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Evaluation of the Impacts of Discharged wastewater on the water quality of the Tigris River in Baghdad City

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Abstract:
Twenty-four water samples were collected from the Tigris River inside Baghdad city and close to the sewage pipes for the winter seasons in October 2022 and the summer seasons in May 2023 to assess the pollution of the Tigris River water. The study included analyzing the physical and chemical properties and studying the concentrations of some heavy elements (iron, manganese, nickel, zinc, copper, chromium, cadmium, and lead). Tigris River samples are characterized during the winter as light alkaline, fresh water, highly mineralized and sodium sulphate type. Water samples during the summer are characterized by light alkalinity, fresh water, high mineralization, and calcium chloride type. River water evaluated for irrigation purposes showed that the sodium absorption ratio (SAR) had no harmful effects on sodium, and dissolved sodium (Na%). In the winter period, all surface water samples are within the permissible limits, While all surface water samples in the summer period are good irrigation water. In terms of (TDS) and (EC), all surface water samples are For two good periods and within the permissible limits for the quality of irrigation water, the results of heavy metals during the summer season showed contamination of surface water samples with cadmium and lead, while water samples during the summer season were characterized by contamination of their water with copper, iron and zinc elements that were outside the permissible limit for the next health organization Global(WHO).

Keywords: Hydrogeochemical, Tigris River's, Heavy Elements, Wastewater.

تقييم التلوث لمياه نهر دجلة الناتجة عن تصريف المياه العادمة في بغداد, العراق

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قسم علم الارض, العلوم, بغداد, بغداد, العراق

الخلاصة
تم جمع 24 عينة مياه من نهر دجلة داخل مدينة بغداد والقريبة على انابيب مياه الصرف الصحي و للموسمين الشتاء في شهر اكتوبر 2022 والصيف في شهر مايو 2023 لتقييم تلوث مياه نهر دجلة حيث شملت الدراسة تحليل الخواص الفيزيائية و الكيمائية و دراسة تراكيز بعض العناصر الثقيلة (الحديد, المنغنيز, النيكل , الخارصين , النحاس , الكروم , الكادميوم , و الرصاص) . تتميز عينات مياه نهر دجلة خلال فصل الشتاء بالقلوية الخفيفة ، مياه عذبة ، شديدة التمعدن ونوع كبريتات الصوديوم في حين تتميز عينات المياه خلال فصل الصيف بالقلوية الخفيفة ، مياه عذبة ، عالية التمعدن ،ونوع كلوريد الكالسيوم. أظهرت مياه النهر التي تم تقييمها لأغراض الري أن نسبة امتصاص الصوديوم (SAR) ليس لها أي آثار ضارة من الصوديوم ،

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نسبة الصوديوم الذائبة (Na%) في فترة الشتاء ، جميع عينات المياه السطحية هي داخل الحدود المسموح ، في حين أن جميع عينات المياه السطحية في فترة الصيف هي مياه الري الجيدة ، ومن حيث (TDS) و (EC) ، تكون جميع عينات المياه السطحية لفترتين جيدة و داخل الحدود المسموح بها لجودة مياه الري ، واظهرت نتائج العناصر الثقيلة خلال موسم الصيف بتلوث عينات المياه السطحية بعنصر الكادميوم والرصاص في حين تتميز عينات المياه خلال فصل الصيف بتلوث مياها بعناصر النحاس و الحديد والخارصين وكانت خارج الحد المسموح به من قبل المنظمة الصحة العالمية (WHO) .

1. Introduction

In Iraq, the Tigris River is a significant water supply for domestic and commercial uses. In recent years, the assessment of water quality in Iraq has gained importance. Mostly because of the worry that fresh water would eventually run out and become more prone to contamination
[1].

The Tigris spans approximately 1800 km, 400 of which pass through Turkey and then enter Syria and Iraq. Including 60 km in Baghdad, the Tigris in Iraq is approximately 1418 km long, or more than three-quarters of its overall length. Nonetheless, Iraq's water quality is still in danger due to pollution from both urban and agricultural areas. Briggs claims that a lot of environmental changes are happening at a rate that has never been seen in the recent history of our planet. [2]

The Tigris River discharge has drastically decreased over the past few decades, even though water demand is at an all-time high. In addition, the treatment plant is facing a shortage of water due to rising wastewater volumes[3] Millions of liters of sewage are consequently dumped into rivers, their tributaries, and groundwater reservoirs without any kind of treatment. Furthermore, most sewage outfalls from several establishments, including hospitals, power stations, oil refineries, and others, situated alongside waterways, have directly poured their liquid and solid waste into rivers, such as the Tigris (Figure1). Due to all of the factors mentioned above, pollution affects the Iraqi ecosystem as a whole, posing serious threats to the environment and the living things that live there. Water quality is determined by the dissolved ions or other impurities in the water [4] Thus, by gathering water samples from the Tigris River in Baghdad, this study aims to assess the level of environmental pollution in the study area. Then, they are examined in labs to look for signs of contamination.

This study aims to ascertain the impact of sewage water on the Tigris River's water quality through chemical and physical examination, including pH, EC, TSS, and TDS measurements. Main anions include sulfate (SO_4^{-2}), chloride (Cl^-), and bicarbonate (HCO_3^-), while main cations include calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+). And identify the minor ions, such NO_3 and PO_4. Measuring the amount of trace metals, such as Pb, Cu, Cr, Mn, Zn, Cd, Ni, and Fe, in samples of river water.

Among the earlier research in this field is a hydrogeological environmental assessment study by Ali [5] that used the Canadian Water Quality Index to examine how the Al-Rasheed electrical power station affected the Tigris River in the southern part of Baghdad. Magnetite polishing using Tigris River stream sediments in Baghdad was evaluated by Alazawii et al. [6] and Awadh and Khalid [7] (CCME WQI).

Figure 1: Releasing wastewater directly into the Tigris River in some areas of Baghdad City.

2. Location of the study area

The river flows through the city of Baghdad for approximately 40 km in length and 500 m in width [8]. The Tigris River in Baghdad is experiencing a late stage of maturity due to its numerous twists, which reflect the river's alterations from its original flow. Numerous tiny, ephemeral islands that form in the river due to sedimentation are present. Reeds and wild grasses cover these islands, which become submerged during flood season and when the river level increases [9]. The study region is bounded by the following geographic coordinates and includes 24 sampling stations along the Tigris River that flow through Baghdad: Latitude: 33.2897-33.366 N, Longitude: 44.3812-44.348 E.

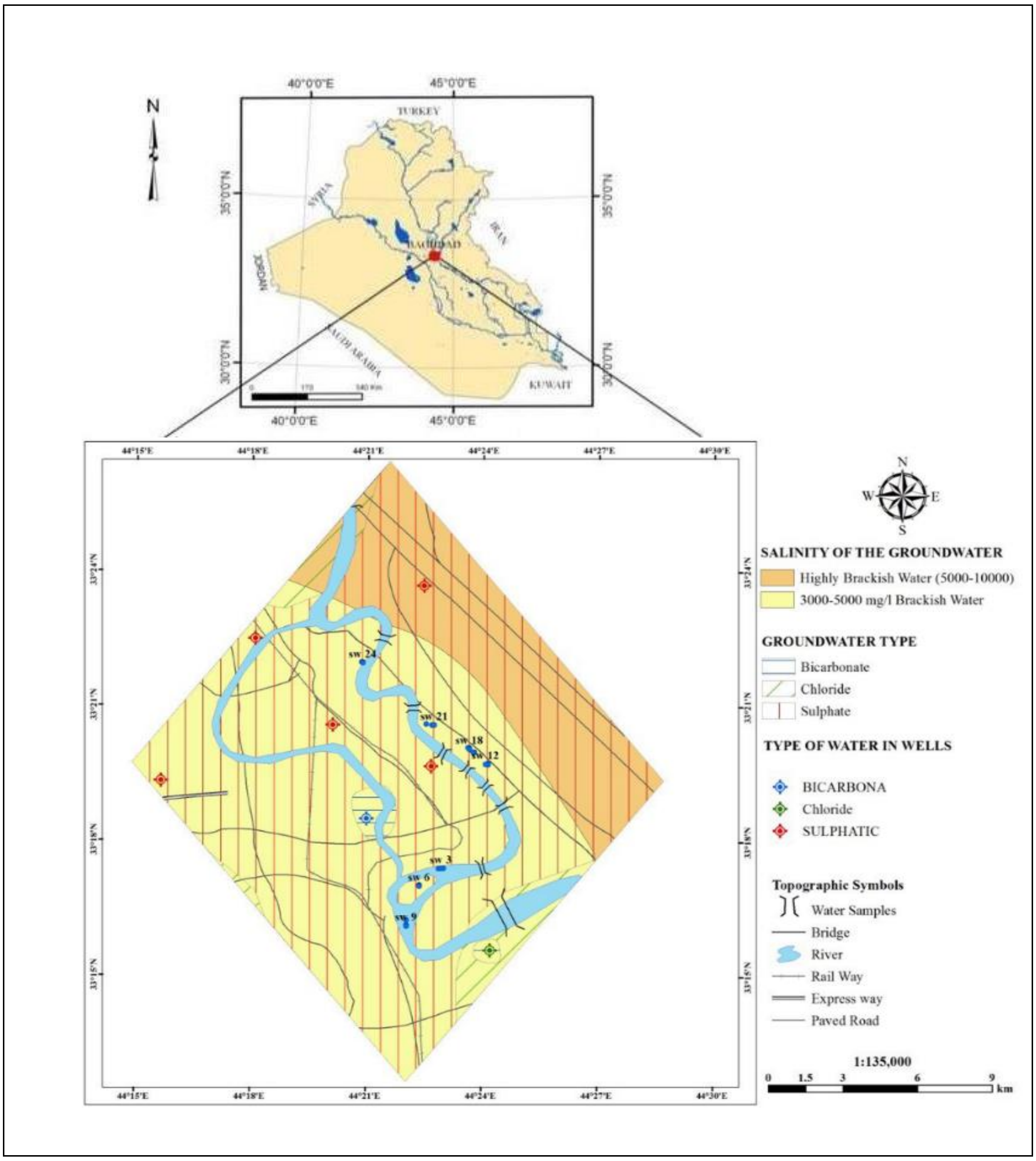

Figure 2: Location of the study area

Table 1: Coordinates of the samples under study

Sample NO.	Location	Latitude	Longitude
SW 1	Iraqi Central Bank	33.28987	44.3812
SW 2		33.28998	44.3832
SW 3		33.28985	44.38222
SW 4	Al-Jadriya Bridge	33.28379	44.37291
SW 5		33.28349	44.37284
SW 6		33.28328	44.37281
SW 7	Al-Dora (Aldora silo)	33.27075	44.36735
SW 8		33.26891	44.36735
SW 9		33.26854	44.36735
SW 10	Al-Sinak Bridge	33.32889	44.40246
SW 11		33.32838	44.40242
SW 12		33.32859	44.40126
SW 13	Ahrar bridge	33.33296	44.39635
SW 14		33.33287	44.39629
SW 15		33.33297	44.39598
SW 16	River street	33.33472	44.39417
SW 17		33.33476	44.39374
SW 18		33.33413	44.39423
SW 19	Medical city	33.34335	44.37553
SW 20		33.34309	44.3781
SW 21		33.34304	44.379
SW 22	Al- kadhimiya	33.3663	44.34747
SW 23		33.36625	44.34791
SW 24		33.366	44.348

3. Materials and methods

Fieldwork and sampling

Using GIS software, the sample locations were plotted on the map (Figure 2). To cover the Tigris River's research reach, twenty-four water samples were taken from various sites. Within two periods, December of 2022 and May of 2023, to collect water samples, (3 samples were taken from the same location at different distances) area:

8 water samples within the mix with river water (near the river bank)

8 samples after the mix (5 meters away)

8 wastewater sample discharge of Tigris River (10 meters away).

