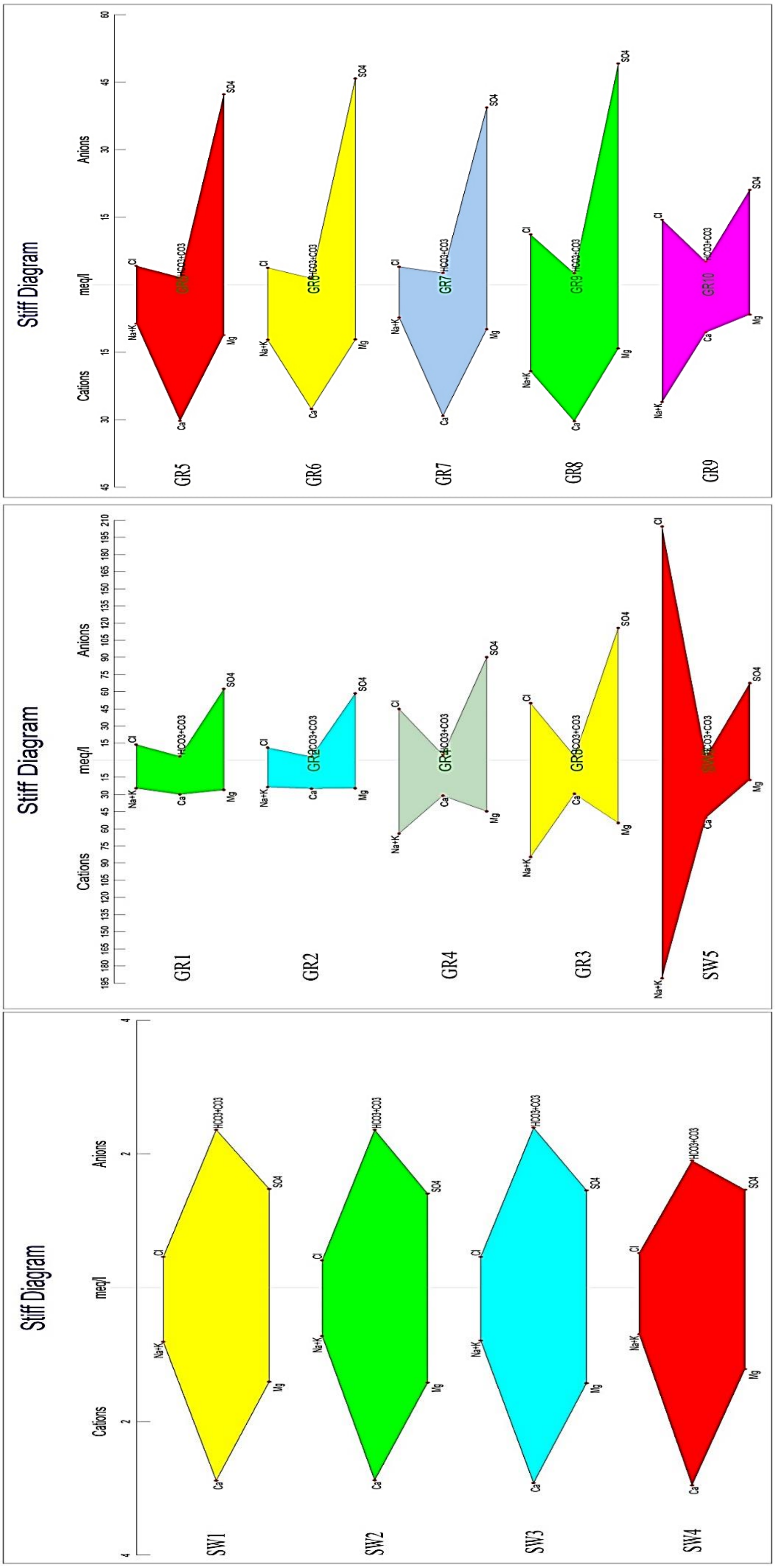

Fig. 3. Stiff's diagram of water sample.

Table 7: total cancer risk of heavy metals.

