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Hydrochemical Study of the Southern Sector of the Al-Massab Al-Aam Canal Water, Southern Iraq

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Abstract

Al- Masab AL-Aam canal (or the Main Drain) is a vital strategic project in Iraq. It collects the drain water from the agricultural lands and drains to the Arabian Gulf via Shatt Al-Basra. Fifteen water samples were collected from different sites along the course of the Al- Masab Al-Aam canal southern sector extending from Nasiriyah Basra to evaluate the hydrochemical properties. The variation of the sediment's texture along the southern sector was investigated. The results reflected that the sediment is characterized by the presence of sand, silt, and clay. It is noted that the amount of salt in the water increases during the summer when temperatures are rising, and consequently, the evaporation rate increases. Changes in the saturation index also continuously affect the dissolution and precipitation of minerals along the river. The results of the saturation index analysis showed that the relationship between sulfate concentration and mineral saturation coefficients tends to increase their solubility for most minerals. The importance of the research lies in knowing and identifying the factors causing the change in water quality through studying the hydrological and hydrochemical properties of water and comparing the results to find out the reasons for the increase and decrease in its concentrations along the study area.

Keywords: Al-Musab Al-Aam, Hydrochemical properties, Multivariate analysis, Iraq.

دراسة هيدروكيميائية لمياه قناة المصب العام , القاطع الجنوبي , العراق

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الخلاصه

تم جمع خمسة عشر عينة مياه من مناطق مختلفة على طول مجرى قناة المصب العام (القطاع الجنوبي) من الناصرية إلى البصرة لغرض تقييم الخصائص الهيدروجيولوجية والهيدروكيميائية للمياه، وبالتالي معرفة كمية تلوث المياه. ويلاحظ التغير في المحتوى النسيجي لنماذج تربة منطقة الدراسة، حيث تميزت الأجزاء الشمالية من المنطقة بوجود الرمال السائدة نتيجة الانتشار الواسع للرواسب الرملية المتمثلة بالكثبان الرملية، بينما تميزت المناطق الوسطى والجنوبية من منطقة الدراسة بالطين والطمي، ومن خلال النتائج يمكن ملاحظة التغيرات المستمرة لهذه الخصائص (زيادة ونقصان) خلال فترة فصلي الصيف والشتاء مما يؤثر سلبا نوعية المياه. حيث

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يلاحظ ان كمية الأملاح في الماء تزداد خلال فصل الصيف عندما ترتفع درجات الحرارة وتزداد معدلات التبخر. بينما يحدث العكس في الشتاء، حيث يساعد المطر على إذابتها وتقل قيمها، بالإضافة إلى انخفاض مستوى تدفق النهر. كذلك تؤثر التغيرات في مؤشر التشبع أيضًا على انحلال وترسيب المعادن على طول النهر بشكل مستمر، حيث أظهرت نتائج تحليل مؤشر التشبع أن العلاقة بين تركيز الكبريتات ومعاملات التشبع المعدني تميل إلى زيادة قابليتها للذوبان لمعظم المعادن. تكمن اهمية البحث في معرفة وتحديد العوامل المسببة في تغيير نوعية المياه من خلال: دراسة الخصائص الهيدرولوجية والهيدروكيميائية للمياه ، ومقارنة النتائج لمعرفة أسباب زيادة وانخفاض تراكيزها على طول منطقة الدراسة.

1. Introduction

Seasonal distribution of precipitation, wind, evaporation, geographical location of the recharge area and land use management are the main factors that cause changes in natural waters and land reclamation. The Al-Massab Alam canal (the third river) is considered one of the important strategic projects that extends from the Ishaqi irrigation project in northern Baghdad to the Shatt Al-Basra Canal, southern Iraq (Figure 1). The main function of the Al-Massab Alam canal is to receive saline water from the irrigated area between the Tigris and Euphrates rivers to reduce the salinity of agricultural soils [1, 2 and 3]. Therefore, there was a need to study the hydrochemical properties of the Al-Massab Alam canal water. The hydrochemical properties include the physical properties of pH, EC, TSS, TDS, TH and the chemical properties of the main ions Na, K, Mg, Ca, SO_4, Cl, and HCO_3, taking into consideration studying the saturation coefficient [4]. The climate of the southern part of Iraq, characterized by a significant change in air temperatures, and low rainfall with high relative humidity %, is classified as a semi-arid climate [5].

The southern sector of the Al-Massab Alam canal is within the southern part of the Mesopotamian plain (Figure 1). It has of about 166 km long, from Nasiriyah, Dhi Qar Governorate to the Zubair, Basra Governorate, between the longitude 48˚ 22′ 30″ E and latitude 31˚ 6′ 9″ N.