Every water sample was put into a 500 mL plastic bottle with a screw-on top. For every sample point, two samples were taken: one for heavy metal analysis and one for main component analysis. Every water sample was promptly labelled precisely and secured with a tight screw-on lid. The plastic screw cap and bottle itself were the only surfaces the water sample in each bottle came into contact with, and there was no free headspace left in the bottle. The Ministry of Science and Technology's laboratory activities included the physical and chemical study of water samples. A pH, EC, and TDS are used to measure physical characteristics such as hydrogen number (PH), electrical conductivity (EC), and Total dissolved solids (TDS). Major cations, including Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), and Potassium (K^{+}), were analyzed using a flame photometer, while major anions, including Sulfate (SO_4^{-2}) determined by spectrophotometer, Chloride (Cl^{-}) and bicarbonate (HCO_3^-). Trace elements including; (Zn, Mn, Cu, Ni, Pb, Cd, Cr, and Fe) were determined by Atomic Absorption Spectrometer.

4. Result and Discussion

4.1 Physical properties:

Research on the physicochemical qualities of water primarily aims to determine the source of the water and the extent of contamination. [10].

Table 2: displays the findings of the surface sample physical analysis.

Sample NO.	Winter season				Summer season			
	pH	EC(μs/m)	TDS(ppm)	TSS Mg/l	pH	TDS(pp m)	EC(μs/ m	TSS Mg/l
SW1	7.0	883	526	15	7.7	676	1315	40
SW2	7.1	703	419	10	8.0	406	788	20
SW3	7.3	702	418	10	8.0	379	779	19
SW4	7.9	697	416	12	8.0	398	799	20
SW5	7.3	697	316	12	8.0	401	782	20
SW6	7.3	698	416	12	8.1	397	780	25
SW7	7.3	1018	607	30	7.7	590	1165	45
SW8	7.3	1443	860	30	7.7	618	1219	50
SW9	7.4	700	417	15	8.0	397	784	30
SW10	7.3	1032	615	28	8.0	402	795	30
SW11	7.3	714	425	15	8.0	367	728	25
SW12	7.4	702	421	12	8.0	403	793	30
SW13	7.0	1415	842	30	7.7	639	1267	50
SW14	7.1	872	518	15	8.0	400	796	20
SW15	7.3	710	422	10	8.0	398	789	22
SW16	7.2	984	585	20	7.7	486	963	20
SW17	7.4	707	421	12	8.0	402	792	20
SW18	7.4	708	421	12	8.0	397	785	25
SW19	7.4	803	477	15	7.7	976	1929	45
SW20	7.3	717	427	10	8.0	398	783	20
SW21	7.5	704	419	10	8.0	399	786	19
SW22	7.4	1366	813	30	7.7	791	1496	60
SW23	7.3	1344	801	28	8.0	398	786	20
SW24	7.5	673	401	12	8.0	385	783	20
Iraqi standards (2009)	6.5_ 8.5	2000	1000		6.5_ 8.5	1000	2000	
WHO standards (2018)	6.5_ 8.5	2500	1000		6.5_ 8.5	1000	2500	
EPA standards (2018)	6.5_ 8.5	_	500		6.5_ 8.5	500	_	

4.1.1 PH

The logarithm of the hydrogen ion concentration, which represents acidity and basicity at standard temperature and pressure, is the definition of hydrogen-oxygen. In the most gas-water-rock reactions, including hydration, polymerization, adsorption, complex formation, food reactions, and reduction, hydrogen is the governing element [11]. The pH is affected by the concentration of carbonate and bicarbonate ions dissolved in water [12]. Also, it affects the way and behaviour of personal elements that speak in different environments [13]. The highest value of pH in the water of the study area in the winter season was (7.9) in the (Al_Jadriya Bridge) area, while the lowest value was (7.0) in the (Iraqi Central Bank and Al ahrar Bridge) area. In the summer season, the highest value was (8.1) in the (Al-Jadriya Bridge) area, while the lowest value was (7.7) in the (Iraqi Central Bank and Al-ahrar Bridge) area.

It turns out that most of the water in the study area is slightly alkaline, and some of it is close to the neutral state. In contrast, the water in the two regions (Iraqi Central Bank and Al-ahrar Bridge) is characterized by neutral acidity.

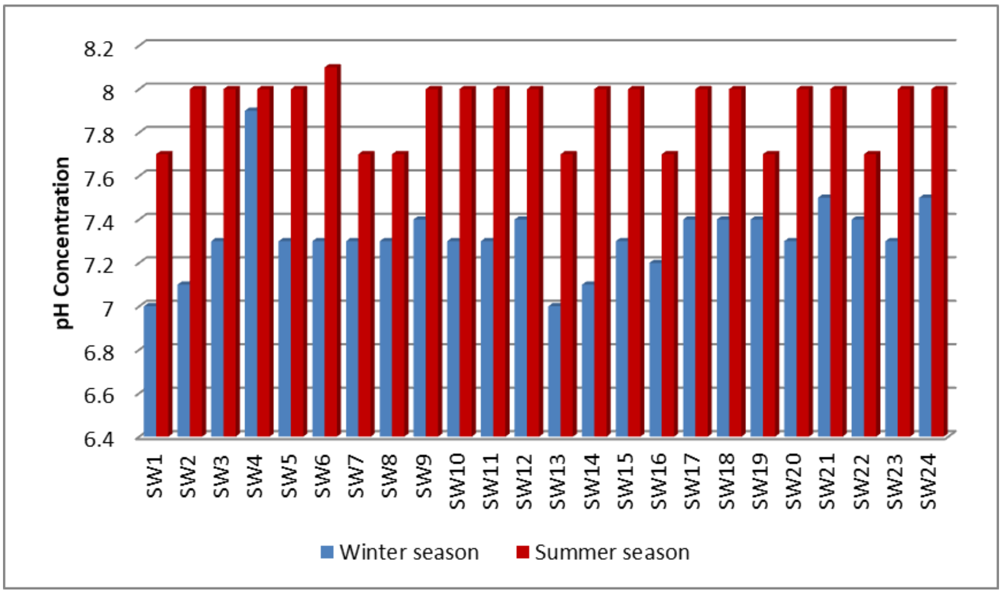

Figure 3: pH value for Water samples**.**

4.1.2 Electrical Conductivity (EC)

Measured in micromoles/cm (µS/cm), electrical conductivity is the capacity of one centimeter squared of water to carry electrical current at a temperature of twenty-five degrees Celsius. The temperature of the water affects electrical conductivity; a one-degree Celsius increase in temperature results in a two per cent increase in electrical conductivity [14]. Electrical conductivity also increases with increasing concentration of dissolved salts [15] . The highest value of electrical conductivity in the winter season for water in the study area was (1443) (µS/cm) in the Medical City area, while its lowest value was (673) (µS/cm) in the Al_kadhmiya area. In the summer season, the highest value was (1929) in the (Medical City) area, while the lowest value was (728) (µS/cm) in the(Al_sinak Bridge) area. Based on a previously documented correlation between electrical conductivity (EC) and the degree of mineralization in water [15] It has been discovered that every water sample in the current study region falls into the category of highly mineralized to excessively mineralized water for both periods (Table 3).

Table 3: Relationship between Electrical Conductivity and Mineralization according to (Detay, 1997)

EC µS/cm	Mineralization	Sample No for both periods
<100	Very Weakly Mineralized water	
100-200	Weakly Mineralized water	
200-400	Slightly Mineralized water	
400-600	Moderately Mineralized water	
600-1000	Highly Mineralized water	Some samples of the surface water
>1000	Excessively Mineralized water	Some samples of the surface water

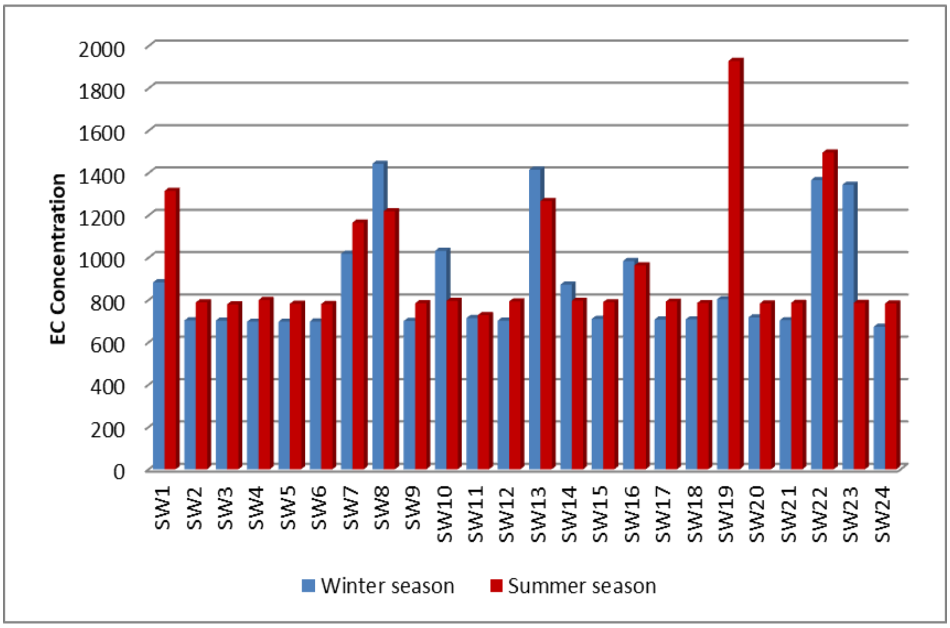

Figure 4: EC value for Water samples

4.1.3 Total Dissolved Solids (TDS)

It is defined as any solid, ionized or not, dissolved in water; dissolved gases, suspended particles, and colloidal substances are not included [16] Another definition of salinity is the amount of dissolved salts in water, measured in parts per million (ppm) after organic matter oxidises, carbonates change into oxides, and bromine and iodine replace chlorine. Concentration, mineralization, or salt contents are terms used to describe the amount of dissolved salts. When the total dissolved salt concentrations in the current study are compared with the categories of [16] [17], (Table 4), it becomes clear that all of the water samples are fresh water. The higher Total Suspended Solid concentration in the winter season for water in the study area was (860) in the Al-dora area, while its lowest value was (316) in Al_ Jadriya Bridge area; in the summer season, the highest value was (976 ppm) near the Medical City area while the lowest value was (728 ppm) near the Al_sinak Bridge area.