Well	Dermal cancer risk					Ingestion cancer risk					Total cancer risk (TCR)
GR1	As	Cd	Cr	Ni	Pb	As	Cd	Cr	Ni	Pb	1.93E-05
GR2	8.77E-08	5.99E-08	1.88E-05	3.72E-07	-	1.55E-08	1.57E-10	2.15E-08	1.32E-08	-	1.30E-05
GR4	1.08E-07	-	1.28E-05	9.82E-08	1.24E-11	1.91E-08	-	1.46E-08	3.47E-09	2.20E-11	1.62E-05
GR3	1.49E-07	1.02E-07	1.58E-05	1.76E-07	1.16E-11	2.63E-08	2.68E-10	1.81E-08	6.22E-09	2.05E-11	1.27E-04
GR5	1.45E-07	-	1.26E-04	1.43E-07	5.80E-12	2.56E-08	-	1.45E-07	5.06E-09	1.02E-11	2.59E-05
GR6	1.17E-07	2.74E-08	2.55E-05	1.39E-07	-	2.07E-08	7.20E-11	2.93E-08	4.92E-09	-	1.84E-04
GR7	5.99E-08	-	1.84E-04	1.27E-07	-	1.06E-08	-	2.11E-07	4.48E-09	-	5.65E-05
GR8	5.99E-08	1.50E-08	5.63E-05	7.78E-08	2.07E-11	1.06E-08	3.93E-11	6.46E-08	2.75E-09	3.66E-11	7.99E-05
GR9	7.31E-08	3.24E-08	7.95E-05	1.15E-07	8.28E-12	1.29E-08	8.51E-11	9.13E-08	4.05E-09	1.46E-11	2.23E-05
SW1	1.52E-07	1.42E-07	2.18E-05	2.25E-07	8.28E-12	2.69E-08	3.73E-10	2.50E-08	7.96E-09	1.46E-11	4.12E-06
SW2	1.97E-07	1.25E-08	3.75E-06	1.19E-07	1.08E-11	3.49E-08	3.27E-11	4.31E-09	4.20E-09	1.90E-11	4.20E-06
SW3	2.51E-07	-	3.75E-06	1.43E-07	-	4.44E-08	-	4.31E-09	5.06E-09	-	4.96E-06
SW4	2.37E-07	4.24E-08	4.50E-06	1.31E-07	4.14E-12	4.18E-08	1.11E-10	5.17E-09	4.63E-09	7.32E-12	3.30E-07
SW5	2.13E-07	1.50E-08	-	6.14E-08	1.57E-11	3.77E-08	3.93E-11	-	2.17E-09	2.78E-11	5.49E-06
Mean	8.62E-08	1.50E-08	5.25E-06	1.15E-07	5.80E-12	1.52E-08	3.93E-11	6.03E-09	4.05E-09	1.02E-11	4.02E-05
Max	1.38E-07	4.64E-08	4.29E-05	1.46E-07	1.04E-11	2.44E-08	1.22E-10	4.92E-08	5.16E-09	1.83E-11	1.84E-04
Min	2.51E-07	1.42E-07	1.84E-04	3.72E-07	2.07E-11	4.44E-08	3.73E-10	2.11E-07	1.32E-08	3.66E-11	3.30E-07
	5.99E-08	1.25E-08	3.75E-06	6.14E-08	4.14E-12	1.06E-08	3.27E-11	4.31E-09	2.17E-09	7.32E-12	

Table 8: total hazard quotient of heavy metals.

Well	Dermal hazard quotient													HI
	As	Cd	Cr	Cu	Ni	Pb	Zn	As	Cd	Cr	Cu	Ni	Pb	
GR1	1.1E-03	5.4E-04	3.7E-02	1.2E-05	1.2E-03	-	1.8E-06	1.8E-04	4.3E-06	7.6E-05	2.0E-06	4.1E-05	-	4.1E-02
GR2	1.3E-03	-	2.5E-02	2.8E-06	3.3E-04	2.4E-06	2.2E-06	2.2E-04	-	5.1E-05	4.5E-07	1.1E-05	3.9E-06	2.7E-02
GR4	1.9E-03	9.2E-04	3.1E-02	1.1E-05	6.0E-04	2.2E-06	2.3E-06	3.1E-04	7.4E-06	6.3E-05	1.8E-06	1.9E-05	3.6E-06	3.5E-02
GR3	1.8E-03	-	2.5E-01	1.1E-05	4.9E-04	1.1E-06	4.6E-06	3.0E-04	-	5.1E-04	1.8E-06	1.6E-05	1.8E-06	2.5E-01
GR5	1.5E-03	2.4E-04	5.1E-02	8.4E-06	4.8E-04	-	1.4E-05	2.4E-04	2.0E-06	1.0E-04	1.3E-06	1.5E-05	-	5.3E-02
GR6	7.7E-04	-	3.6E-01	7.0E-06	4.3E-04	-	3.6E-06	1.2E-04	-	7.4E-04	1.1E-06	1.4E-05	-	3.7E-01
GR7	7.7E-04	1.3E-04	1.1E-01	1.1E-05	2.6E-04	4.0E-06	3.9E-06	1.2E-04	1.1E-06	2.2E-04	1.8E-06	8.6E-06	6.5E-06	1.1E-01
GR8	9.4E-04	2.9E-04	1.6E-01	1.1E-05	3.9E-04	1.6E-06	4.2E-06	1.5E-04	2.3E-06	3.2E-04	1.8E-06	1.2E-05	2.6E-06	1.6E-01
GR9	1.9E-03	1.2E-03	4.3E-02	9.8E-06	7.7E-04	1.6E-06	3.0E-06	3.1E-04	1.0E-05	8.8E-05	1.6E-06	2.5E-05	2.6E-06	4.8E-02
SW1	2.5E-03	1.1E-04	7.5E-03	9.8E-06	4.1E-04	2.1E-06	6.2E-06	4.1E-04	9.1E-07	1.5E-05	1.6E-06	1.3E-05	3.3E-06	1.1E-02
SW2	3.2E-03	-	7.5E-03	4.2E-06	4.9E-04	-	4.7E-06	5.2E-04	-	1.5E-05	6.8E-07	1.6E-05	-	1.1E-02
SW3	3.0E-03	3.8E-04	9.0E-03	7.0E-06	4.5E-04	8.0E-07	4.0E-06	4.9E-04	3.1E-06	1.8E-05	1.1E-06	1.4E-05	1.3E-06	1.3E-02
SW4	2.7E-03	1.3E-04	-	5.6E-06	2.1E-04	3.0E-06	3.2E-06	4.4E-04	1.1E-06	-	9.1E-07	6.8E-06	4.9E-06	3.5E-03
SW5	1.1E-03	1.3E-04	1.0E-02	1.4E-06	3.9E-04	1.1E-06	7.9E-07	1.8E-04	1.1E-06	2.1E-05	2.2E-07	1.2E-05	1.8E-06	1.2E-02
Avg.	1.7E-03	4.2E-04	8.6E-02	8.1E-06	5.0E-04	2.0E-06	4.2E-06	2.8E-04	3.4E-06	1.7E-04	1.3E-06	1.6E-05	3.2E-06	8.3E-02
Max	3.2E-03	1.2E-03	3.6E-01	1.2E-05	1.2E-03	4.0E-06	1.4E-05	5.2E-04	1.0E-05	7.4E-04	2.0E-06	4.1E-05	6.5E-06	3.7E-01
Min	7.7E-04	1.1E-04	7.5E-03	1.4E-06	2.1E-04	8.0E-07	7.9E-07	1.2E-04	9.1E-07	1.5E-05	2.2E-07	6.8E-06	1.3E-06	3.5E-03

Table (9) correlation matrix between Major component, heavy metals, physical properties and health risk parameters.