Table 4: Water classification based on total dissolved solids

Water Class	Davis and Dewiest,1966 T.D.S. (ppm)	Drever,1997 T.D.S. (ppm)
Fresh Water	**0 – 1000**	**< 1000**
Brackish Water	**1000 – 10000**	**1000 – 20000**
Salty Water	**10000 – 100000**	**-**
Saline Water	**-**	**35000**
Brine Water	**>100000**	**> 35000**

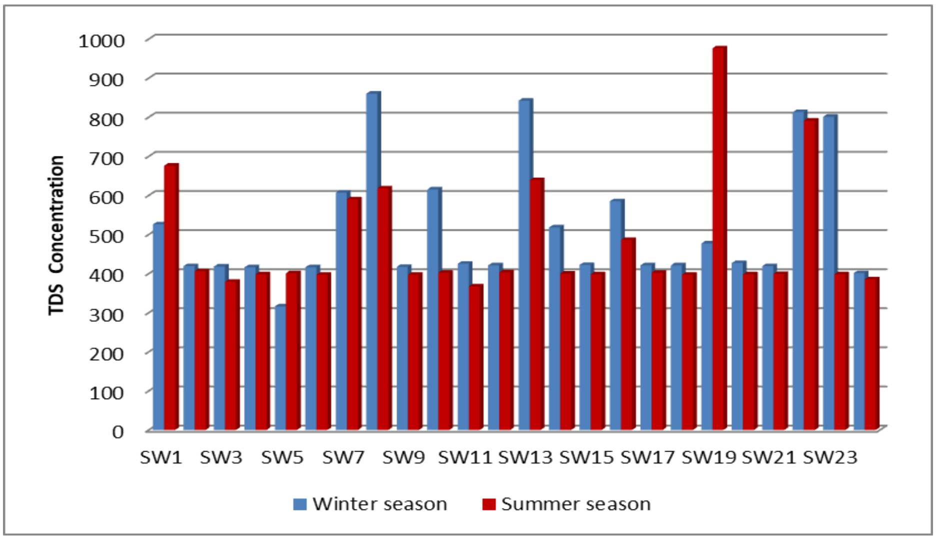

Figure 5: shows the direct relationship between total dissolved solids (T.D.S.) and electrical conductivity (E.C.) in the water of the study area.

4.1.4 Total Suspended Solids (TSS)

A wide range of dissolved or solid contaminants may be present in environmental waters. Particles in the water column are referred to as suspended solids when measuring the levels of these impurities. They are essentially defined as particles too big to fit through the filter to separate them from the water. Dissolved solids include ionic species as well as smaller particles. A measurement of water's cloudiness is called turbidity. TSS might be the cause. Total Suspended Solids (TSS) is the amount of filterable solids in a sample of water that can be extracted from the raw water through mechanical or physical processes like filtration or precipitation [18]. The highest value of Total Suspended Solids in the winter season for water in the study area was (30) mg/l in the Al_Kadhimiya area, while its lowest value was (10) mg/l near the Iraqi Central Bank. In the summer season, the highest value of Total Suspended Solids in the winter season was (60) mg/l in the Al_Kadhmiya area, while its lowest value was (19) mg/l near the Iraqi Central Bank.

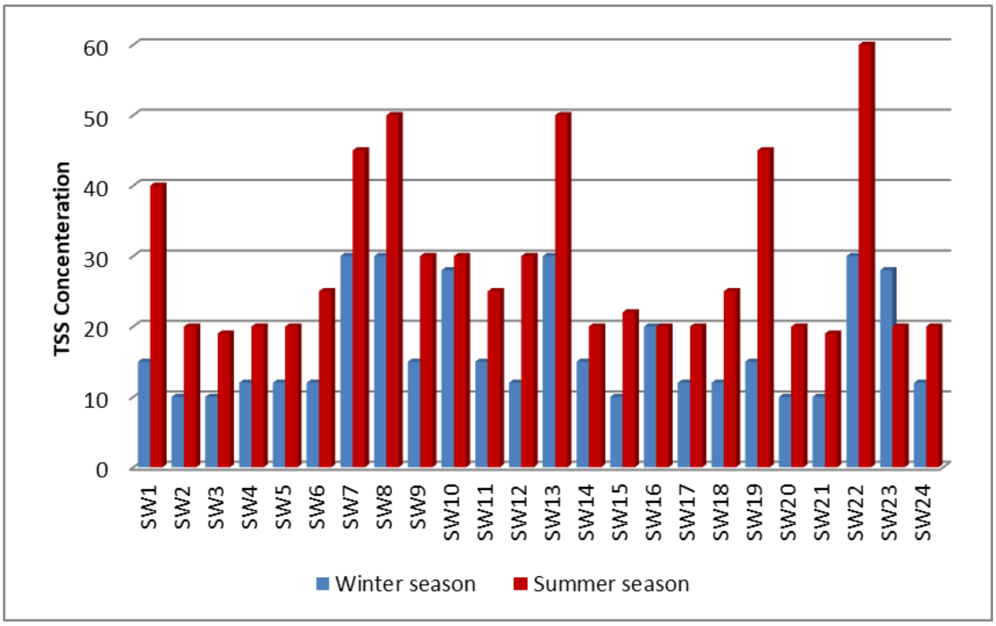

Figure 6: TSS value for Water samples.

4.2 Chemical Properties

Ion concentrations are the principal means of detecting the chemistry of water. The following seven ions account for more than 90% of the dissolved solids in surface water: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, and HCO_3^{-} [19] [20]. The results of the chemical examination of the samples from the present study are shown in Tables 5:

Table 5: Chemical analysis results for the samples of water during the winter season.

Sample NO.	Unit	Cations				Σ Cations	Anions			Σ Anions
		HCO_3^-	SO_4^{-2}	Cl^-	K^+		HCO_3^-	SO_4^{-2}	Cl^-	
1	Ppm	105	70	400	12	587	250	184.75	14.29	449.04
	Epm	5.25	5.83	17.39	0.30	28.77	0.4	3.84	0.40	4.64
	epm%	18.24	20.26	60.42	1.07	99.99	47.43	44.54	4.72	96.69
2	Ppm	90	32	210	8.2	340.2	180	213.75	9.58	403.33
	Epm	4.5	2.66	9.13	0.21	16.5	2.95	4.45	0.27	7.67
	epm%	27.26	16.15	55.31	1.27	99.99	37.71	56.9	3.50	98.11
3	Ppm	85	355	210	7.8	657.8	200	202.7	9.37	412.07
	Epm	4.25	27.9	9.13	0.2	41.48	3.27	4.22	0.26	7.75
	epm%	10.24	67.27	22	0.48	99.99	41.44	53.37	3.38	98.19
4	ppm	90	3.2	200	7.2	300.4	210	207	11.55	428.55
	epm	4.5	0.26	8.69	0.18	13.63	3.44	4.31	0.33	8.08
	epm%	32.97	1.95	63.7	1.35	99.97	41.86	52.42	4	98.28
5	ppm	65	23	210	7.9	305.9	200	217	9.56	426.56
	epm	3.2	1.9	9.1	0.2	14.4	3.2	4.5	0.27	7.97
	epm%	22.4	13.22	62.96	1.4	99.98	39.9	55	3.3	98.2
6	ppm	95	32	200	7.7	334.7	200	200	8.18	408.18
	epm	4.75	2.66	8.69	0.19	16.29	3.27	4.16	0.23	7.66
	epm%	29.1	16.35	53.3	1.20	99.95	4.19	53.3	2.99	60.48
7	ppm	130	42	350	10.2	532.2	250	280	13.48	543.48
	epm	6.5	3.5	15.21	0.26	25.47	4.09	5.83	0.38	10.3
	epm%	25.51	13.73	59.72	1.02	99.98	39.48	56.19	3.7	99.37
8	ppm	190	67	540	11.4	808.4	270	381.5	17.43	668.93

	epm	9.5	5.58	23.47	0.29	38.84	4.42	7.94	0.49	12.85
	epm%	24.45	14.37	60.42	0.75	99.99	34.13	61.28	3.84	99.25
9	ppm	85	36	200	6.3	327.3	130	205.25	7.93	343.18
	epm	4.25	3	8.69	0.16	16.1	2.1	4.27	0.22	6.59
	epm%	26.38	18.62	53.98	1	99.98	31.42	63.05	3.34	97.81
10	ppm	120	49	290	3.6	495	230	284.5	11.4	525.9
	epm	6	4.09	12.6	0.092	23.61	3.77	5.9	0.32	9.99
	epm%	26.4	22.29	70.39	0.59	99.98	37.29	58.63	3.2	99.12
11	ppm	95	33	200	6.3	214.1	170	205.5	8.1	368.82
	epm	4.28	2.75	8.65	0.17	9.86	2.76	4.28	0.23	8.15
	epm%	29	16.75	53.12	1.06	99.98	37.4	57.4	3	75.4
12	ppm	90	32	200	6.5	241.5	150	211.24	8	518.24
	epm	4.25	2.6	8.6	0.16	10.6	2.45	4.06	0.3	11.82
	epm%	28.8	16.49	54.24	1.04	99.98	34.1	61.08	3.17	81.37
13	ppm	180	56	340	5.5	631	350	390	15.96	755.96
	epm	9	4.66	14.78	0.14	29.84	5.73	8.12	0.45	14.3
	epm%	31.14	16.6	51.5	0.472	99.96	39.32	55.68	3.12	98.12
14	ppm	110	40	240	12.2	402.2	180	232.5	9.35	421.85
	epm	5.5	3.33	10.43	0.3	19.56	2.95	4.84	0.26	8.05
	epm%	28	17	53.29	1.95	100.24	36.28	59.55	3.28	99.11
15	ppm	80	38	200	6.4	324.4	170	200	7.57	377.57
	epm	4	3.1	8.69	0.16	15.95	2.78	4.16	0.2	7.14
	epm%	24.95	19.76	54.25	1.02	99.98	38.12	56.99	2.96	98.07
16	ppm	110	37	220	14.1	381.1	250	270	7.57	527.57
	epm	5.5	3	9.56	0.36	18.42	4.09	5.6	0.21	9.9
	epm%	29.71	16.65	51.67	1.95	99.98	40.89	56.1	2.16	99.15
17	ppm	95	32	200	6.3	333.3	180	181.5	7.63	369.13
	epm	4.75	2.66	8.69	0.16	16.26	2.95	3.78	0.2	6.93
	epm%	29.18	16.3	53.4	0.9	99.78	41.65	53.36	3	98.01
18	ppm	85	33.5	200	7.9	326.4	180	187.2	9.5	376.7
	epm	4.25	2.79	8.69	0.2	15.93	2.95	3.9	0.2	7.05
	epm%	26.66	17.5	54.5	1.2	99.86	40.64	53.72	53.7	148.06
19	ppm	80	43	230	8.8	361.8	100	213	7.84	320.84
	epm	4	3.58	10	0.2	17.78	1.63	4.43	0.22	6.28
	epm%	22.46	20.11	56.15	1.26	99.98	25.53	69.12	3.48	98.13
20	ppm	90	35	200	7.3	332.3	150	192.2	8.3	350.5
	epm	4.5	2.91	8.69	0.18	16.28	2.45	4	0.2	6.65
	epm%	27.6	17.84	53.35	1.14	99.93	35.87	58.4	3.45	97.72
21	ppm	75	34	200	7.1	75	120	180	8.8	309
	epm	3.75	2.8	8.6	0.18	3.75	1.9	3.7	0.25	15.33
	epm%	24.2	18.3	56.2	1.17	24.2	32.2	61.4	4.1	99.87
22	ppm	200	51	440	14.9	705.9	150	316	12.13	478.13

	epm	10	4.2	19.13	0.38	33.71	2.45	6.58	0.34	9.37
	epm%	29.6	12.58	56.6	1.13	99.91	25.6	68.6	3.6	97.8
23	ppm	190	54	420	14.8	678.8	150	320	12.25	482.25
	epm	9.5	4.5	18.26	0.37	32.63	2.45	6.66	0.35	9.46
	epm%	29.1	13.78	55.9	1.16	99.94	25.4	68.97	3.62	97.99
24	ppm	75	32	188	6	301	110	161.75	8	279.75
	epm	3.75	2.66	8.17	0.15	14.73	1.8	3.37	0.2	5.37
	epm%	25	18.08	55.4	1	99.48	32.4	60.6	4.1	97.1

Table 6: Chemical analysis results for the samples of water during the summer season.

Sample NO.	Unit	Cations				Σ Cations	Anions			Σ Anions
		HCO_3^-	SO_4^{-2}	Cl^-	K^+		HCO_3^-	SO_4^{-2}	Cl^-	
1	ppm	145	38	102.2	26.2	547.2	300	120.57	80.16	500.73
	epm	7.25	3.16	4.44	0.66	21.56	4.9	2.51	2.29	9.7
	epm%	46.67	20.39	28.5	4.29	99.89	35.30	18.03	16.43	69.76
2	ppm	85	23	60.4	9.1	259.4	170	156.67	240	566.67
	epm	4.25	1.91	2.62	0.233	11.11	2.78	3.26	6.85	12.89
	epm%	47.08	21.23	29.09	2.58	79.02	17.76	20.97	43.69	82.42
3	ppm	70	30	59.3	7.8	237.3	120	149.75	238	507.75
	epm	3.5	2.5	2.57	0.2	9.57	1.96	3.12	6.8	11.88
	epm%	39.8	28.48	29.3	2.27	99.98	13.38	21.22	46.26	80.86
4	ppm	70	27	60	7.2	229	110	153.45	250	513.45
	epm	3.5	2.25	2.60	1.8	10.21	1.80	3.19	7.14	12.13
	epm%	40.96	26.33	30.53	2.16	99.97	11.90	21.10	47.16	80.16
5	ppm	80	29	61.5	10.2	272.5	110	153.20	260	523.2
	epm	4	2.41	2.67	0.26	11.69	1.80	3.19	7.42	12.41
	epm%	42.76	25.64	28.59	2.8	99.98	11.81	20.91	48.66	81.38
6	ppm	85	21	60.3	10.1	267.3	110	153.4	255	518.4
	epm	4.25	1.75	2.62	0.259	11.21	1.80	3.19	7.28	12.27
	epm%	47.90	19.60	29.38	2.91	99.98	11.88	21.05	48	80.93
7	ppm	130	30	103.9	14	403.9	180	250.3	175	605.3
	epm	6.5	2.5	4.51	0.359	17.1	2.95	5.21	5	13.16
	epm%	46.99	17.61	32.40	2.58	99.98	19.11	33.77	32.38	85.26

8	ppm	140	38	109.3	8.8	375.3	200	255.35	275	730.35
	epm	7	2.16	4.75	0.225	16.16	3.27	5.32	7.85	16.44
	epm%	46.75	20.44	31.66	1.63	99.98	17.50	28.39	41.93	87.82
9	ppm	90	23	59.3	5.3	225.3	150	165.25	200	515.25
	epm	4.5	1.91	2.57	0.13	10.33	2.45	3.44	5.71	11.6
	epm%	49.26	20.99	28.2	1.48	99.98	17.11	23.96	39.77	80.84
10	ppm	95	20	24.6	10.5	244.6	160	156.12	150	466.12
	epm	4.75	1.66	1.07	0.269	10.17	2.62	3.25	4.28	10.15
	epm%	61.24	21.49	13.71	3.46	99.98	20.11	24.94	32.87	77.92
11	ppm	75	27	56.1	5.6	214.1	110	133.82	125	368.82
	epm	3.75	2.25	2.43	0.143	9.86	1.80	2.78	3.57	8.15
	epm%	43.97	26.78	28.69	1.54	99.98	16.65	25.76	32.99	75.4
12	ppm	85	21	63.5	7.2	241.5	150	147.24	221	518.24
	epm	4.25	1.75	2.76	0.184	10.6	2.45	3.06	6.31	11.82
	epm%	47.5	9.56	30.86	2.06	99.98	16.9	21.08	43.39	81.37
13	ppm	140	41	97.3	25.6	534.3	270	186.92	324	780.92
	epm	7	3.41	4.23	0.65	21.2	4.42	3.89	9.25	17.56
	epm%	45.74	22.32	27.64	4.28	99.54	21.83	19.20	45.65	86.68
14	ppm	85	21	64.5	10.1	271.5	150	146.16	215	511.16
	epm	4.25	1.75	2.80	0.25	11.39	2.45	3.04	6.14	11.63
	epm%	46.93	19.32	30.90	2.86	99.98	17.15	21.24	42.85	81.24
15	ppm	75	27	22.3	4.3	167.3	180	157.2	130	467.2
	epm	3.75	2.25	0.97	0.11	8.07	2.95	3.27	3.71	9.93
	epm%	52.96	31.78	13.71	1.55	99.99	23.31	25.87	29.33	78.51
16	ppm	120	29	14.5	10.2	265.5	150	226.8	821	1197.8
	epm	6	2.41	0.63	0.26	11.65	2.45	4.72	4.72	11.89
	epm%	64.44	25.92	6.70	2.82	99.98	7.47	14.37	14.37	36.21

17	ppm	85	23	64	9.3	265	166.8	143.16	98	407.96
	epm	4.25	1.91	2.78	0.238	11.32	2.69	2.98	2.8	8.47
	epm%	46.25	20.86	30.55	2.59	99.99	23.23	26.87	25.23	75.33
18	ppm	60	24	64.6	8.8	236.6	160	144.5	144	448.5
	epm	3	2	2.90	0.225	10.15	2.62	3.01	4.11	9.74
	epm%	37.33	24.87	34.90	2.81	99.98	21.09	24.22	33.08	78.39
19	ppm	260	43	174.4	30	777.4	340	399.22	315	1054.22
	epm	13	3.58	7.58	0.769	31.85	5.57	8.31	9	22.88
	epm%	52.13	14.36	30.41	3.14	99.98	21.47	32.04	34.67	88.18
20	ppm	75	24	64.2	10.4	267.2	140	167.5	110	417.5
	epm	3.75	2	2.79	0.266	11.2	2.29	3.49	3.14	8.92
	epm%	42.45	22.84	31.68	3.079	99.98	19.73	30.01	27.03	76.77
21	ppm	85	22.5	64.4	10.6	277.9	150	153.5	110	413.5
	epm	4.25	1.87	2.8	2.71	11.63	2.45	3.19	3.14	8.78
	epm%	46.50	20.10	30.44	2.95	99.98	21.23	27.61	27.13	75.97
22	ppm	200	36	136.8	12.2	494.8	270	156.65	280	706.65
	epm	10	3	5.94	0.31	22.06	4.42	3.26	8	15.68
	epm%	51.59	15.58	30.94	1.63	99.97	23.43	17.27	42.35	83.05
23	ppm	80	24	117.5	13	351.5	150	158.72	133	441.72
	epm	4	2	5.10	0.33	14.43	2.45	3.30	3.8	9.55
	epm%	34.96	17.84	44.65	2.97	99.97	20.06	26.98	31.01	78.05
24	ppm	75	27	115	12.5	342	130	147.94	135	412.94
	epm	3.75	2.25	5	0.320	14.2	2.13	3.08	3.85	9.06
	epm%	33.12	19.83	44.19	2.856	89.41	18.05	26.11	32.68	76.84

4.2.1 Cations

Calcium (Ca^{2+})

Calcium concentrations in surface water samples range from (65-200) ppm with an average of (132.5) ppm in the winter to (60-260) ppm with an average of (160) ppm in the summer. The agriculture region and the irrigation canals' wastewater are blamed for the Tigris River's higher calcium ion content. Furthermore, most of the calcium in surface water comes from streams that traverse gypsum, limestone, and other rocks and minerals that contain calcium [21].