	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Se	Zn	Ca	Mg	Na	K	Cl	SO4	NO3	HCO3	TH	pH	TDS	EC	TCRing	TCRderm	TIQing	THQderm	WQI	HPI
As	1.0																											
Cd	0.0	1.0																										
Cr	-0.5	-0.3	1.0																									
Cu	-0.2	0.4	0.3	1.0																								
Hg	-0.4	0.2	0.6	0.1	1.0																							
Mo	-0.3	0.2	0.7	0.3	0.5	1.0																						
Ni	-0.1	0.5	-0.1	0.5	0.1	0.3	1.0																					
Pb	-0.1	0.0	-0.2	0.1	-0.4	-0.2	-0.5	1.0																				
Se	-0.4	-0.2	0.7	0.4	0.2	0.8	0.1	-0.3	1.0																			
Zn	0.1	-0.2	0.0	0.2	0.2	-0.1	-0.2	-0.3	0.1	1.0																		
Ca	-0.8	-0.1	0.3	0.0	0.1	0.2	0.1	-0.1	0.4	-0.1	1.0																	
Mg	-0.3	0.1	0.3	0.3	-0.2	0.7	0.3	0.0	0.8	-0.2	0.6	1.0																
Na	-0.3	0.0	0.0	-0.3	-0.2	0.0	0.0	-0.1	0.2	-0.4	0.7	0.5	1.0															
K	-0.5	0.1	0.0	0.1	-0.3	0.4	0.4	-0.2	0.5	-0.2	0.8	0.8	0.6	1.0														
Cl	-0.3	0.0	-0.1	-0.4	-0.2	-0.2	0.0	-0.1	0.0	-0.3	0.7	0.3	1.0	0.5	1.0													
SO4	-0.6	0.0	0.4	0.3	-0.1	0.6	0.2	0.0	0.8	-0.2	0.8	1.0	0.6	0.9	0.4	1.0												
NO3	-0.5	-0.2	0.6	0.4	0.4	0.5	0.0	-0.3	0.7	0.6	0.4	0.4	-0.1	0.3	-0.2	0.5	1.0											
HCO3	0.0	0.8	-0.2	0.3	-0.1	0.3	0.5	0.2	0.1	-0.5	0.2	0.5	0.4	0.4	0.3	0.4	-0.3	1.0										
TH	-0.6	0.0	0.4	0.2	-0.1	0.5	0.2	0.0	0.7	-0.2	0.9	0.9	0.7	0.9	0.5	1.0	0.4	0.4	1.0									
pH	0.5	0.0	-0.2	0.3	-0.6	0.1	0.2	0.2	0.0	-0.2	-0.5	0.2	-0.4	0.0	-0.5	0.0	-0.2	0.2	-0.1	1.0								
TDS	-0.4	0.0	0.1	-0.2	-0.2	0.1	0.1	-0.1	0.4	-0.3	0.8	0.6	1.0	0.8	0.9	0.8	0.1	0.4	0.8	-0.4	1.0							
EC	-0.4	0.0	0.1	-0.2	-0.2	0.1	0.1	-0.1	0.3	-0.3	0.8	0.6	1.0	0.7	0.9	0.7	0.0	0.4	0.8	-0.4	1.0	1.0						
TCRing.	-0.4	-0.3	1.0	0.3	0.6	0.7	-0.1	-0.3	0.7	0.0	0.2	0.3	-0.1	-0.1	-0.2	0.4	0.6	-0.2	0.3	-0.2	0.0	0.0	1.0					
TCRdermal	-0.5	-0.3	1.0	0.3	0.6	0.7	-0.1	-0.2	0.7	0.0	0.3	0.3	0.0	0.0	-0.1	0.4	0.6	-0.2	0.4	-0.2	0.1	0.1	1.0	1.0				
TIQing	0.1	-0.3	0.8	0.2	0.5	0.6	-0.1	-0.3	0.6	0.1	-0.2	0.2	-0.2	-0.3	-0.3	0.1	0.4	-0.3	0.0	0.1	-0.2	-0.2	0.9	0.8	1.0			
THQdermal	-0.5	-0.3	1.0	0.3	0.6	0.7	-0.1	-0.2	0.7	0.0	0.3	0.3	0.0	0.0	-0.1	0.4	0.6	-0.2	0.4	-0.2	0.1	0.1	1.0	1.0	0.8	1.0		
WQI	-0.5	0.0	0.2	0.0	-0.2	0.3	0.2	-0.1	0.5	-0.3	0.9	0.8	0.9	0.9	0.8	0.9	0.2	0.4	0.9	-0.3	1.0	1.0	0.1	0.2	-0.2	0.2	1.0	
HPI	0.3	0.3	0.5	0.4	0.4	0.7	0.2	-0.2	0.6	0.0	-0.3	0.3	-0.2	-0.1	-0.4	0.2	0.3	0.3	0.0	0.2	-0.2	-0.2	0.6	0.5	0.8	0.5	-0.1	1.0