Magnesium (Mg^{2+})

Magnesium concentrations in surface water samples range from 3.5–355 ppm, with an average of 179 ppm in the winter, to 20–43 ppm, with an average of 31.5 ppm in the summer. Following calcium ions, magnesium ions are among the most common alkalis in the earth's crust and are produced by the chemical weathering, melting, and replacement of rocks (dolomite and marl) [22].

Sodium (Na^{+})

Sodium concentrations in surface water samples range from 56–540 ppm, with an average of 298.05 ppm in the winter, to 14.5–174.4 ppm, with an average of 94.45 ppm in the summer. The sodium ion is a component of most rocks and soils and is readily dissolved in water. The precipitation of salt rocks and the weathering of rocks, including carbonate rocks, are the sources of sodium ions [22].

Potassium (K^{+})

Potassium concentrations in surface water samples varied from (3.6-14.9) ppm with an average of 9.25 ppm in the winter to (3-26.2) ppm with an average of 14.6 ppm in the summer. The weathering of sedimentary and metamorphic rocks and clay minerals, as well as industrial sources, pesticides, and chemical fertilizers, are the causes of potassium ion presence in water [22].

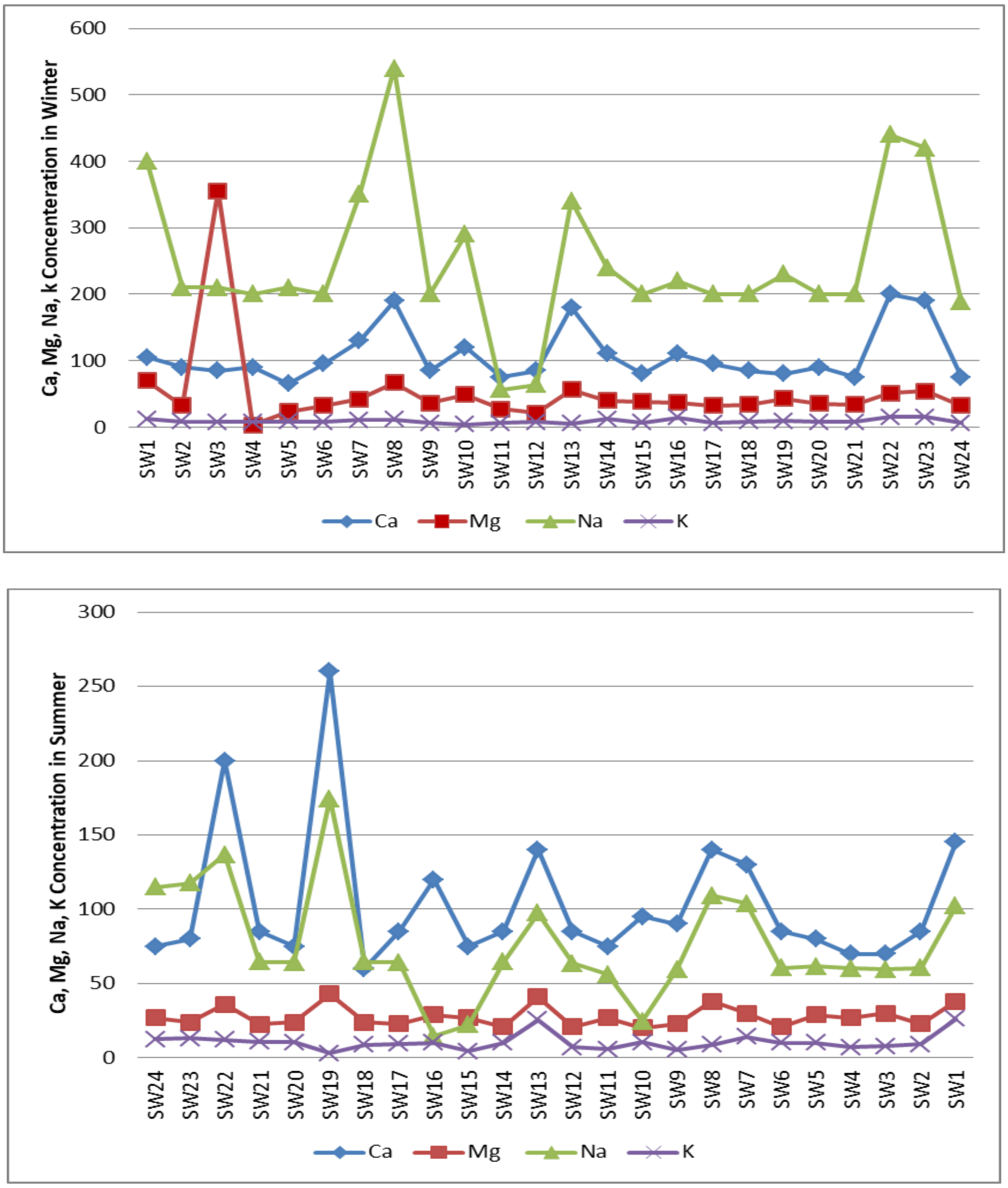

Figure 7: Concentration of cations in water samples for winter and summer season

4.2.2 Anions

Sulfate (SO_4^{2-})

Sulfate is one of the primary negative ions which are abundant in the crust of the earth and one of the primary natural sources of water that come from weathering processes. Melting of sulfur-containing rocks and minerals like pyrite, anhydrite, and gypsum, as well as the breakdown and oxidation of sulfur-containing materials like fossil fuels [22]. Surface water sample sulfate concentrations range from 171 to 178 ppm, with an average of 174 ppm during the winter period, but from 158 to 168% ppm with an average of 164.5 ppm during the summer period.

Chloride (Cl^-)

One of the primary negative ions, chloride, is highly soluble in water and is typically found as chlorine salts. Sedimentary rocks and evaporated minerals are among the most significant natural sources of chloride ions (NaCl, CaCl, and MgCl). Their natural presence in water is associated with the leaching processes that remove minerals from rocks and salt sediments, such as (Gallite, Sylvite) [22] Surface water sample chloride concentrations vary from (141–147) ppm with an average of 144 ppm during the winter period to (126–136) ppm with an average of 130.50 ppm during the summer period.

Bicarbonate (HCO_3^-)

This ion is a source of alkalinity, or the capacity of water to react with H^+. The measurement of bicarbonates, carbonates, and hydroxyls (OH^-) dissolved in water is known as total alkalinity. The majority of the carbons in water convert to bicarbonate [22]. At pH levels lower than 8.2.20. The bicarbonate concentration of the surface water samples varies from (131–137) ppm with an average of (133.67) ppm during the winter period to (132–139) ppm, with an average of (135.3) ppm during the summer period.

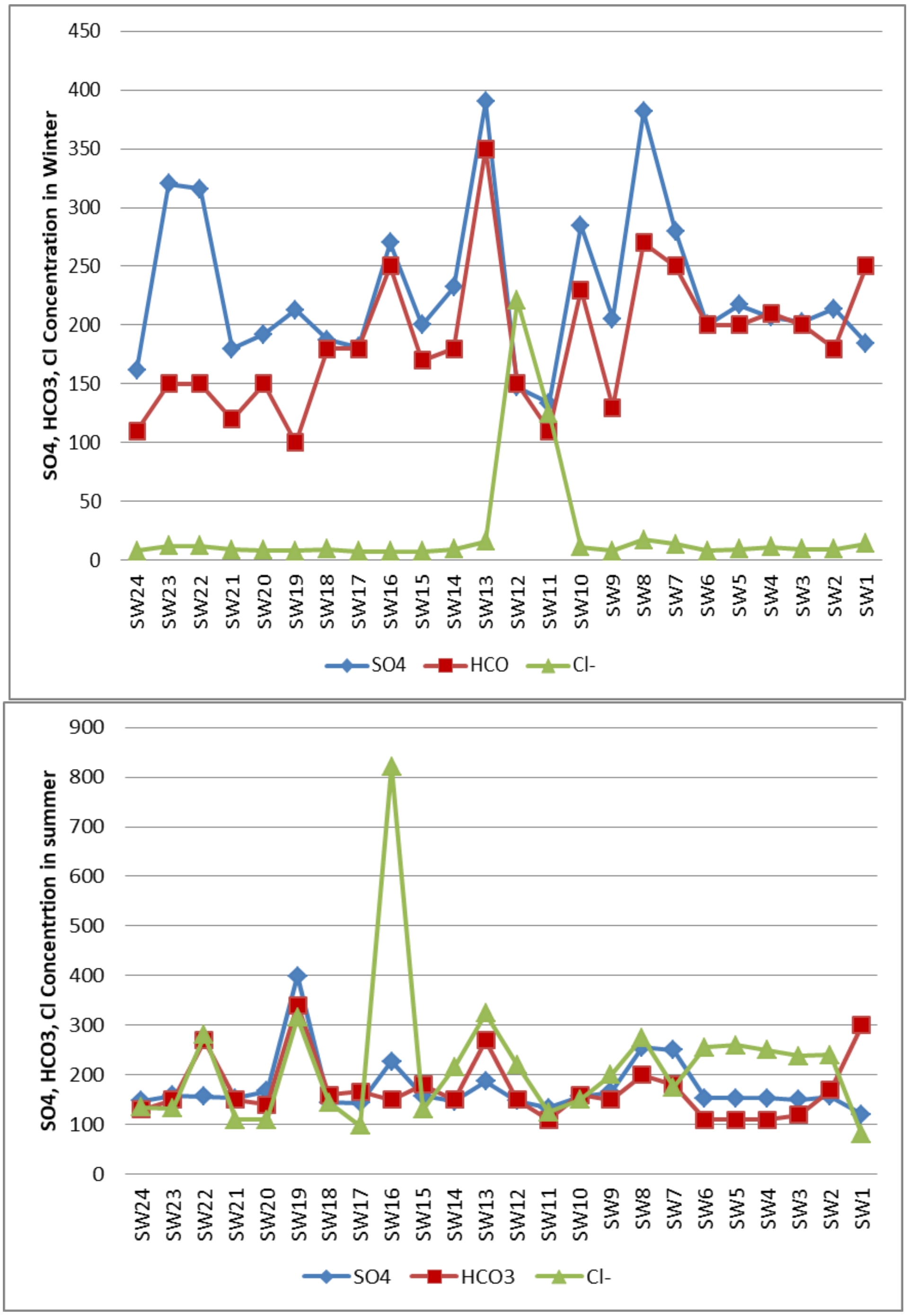

Figure 8: Concentration of anions water samples for winter and summer season

4.2.3 Minor ions

Nutrients are a considerable indication of water quality involves (PO_4 and NO_3) and derive from various sources including wastewater effluent discharge and agricultural runoff (fertilizer, livestock waste). Excessive nutrients may lead to eutrophication and algae blooms to have a significant impact on aquatic ecosystem health and recreational value of freshwater supplies [23]. Although, agricultural releases can play a role in increasing nitrate concentrations, over-utilization of fertilizers in agriculture, when microorganisms decompose fertilizers, fattening schemes, decomposing plants, as well as other organic waste. Results of the minor ions of the present study are presented in (Table 7).