Discussion

Hydrochemical Properties

The physicochemical results (table 4) show that the water classified into three groups. The Tigris River [SW1, SW2, SW3 and SW4] samples are first group. it has the following values for the physical and chemical properties; pH (8.2-8.3), TDS (271-298) mg/l, EC (427-470) uS/cm, TH (41.74 -43.49) mg/l, Ca (57.7-59.2) mg/l, Mg (14.8) -17.35) mg/l, Na (14.95-17.25) mg/l, K (1.8-2.24) mg/l, Cl (14.5-18.3) mg/l, SO_4 (67.6-70.9) mg/l, NO_3 (0.58-9.2) mg/l and HCO_3 (116-146) mg/l. Water type of this group accepted as drinkable water compared with the international standard specifications for drinking water.

The second group is groundwater wells [GR1, GR2, GR3, and GR4]. These wells located in north of Qayarah city. It's distinguished by values of physical and chemical properties (table 4): pH (7.9-8.3), TDS (4390-10900) mg/l, EC (5240-12200) uS/cm, TH (494.45-843.1) mg/l, Ca (499-622) mg/l, Mg (298-667) mg/l, Na (536-1940) mg/l, K (9.02-11.1) mg/l, Cl (392-1770) mg/l, SO_4 (2810-5560) mg/l, NO_3 (7.78-25.7) mg/l and HCO_3 (193-273) mg/l.

The third group is groundwater wells [GR5, GR6, GR7, GR8, GR9], which are all located south of the city of Qayarah. It has distinguished by the following values of physical and chemical properties. pH (8.0-8.2), TDS (2680-4210) mg/l, EC (3250-4690) uS/cm, TH (173.1-446.1) mg/l, Ca (213-609) mg/l, Mg (81.1) -172.5) mg/l, Na (166.5-598) mg/l, K (3.28-6.92) mg/l, Cl (132-511) mg/l, SO_4 (1010-2360) mg/l, NO_3 (1.65-33.6) mg/l and HCO_3 (85-312) mg/l.,

In contrast. The sulfurous water spring sample [SW5] recorded the following values; pH (7.9), TDS (18700) mg/l, EC (22900) uS/cm, TH (676.4) mg/l, Ca (1010) mg/l, Mg (209) mg/l, Na (4380) mg/l, K (10.25) mg/l, Cl (7250) mg/l, SO_4 (3240) mg/l, NO_3 (0) mg/l and HCO_3 (192) mg/l.

The above results showed a large discrepancy between surface water samples and two sets of groundwater samples in the study area due to differences in the area's lithology and geochemical processes. The first group, which is the water of the Tigris River, flows at a high speed due to the high slope, which helps in not concentrating ions and elements. It is also very little affected by the lithology within the study area, in addition to covering the river course with sediments of the modern era, which are gravel, sand, and concretions, but there is an effect. It may be from sources located upstream before the current study area, according to the (Gibbs, 1970) classification of the of the water origin, (Fig. 4). The second group, which is the groundwater wells north of the city of Qayarah, it was affected by the sulfur spring [SW5]. The flow direction of water from sulfur spring (SW5) towards the Tigris River, passing through the wells (GR5, GR6, GR7, GR8, GR9). In addition to, rock column of the northern wing of the Qayarah anticline effect, as this limb is steeper and the evaporite rocks (gypsum and anhydrite) are closer to the surface, while the southern limb is less steep and the silt, marl and limestone are closer to the surface than the evaporites. (Alfaris, 2022).

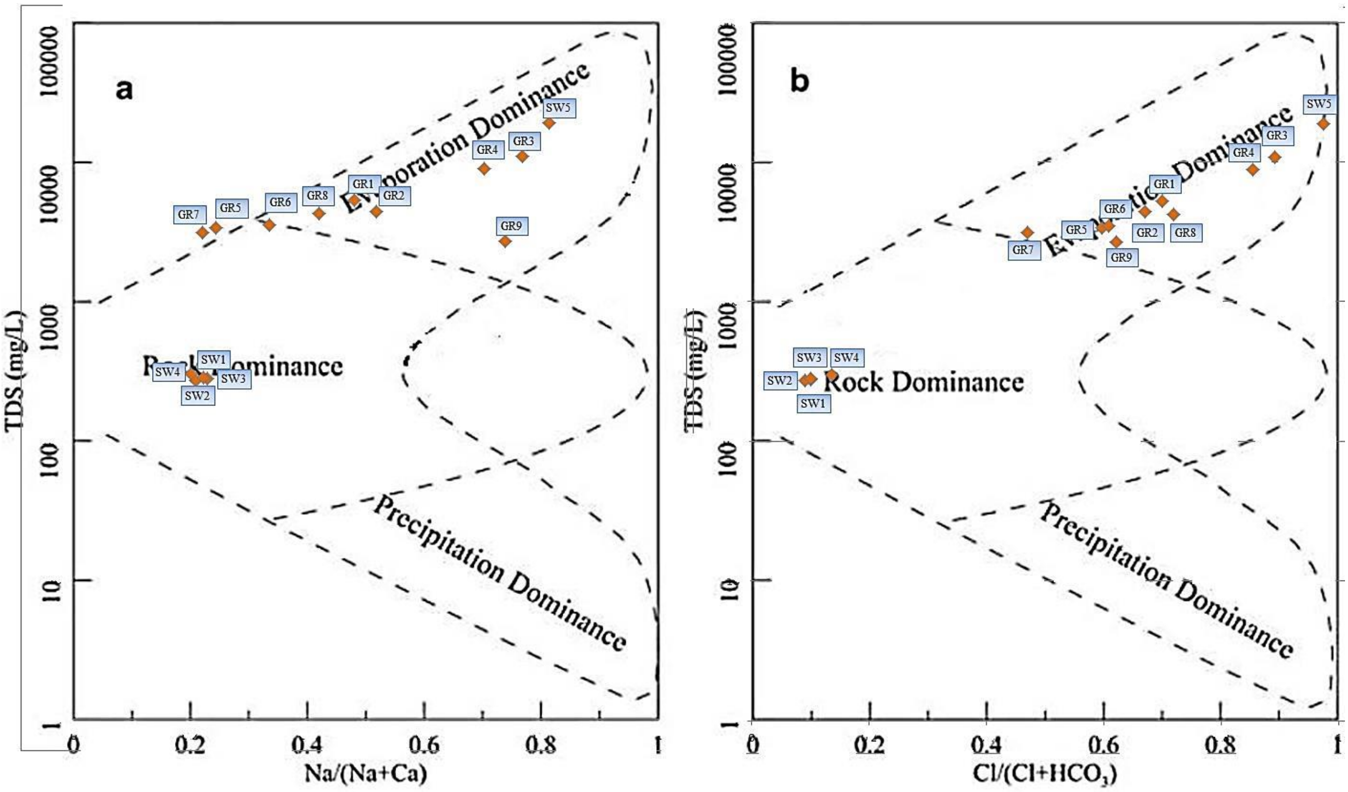

Fig. 4. Gibbs plot of the studied water samples, showing the groundwater of rock, precipitation and evaporation dominance.

The high values of the cations and anions come from distribution of carbonate and evaporates rocks, which has a big impact on the studied water samples quality. Its impact was greater on the water samples of studied wells at the northern part of the current study area due to the spread of evaporite rocks in this part, while in the southern part the influence of carbonate rocks increases in addition to clastic rocks, which played a role in mitigating this effect. Concentration of the basic components by Evaporation. in addition to, infiltration of water through the soil in the study area consisting of Calcrete and gibscrete sediments which play a major role in changing their properties during the process of filtering them into the surface aquifer, and thus form evaporating water according to the classification (Gibbs, 1970), as shown in (Fig. 4).