Table 7: Concentration of minor elements in water samples of two season .

NO.	Site	Winter season		Summer season	
		NO_3^-	PO_4^{3-}	NO_3^-	PO_4^{3-}
1	Iraqi Central Bank	17.5	0.1	257.11	2
2		8.9	0.1	172.67	BDL
3		8.6	0.1	174.3	BDL
4	Al-Jadriya Bridge	8.5	0.1	186.16	BDL
5		8.4	0.1	176.12	BDL
6		8.3	0.1	179.33	BDL
7	Al-Dora (Aldora silo)	3.8	0.1	140.43	0.24
8		5.4	0.3	140.82	0.27
9		8.9	0.1	170.54	BDL
10	Al-sinak Bridge	4.9	0.2	178.35	BDL
11		9.2	0.1	164.96	BDL
12		7	0.1	167.93	BDL
13	Al-ahrar bridge	16.1	0.4	165.25	1
14		4.1	0.2	166.56	BDL
15		8.5	0.1	168.56	BDL
16	River Street	4.9	0.3	138.16	0.3
17		8.3	0.02	166.84	BDL
18		8.3	0.1	166.5	BDL
19	Medical City	7.2	0.1	186.74	1.6
20		9.5	0.02	167.31	BDL
21		8.2	0.04	172.46	BDL
22	Al-kadhimiya	11.6	0.5	195	1.7
23		10.8	0.5	166.64	BDL
24		9.7	0.03	169.25	BDL
Mean		8.45	0.1	168.905	1
WHO (2008)		50	0.4	50	0.4
Iraqi standards (2009)		50	0.4	50	0.4

Nitrate (NO_3^-)

NO_3 is the most highly oxygenated form of nitrogen composition, and is common on the surface water, as it is the last effect of airborne decomposition of organic nitrogen materials [18]. The highest concentration of Nitrate (NO_3^-) in the winter season for water in the study area was (17.5) mg/l in the Iraqi Central Bank, while its lowest value was (3.8) mg/l in the Al_ Dora area. In the summer season, The highest value of (NO_3^-) for water in the study area was (257.11) mg/l in the Iraqi Central Bank. While its lowest value was (140.4) mg/l in the Al_ Dora area. It is noted that all surface water samples in the study area fall outside the permissible limit for drinking water in winter, which is set at (50) mg/L according to international specifications (WHO, 2008) while they were within the permissible range in summer.

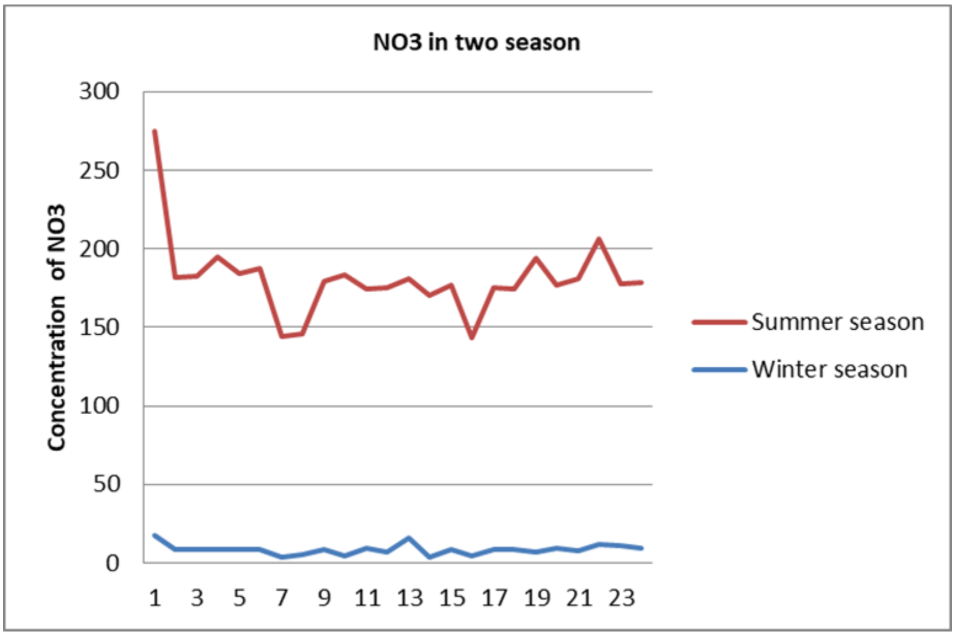

Figure 9: Concentration of NO_3 water samples for winter and summer season.

Phosphate (PO_4^{-3})

Phosphate is a natural substance, consisting mainly of tri-calcium phosphate, which is slightly soluble in water. Phosphate derivatives are used in the form of phosphorus fertilizers and the quality of Phosphate is measured by the proportion of phosphorus pentoxide water is suitable for human use if its phosphate content is low [24] The highest Concentration of Phosphate PO_4 in the winter season for water in the study area was (0.5) mg/l in the AL_Kadmiay area, while its lowest value was (0.03) mg/l in the River Street area. In the summer season the highest value of PO4 for water in the study area was (2) mg/l in the Iraqi Central Bank area. While its lowest value was (0.3) mg/l in the Al_ Nahar Street area. The reason for its increase near AL_kadhmiay and the Central Bank of Iraq area is due to water pollution with chemical fertilizers that come from nearby agricultural areas from the river when sewage water is thrown into the river containing phosphorous.

4.2.4 Heavy Elements

They are known as those metallic elements whose atomic number exceeds 20, and come either from the weathering of rocks or human activities [25]. The concentrations of heavy elements are affected by several factors, including pH, oxidation and reduction potential, the degree of transition of the element, and adsorption on the surfaces of clay minerals [26]. The importance of studying these elements lies in determining the pollution resulting from human activities such as industrial and agricultural activities, and the discharge of surplus water. Eight heavy elements were analyzed in surface water within the study area, which are: (Fe, Zn, Pb, Ni, Cr, Cu, Cd, Mn) for the two periods. The differences in trace element contents for water samples in the research area across two time periods are explained in Tables -8 and 9.

Table 8: Wintertime concentrations of heavy metals in water samples .

Site	Element							
	Fe	Mn	Cu	Ni	Zn	Cr	Cd	Pb
SW1	N.D	N.D	0.002	N.D	N.D	0.005	N.D	0.134
SW2	N.D	N.D	0.005	N.D	N.D	0.005	N.D	0.166
SW3	N.D	N.D	0.001	N.D	N.D	0.003	N.D	0.173
SW4	N.D	N.D	0.002	N.D	N.D	0.003	0.032	0.001
SW5	N.D	N.D	0.002	N.D	N.D	0.004	N.D	0.456
SW6	N.D	N.D	0.001	N.D	N.D	0.004	0.034	0.558
SW7	N.D	N.D	0.003	N.D	N.D	0.004	0.036	0.244
SW8	N.D	N.D	0.001	N.D	N.D	0.004	N.D	0.056
SW9	N.D	N.D	0.002	N.D	N.D	0.004	0.001	0.056
SW10	N.D	N.D	0.002	N.D	N.D	0.004	N.D	0.189
SW11	N.D	N.D	0.003	N.D	N.D	0.005	0.044	0.354
SW12	N.D	N.D	0.002	N.D	N.D	0.004	0.038	0.111
SW13	N.D	0.48	0.002	N.D	N.D	0.004	0.013	0.260
SW14	N.D	0.35	0.001	N.D	N.D	0.004	0.011	0.407
SW15	N.D	0.42	0.003	N.D	N.D	0.004	0.038	0.339
SW16	N.D	0.31	0.002	N.D	N.D	0.003	0.034	0.291
SW17	N.D	0.63	0.003	N.D	N.D	0.004	0.040	0.048
SW18	N.D	0.74	0.001	N.D	N.D	0.003	0.059	0.338
SW19	N.D	0.61	0.002	N.D	N.D	0.004	0.028	0.040
SW20	N.D	0.65	0.002	N.D	N.D	0.005	0.009	0.228
SW21	N.D	0.74	0.001	N.D	N.D	0.004	0.098	0.095
SW22	N.D	0.89	0.002	N.D	N.D	0.005	0.098	0.048
SW23	N.D	0.57	0.001	N.D	N.D	0.005	0.015	N.D
SW24	N.D	0.85	0.002	N.D	N.D	0.004	0.022	0.017
Median value (WHO, 2018)	0.3	0.1	1.5	0.02	3	0.3	0.005	0.01

N.D= Not detected

Table 9: Summertime concentrations of heavy metals in water samples .

Site	Element							
	Fe	Mn	Cu	Ni	Zn	Cr	Cd	Pb
SW1	B.D.L.	1.09	B.D.L.	0.12	B.D.L.	2.80	B.D.L.	0.093
SW2	B.D.L.	0.81	B.D.L.	0.1	B.D.L.	1.44	B.D.L.	0.050
SW3	B.D.L.	0.76	B.D.L.	1.47	B.D.L.	0.96	B.D.L.	0.069
SW4	B.D.L.	0.72	B.D.L.	0.74	B.D.L.	0.40	B.D.L.	0.089
SW5	B.D.L.	0.74	B.D.L.	B.D.L.	B.D.L.	B.D.L.	B.D.L.	0.096
SW6	B.D.L.	0.52	B.D.L.	0.03	B.D.L.	0.48	B.D.L.	0.088
SW7	B.D.L.	0.87	B.D.L.	B.D.L.	B.D.L.	0.88	B.D.L.	0.093
SW8	B.D.L.	0.37	B.D.L.	0.91	B.D.L.	0.32	B.D.L.	0.086
SW9	B.D.L.	0.87	B.D.L.	0.59	B.D.L.	0.89	0.037	0.055
SW10	B.D.L.	1.18	B.D.L.	0.38	B.D.L.	1.12	0.103	0.983
SW11	B.D.L.	0.81	B.D.L.	B.D.L.	B.D.L.	1.20	B.D.L.	0.076
SW12	B.D.L.	0.96	B.D.L.	B.D.L.	B.D.L.	1.28	B.D.L.	0.062
SW13	B.D.L.	0.52	B.D.L.	B.D.L.	B.D.L.	1.60	0.37	0.096
SW14	B.D.L.	0.72	B.D.L.	B.D.L.	B.D.L.	1.28	B.D.L.	0.125
SW15	B.D.L.	1.18	B.D.L.	0.21	B.D.L.	2.08	0.120	0.122
SW16	B.D.L.	0.89	B.D.L.	0.23	B.D.L.	0.64	0.123	0.137
SW17	B.D.L.	1.05	B.D.L.	B.D.L.	B.D.L.	2.56	0.159	0.093
SW18	B.D.L.	0.94	B.D.L.	0.71	B.D.L.	2.48	0.042	0.117
SW19	B.D.L.	1.50	B.D.L.	0.02	B.D.L.	2.16	0.047	0.137
SW20	B.D.L.	1.11	B.D.L.	1.04	B.D.L.	2.32	0.094	0.155
SW21	B.D.L.	1.35	B.D.L.	0.95	B.D.L.	0.88	0.189	0.137
SW22	B.D.L.	1.39	B.D.L.	0.85	B.D.L.	2.96	0.113	0.083
SW23	B.D.L.	1.42	B.D.L.	B.D.L.	B.D.L.	2.00	0.050	0.149
SW24	B.D.L.	1.31	B.D.L.	B.D.L.	B.D.L.	3.04	0.138	0.091
Median value(WHO, 2018)	0.3	0.1	1.5	0.02	3	0.3	0.005	0.01

B.D.L.= (Below Detection Limit)

Hydrochemical formula and water type

The samples' water type was ascertained using the subsequent formula, known as the Kurlov formula [27] [28]:

$$\text{TDS (mg/l)} = \frac{SO\ Cl\ HCO3\ epm\%}{Na\ Ca\ Mg\ k\ epm\%} pH \ldots \ldots$$

The results of water type are shown in (Table-10)

Table 10: The percentage ratio of prevailing water type in water samples for both periods

Winter season			Summer season		
Water type	**Frequency**	**Occurs Ratio (%)**	**Water type**	**Frequency**	**Occurs Ratio (%)**
Na SO4	22	91.66	Ca Cl	18	75
Mg SO4	1	4.16	Ca SO4	4	16.66
Na HCO3	1	4.16	Na Cl	2	8.33

According to Piper diagrams, all of the water samples fall into the Earth's alkaline water field, which has an increase in the proportion of alkali and alkaline water. Na^{+} and Ca^{2+} are the most abundant in this field, along with Mg^{2+} and sulfate or chloride, as shown in Figures (9,10).

Surface Water classification

Piper Diagram

The Aq.Qa program was used to classify the Tigris River water and display the relative concentration of the various ions, as shown in Figure (9) and (10). The water was categorized as earth-alkaline water with an elevated alkaline component and a predominance of sulfate and chloride in two seasons, according to the data.

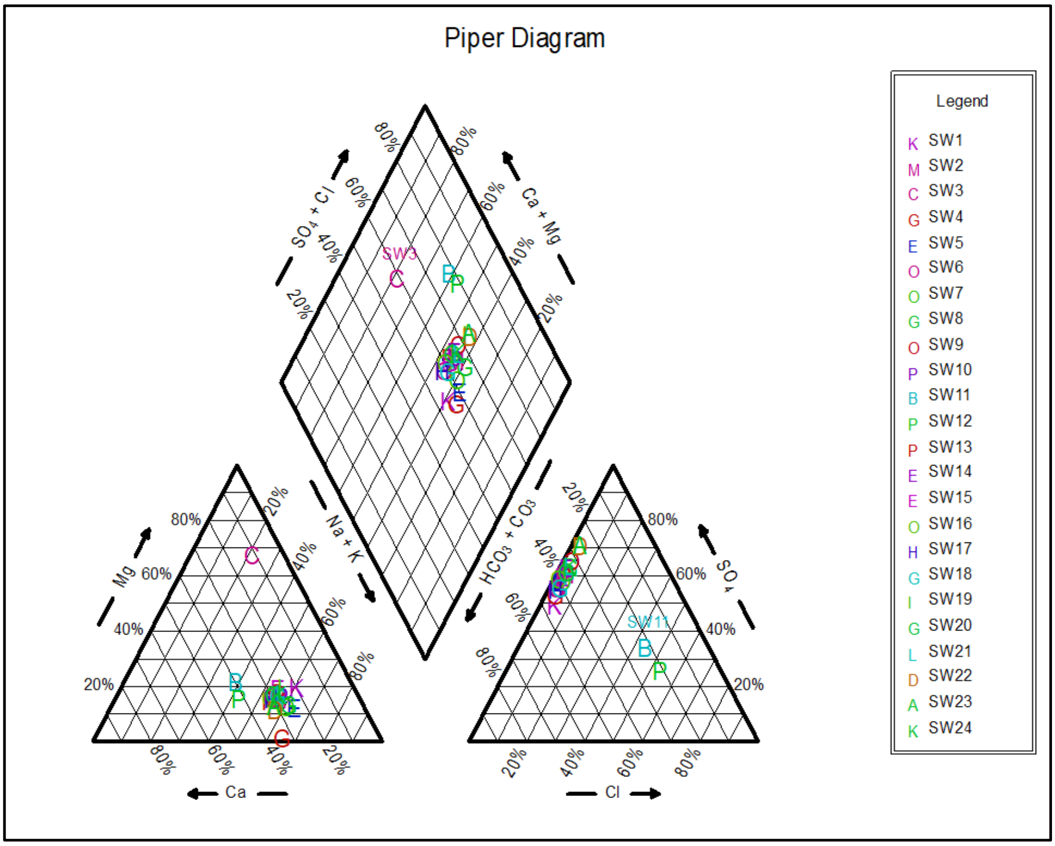

Figure 10: The water samples' pipe diagram during the winter season.

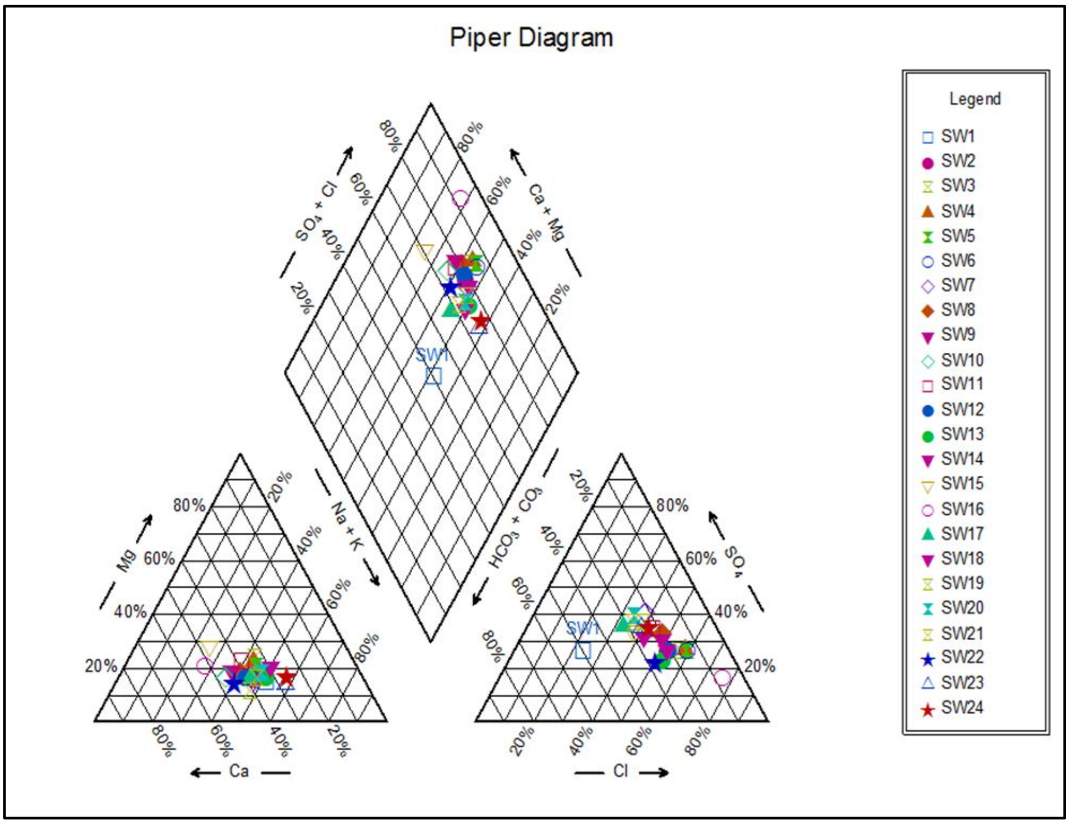

Figure 11: The water samples' pipe diagram during the summer season.

Schoeller Classification

Applying Schuler's classification (1972) to hydrological models during the winter season revealed one distinct group (B4), r(Na+K)>rCa>rMg—rSO4>rHCO3>rCl, which was more dominant, while during the summer season, there were two distinct groups (E1,E3), rCa> r(Na+K) > rMg—rCl > rSO4 > rHCO3, rCa> r(Na+K) >rMg - rSO4>rCl> rHCO3.

Figures-(11 and 12) illustrate the results of the application of Schoeller classification on water

Samples for the two periods. The outcomes seem to be nearly in line with the hydrochemical formula.