Hydrochemical Facies:

Piper's classification was used to classify the studied water samples (Table 5) and (Fig. 2). It shown that water divided into groups: The first group is belonging to water samples of the Tigris River [SW1, SW2, SW3, and SW4], as they are clearly present within the range of Hydrochemical facies (B). This means that the water of these samples is normal alkaline ground water with the dominant presence of bicarbonate, sulfate, or chloride, and this is the result. Corresponds to Stiff's chart. The groundwater samples; GR5 and GR7 classified in Hydrochemical facies (C). In contrast, the groundwater samples GR1, GR2, GR4, GR6, GR3 and GR8 classified in the Hydrochemical facies (E). Samples GR9 and SW5 in Hydrochemical facies (G). The Stiff diagram (Fig. 3) shows that the groundwater samples GR5, GR6, GR7, and GR8 classified, as it is alkaline water with an increase of SO_4. The samples GR3 and GR4, their water is alkaline ground with a greater increase of sulfates and chloride. The sample of sulfurous spring water SW5 characterized by alkaline ground water with an increase in the alkali and chloride fraction. The samples of GR1 and GR2, their water is alkaline, with an increase in sulfate, while the GR9 sample characterized by alkaline ground water with an increase in the chloride fraction and an excess of SO_4.

Water quality index (WQI):

The water samples results classified by Water Quality Index (WQI) into several groups (table 4); the samples SW1, SW2, SW3 and SW4 are excellent drinking water quality, it recorded a WQI value within the range (20.81 - 22.19). The GR9 samples poor drinking water quality, it recorded WQI value equal to (69.03). Samples GR6 and GR7 were very poor drinking quality with WQI values (95.75) and (85.72), respectively. In contrast, samples of GR1, GR2, GR3, GR4, GR5, GR8 and SW5 are unsuitable for the drinking with WQI values within the range (111.62 - 341.57).

Heavy metal and heavy metal pollution index (HPI):

The most important heavy elements in the water samples in the current study, whether surface or groundwater, are shown in (Table 6). The concentration of as range (0.41-1.72) µg/l. Cd range (0.01-0.06) µg/l, Cr range (0.5-24.5) µg/l, Cu range (0.1-0.9) µg/l. Hg range (0.05 - 0.12) µg/l. Mo range (0.12 - 20.1) µg/l. Ni range (1.5 - 9.1) µg/l, Pb range (0.05 - 0.25) µg/l, Se range (0.18-9.76) µg/l, and Zn range (0.7 - 13.1) µg/l. We calculated the values of the heavy metal pollution index (HPI) for water samples in the study area for the elements (As, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Se and Zn). It was found that the average heavy metal pollution index was (2.41) as mention in (Table 6), the HPI index for the samples in the study area showed that contamination with heavy metals is low within the range (1.18 - 3.65).

Health risk assessment:

The Hazard index (HI), total Ingestion hazard Quotient (THQ_{ing}) and Total Dermal hazard Quotient (HQ_{dermal}) were calculated. The (Table 8) shows that the total non-carcinogenic risk resulting from exposure through ingestion (THQ_{ing}) to heavy metals in the samples of the current study follows the following order: (As > Cr > Ni > Cd > Pb > Cu > Zn) at the rate of the following values: (2.88E-04>1.74E-04>1.63E-05>3.40E-06>3.26E-06>1.32E-06>1.15E-06). The total risk quotient by skin exposure (THQ_{dermal}) to the heavy metals shows order: Cr > As > Ni > Cd > Cu > Zn > Pb. by the following order of values: 8.61E-02>1.78E-03>5.03E-04>4.20E-04>8.17E-06>4.28E-06> 2.02E-06. The non-carcinogenic hazard quotient (HI) values of heavy metals show the following order: GR6>GR3>GR8>GR7>GR5>GR9>GR1>GR4>GR2>SW3>SW5>SW2>SW1>SW4, with order of values; 3.71E-01>2.56E-01>1.62E-01>1.15E-01>5.38E-02>4.82E-02>4.09E-02>3.55E-02>2.76E-02>1.35E-02>1.24E-02>1.18E-02>1.11E-02>3.57E-03. The total carcinogenic risk (Table7) calculations for exposure to heavy metals through ingestion (TRC_{ing}.) show following order; Cr > As > Ni > Cd > Pb with order of values; 4.92E-08>2.44E-08>5.16E-09>1.22E-10>1.83E-11. In contrast, the the total carcinogenic effect of heavy metals through skin exposure (TRC_{dermal}) show the following order: Cr>Ni>As>Cd>Pb. With order of values: 4.28E-05>1.45E-07>1.38E-07>4.64E -08>1.03E-11. The total carcinogenic risk by heavy metals showed the following order; GR6 > GR3 > GR8 > GR7 > GR5 > GR9 > GR1 > GR4 > GR2 > SW5 > SW3 > SW2 > SW1 > SW4 with values arranged in the following order: 1.84E04 > 1.27E-04 > 7.99E-05 > 5.65E-05 > 2.59E-05 > 2.23E-05 > 1.93E-05 > 1.62E-05 > 1.30E-05 > 5.49E-06 > 4.96E-06 > 4.20E-06 > 4.12E-06 > 3.30E-07.

Correlation matrix:

The relationship between the major components and heavy elements using the correlation matrix shown in (Table 9), which showed the basic components affecting (TDS) are affected by the following components, in the order Na>Cl>Ca>SO_4>K>Mg, while the components affecting EC were in the following order: Na>Cl>Ca>K>SO_4>Mg. As for the quality index Water quality (WQI) was affected by the following components, in the following order: TDS>EC>TH>K,Na>SO_4>Ca>Cl>Mg>HCO_3, Total hardness (TH) was affected by the following components: SO_4>Mg >K>Ca>Na>Cl. The main components that correlate to sulfates (SO_4) follow the order; Mg>K>Ca>Na, and the components that correlate with carbonates (HCO_3) follow the order; Mg>K>Na>Ca. The pH values have a negative significant relationship with; Ca, Na, K, Cl, SO_4 and NO_3. The correlation of heavy elements with the heavy metal pollution factor (HPI) is in the following order: Mo>Se>Cr>Hg>Cu>Cd>As. The pollution factor is related to heavy metals (HPI) with a healthy estimate in the following order THQing>TCR_{ing}.>THQ_{dermal}>TCR_{dermal}. Arsenic (As) showed a negative correlation with the basic components and a weak positive correlation with ph. In contrast, NO_3 showed a positive correlation with Cd, Ni, Mo, Cu, Pb. In contrast, it shows negative correlation with As, Hg, Cr, and Zn. We conclude control factor of distribution of heavy elements, cations, anions, are geological structures, type of rocks and the speed of the flow of the waters of the Tigris River. In addition to, chemical impact such as pH and basic it contributed largely on the movement or non-movement (bounded to the soil or rocks) of these elements within the aquatic environment.

Conclusion:

Three hydrogeochemical facies distinguished using the basic components and physical characteristics. The first one was the surface water samples of Tigris River [SW1, SW2, SW3 and SW4], it was type (B) according to Piper's classification. The samples [GR5 and GR7] in (C) facies, Samples [GR1, GR2, GR4, GR6, GR3, GR8] in facies (E). Samples [GR9, SW5] in facies (G).

Using the WQI water quality index to classify the study water showed several groups: The water samples from the Tigris River [SW1, SW2, SW3 and SW4] very good for drinking. Sample [GR9] poor quality for drinking use. Samples [GR6 and GR7] very poor. Other water samples unsuitable for drinking. The Heavy Metal Pollution Index (HPI) shows low water contamination. Total cancer risk shows acceptable risk values for cancer risk except GR3 showing a potentially high cancer risk. The cancer risk of through dermal exposure and ingestion by heavy metals was more effect on adults than children The quality of water in the study area is affected by the basic components in the following order: Na>Cl>Ca>SO_4>Na>Mg, while the heavy elements, their association with the main anions follows the following order: NO_3>SO_4>HCO_3.

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