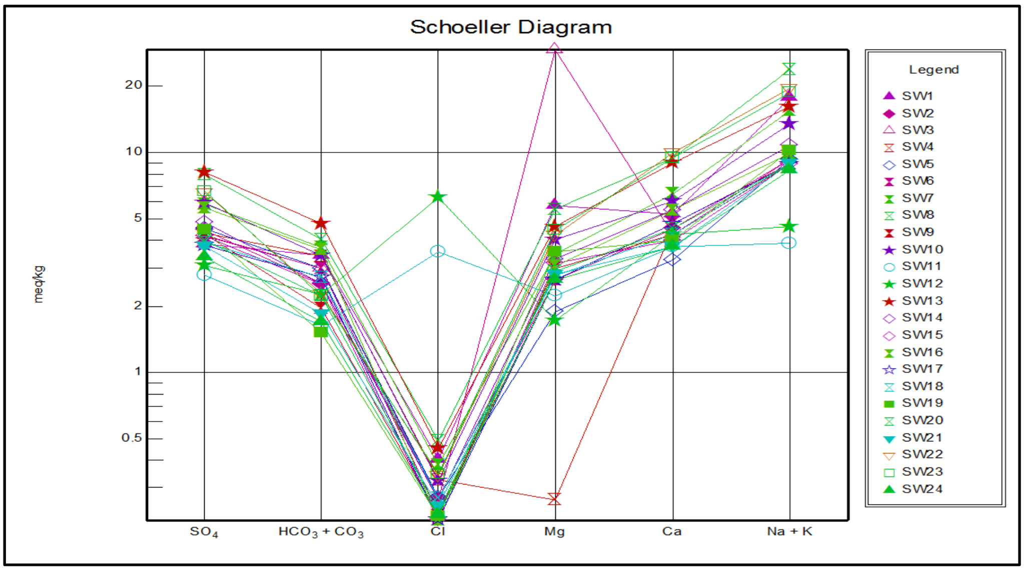

Figure 12: Schoeller diagram of the water samples in the winter period

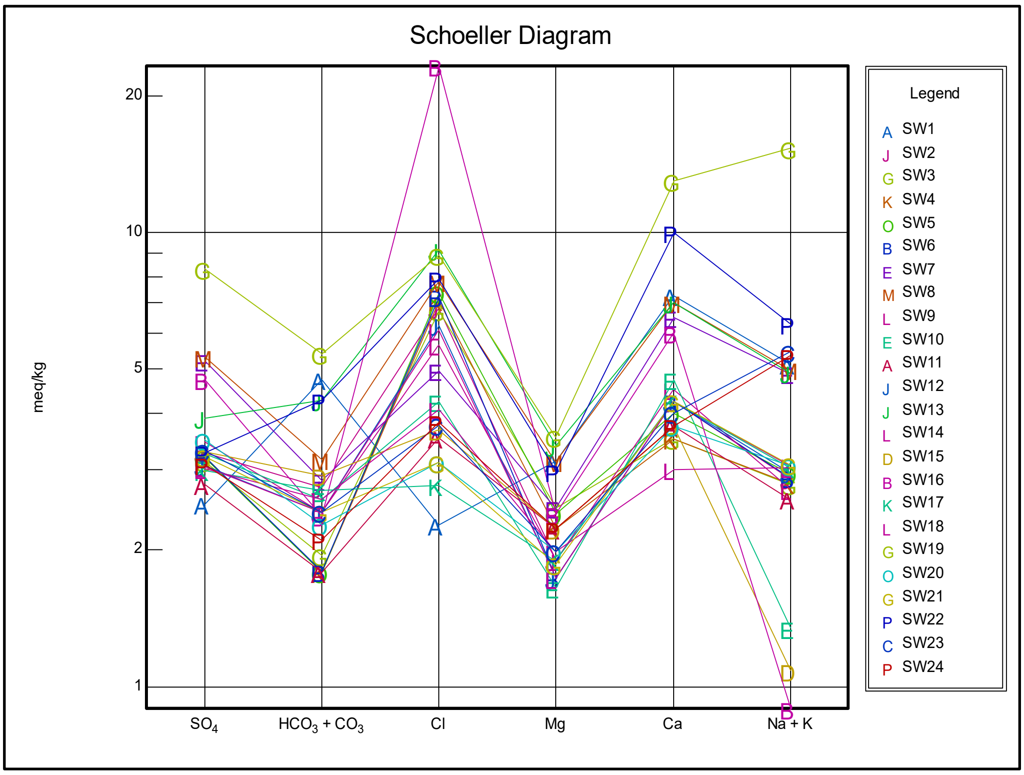

Figure 13: Schoeller diagram of the water samples in the summer period.

Water suitability for irrigation purposes

Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio (SAR) is typically used to express sodium alkali danger. The ratio of sodium to calcium and magnesium ions in a samples are measured by the index. Elevated SAR values suggest a potential for sodium to replace taken-up calcium and magnesium, ultimately leading to the disintegration of the soil structure[29] [28]. This indicator calculates the effect of soil sodium buildup concerning the concentration of relative cations. The premise for determining SAR values is [29].

$SAR = rNa/\sqrt{\text{rCa} + \text{Mg}/2}$

Where:

r: Concentration of ions by (epm) units.

Table 11: Classification of irrigation water based on the SAR values [30]

SAR	Alkalinity hazard	water class
< 10	S1	Excellent
10- 18	S2	Good
18-26	S3	Doubtful
> 26	S4	Unsuitable

Based on this classification, all surface water samples fall into class S1(Excellent Irrigation) .

Table 12: The standard categories based on [31] classification were utilized for the water assessment for irrigation.

EC(µs\cm	TDS(ppm)	SAR	Na%	pH	Water Quality
< 250	< 175	<3	< 20	<6.5	Excellent
250−750	175-525	3-5	20-40	6.5-6.8	Good
750−2000	525-1400	5-10	40-60	6.8-7.0	Permissible
2000−3000	1400-2100	10-15	60-80	7- 8	Doubtful
>3000	>2100	>15	80<	>8	Unsuitable

Table 13: SAR, TDS, EC and Na% values in the Surface Water

NO.	Winter season					Summer season				
	SAR	Na%	pH	EC (µs/m)	TDS (ppm)	SAR	Na%	pH	TDS (ppm)	EC (µs/m)
SW1	7.41	61.48	7.0	883	526	1.94	32.88	7.7	676	1315
SW2	4.82	56.60	7.1	703	419	1.49	31.65	8.0	406	788
SW3	2.27	22.49	7.3	702	418	1.52	31.58	8.0	379	779
SW4	5.63	65.07	7.9	697	416	1.53	43.34	8.0	398	799
SW5	5.69	64.58	7.3	697	316	1.49	31.37	8.0	401	782
SW6	4.51	54.51	7.3	698	416	1.42	23.42	8.1	397	780
SW7	6.79	60.73	7.3	1018	607	2.12	35.10	7.7	590	1165
SW8	8.54	61.17	7.3	1443	860	2.21	35.19	7.7	618	1219
SW9	4.56	54.96	7.4	700	417	1.43	29.63	8.0	397	784
SW10	5.60	55.71	7.3	1032	615	0.59	17.27	8.0	402	795
SW11	4.61	55.64	7.3	714	425	1.40	30.01	8.0	367	728
SW12	4.64	56.11	7.4	702	421	1.59	32.91	8.0	403	793
SW13	0.56	52.20	7.0	1415	842	1.85	31.91	7.7	639	1267
SW14	4.96	54.85	7.1	872	518	1.62	33.70	8.0	400	796
SW15	4.61	55.48	7.3	710	422	0.56	15.25	8.0	398	789
SW16	4.63	53.85	7.2	984	585	0.30	9.56	7.7	486	963
SW17	4.53	54.42	7.4	707	421	1.58	32.88	8.0	402	792
SW18	4.66	55.80	7.4	708	421	1.83	38.46	8.0	397	785
SW19	5.13	57.36	7.4	803	477	2.63	33.49	7.7	976	1929
SW20	4.51	54.48	7.3	717	427	1.64	34.70	8.0	398	783
SW21	4.75	57.27	7.5	704	419	1.60	47.37	8.0	399	786
SW22	7.17	57.87	7.4	1366	813	2.32	32.46	7.7	791	1496
SW23	6.90	57.09	7.3	1344	801	2.94	47.50	8.0	398	786
SW24	4.56	56.48	7.5	673	401	2.88	46.99	8.0	385	783

Since all of the SAR values in the water sample under study are (higher than 3), they are all categorized as good to permissible. As indicated by the classification above (Table 12) in the winter season. However, because the SAR values were (lower than 3) during the summer, all of them were categorized as excellent.

TDS and EC

Since TDS and EC indicate the amount of ions present, they are frequently employed as indicators to evaluate the water quality . When big cation salts like calcium, magnesium, sodium, and potassium dissolve in irrigation water, it can harm to plants. A surplus can prevent adequate aeration and reduce the plants' osmotic activity. An electric current's electrical conductivity (EC) can be used to physically quantify the amount of dissolved solids present in the current. It increases in tandem with an increase in ion concentration. The acceptable water for irrigation is indicated by the values of the TDS and EC in both seasons [32]. Table -12

Soluble Sodium Percentage (Na%)

Raising the concentration of sodium ions in irrigation water can affect the soil, reducing its permeability and porosity and thus affecting or stunting plant growth. Similar to SAR (Na%) measurements, the percentage of sodium is crucial for assessing the quality of water suitable for irrigation. It is determined using the followings formula [30]

$$Na\% = \frac{Na+k}{Ca+Mg+Na+K} \times 100\ \%$$

Where: The concentrations of ions by (epm) units

In meq/l, all ion concentrations are expressed. The surface water's Na% results suggest that it permissible to use for irrigation during the winter, but during the summerThe surface water under investigation has Na% readings that range from good to permissible for irrigation. Table-12

Conclusions

This study provided a detailed description of the physicochemical properties of the surface water in Baghdad City.Seasonal studies revealed that during the wet season, the concentrations of Ca, Mg, Na, Cl, and SO4 are relatively low in all sites, while during the dry season, they are high, as precipitation throughout the winter months dilutes the elemental concentrations [33].

The pH levels in the two seasons differed. Given the TDS concentrations, the surface water samples from both time periods are regarded as fresh water. Values of EC for surface water samples indicated highly mineralized to excessively mineralized water for both periods. Some water samples are polluted with heavy metals such as Pb and Cd in the winter season This is due to the dumping of sewage directly into the river without effective treatment. But in the summer season, in which all of heavy metals were over the permeation limits of WHO (2018), except for Fe, Cu and Zn were the only heavy metals within the limits.

Piper (1944) categorized all surface water samples from the two periods as being earthly alkaline fluids with a stronger alkaline component and a predominance of sulfate and chloride, or the (e,g), which is earth-alkaline water with an increased alkaline component and a predominance of sulfate and chloride hydrochemical facies.

Using Schuler's classification (1972) on hydrological models in the winter revealed one distinct group, which was more dominant, r(Na+K)>rCa>rMg—rSO4>rHCO3>rCl. In the summer, there were two distinct groups, rCa> r(Na+K) > rMg—rCl > rSO4 > rHCO3, and rCa> r(Na+K) >rMg - rSO4>rCl> rHCO3.

For surface water samples collected during the winter, sodium ions were the main cation and sulfate was the dominating anion; for samples collected during the summer, calcium ions were the prominent cations and chloride was the predominant anion. This may be because the primary sources of these ions are the existence of halite minerals and limestone rocks. Regarding surface suitability for irrigation, every surface water sample collected during the winter was within the good to the permissible limits of irrigation water quality; nevertheless, every sample collected during the summer was within the excellent of irrigation water quality.

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