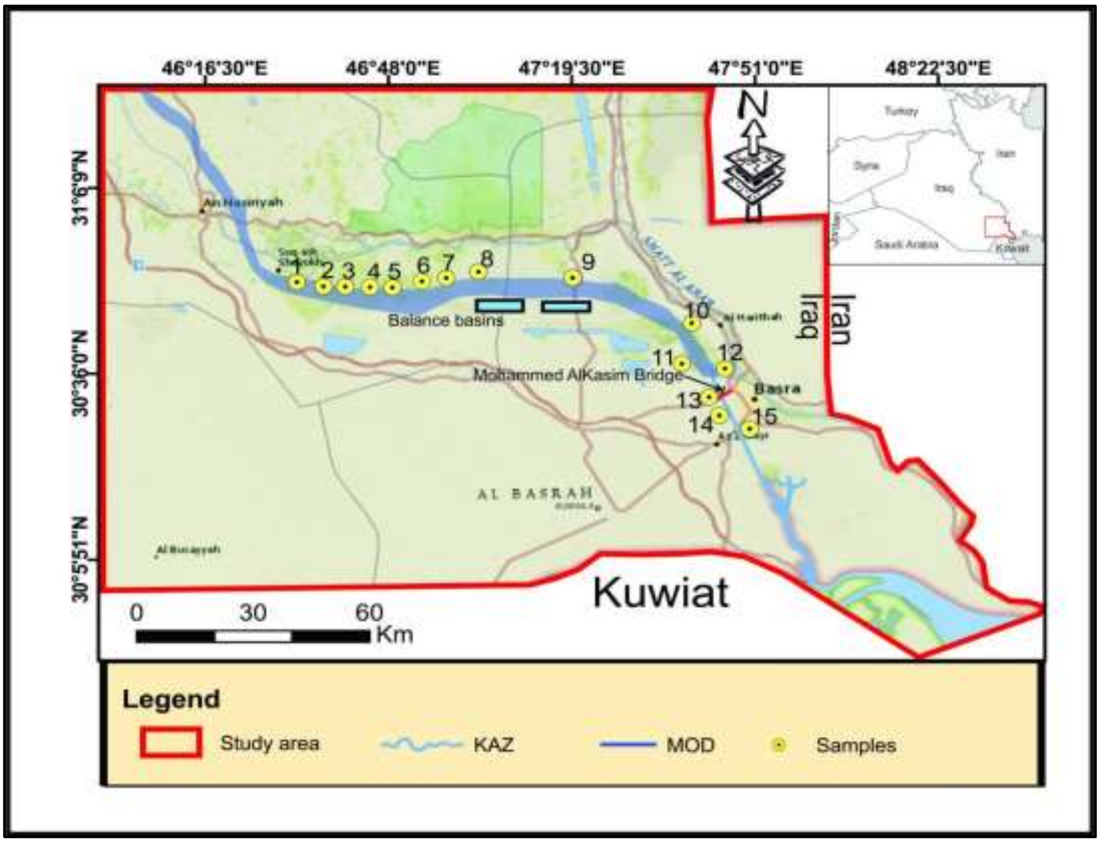


Figure 1- Location map of the study area [2]

The water elevation ranges from a maximum value of 3.06 m above sea level at Nasiriya to a minimum of 1.49 m at Zubair, Basra. The Water discharge in the Al-Massab Al-Aam canal ranges between 43.64 m3/sec at Nasiriya and 14.69 m3/sec at Basra, with an average of 29.16 m3/sec (Table 1).

Table 1- The monthly average discharge and water level elevation values of the Al-Masab Al-Aam canal at Nasiriya and Basra.

Months	Location	Discharge (m^3/Sec)	Water level elevation (m.a.s.l)
Jan.	Nasiriya	24.5	3.7
	Basra	8.1	1.6
Feb.	Nasiriya	45.4	3.5
	Basra	15.2	1.4
Mar.	Nasiriya	74	3.3
	Basra	26.3	1.5
Apr.	Nasiriya	26	3.3
	Basra	8.31	1.7
May.	Nasiriya	22	2.9
	Basra	7.44	1.4
Jun.	Nasiriya	34	3.1
	Basra	11.5	1.5
Jul.	Nasiriya	29.5	2.6
	Basra	9.4	1.3
Aug.	Nasiriya	26.8	2.6
	Basra	9.1	1.5
Sep.	Nasiriya	37.5	2.81
	Basra	13.8	1.60
Oct.	Nasiriya	71	3.1
	Basra	23.2	1.55
Nov.	Nasiriya	68	3.43
	Basra	21	1.60
Dec.	Nasiriya	65	2.34
	Basra	23	1.30
Average	Nasiriya	43.64	3.064
	Basra	14.69	1.49

It is noted that the monthly average discharge and water level elevation values of the Al-Masab Al-Aam canal at Nasiriya and Basra depend on the rain and the agricultural activity seasons. Moreover, the tidal phenomena affect the water discharges and, consequently the Al-Masab Al-Aam canal hydrochemical characteristics at Basra.

Geologically, the study area is located within the Mesopotamian plain, mainly covered by Holocene deposits derived from the Tigris and Euphrates rivers sediments of alternating sequences of sand, silt and clay. These sediments' thickness are changing in the vertical and lateral directions [6 and7].

This research aims to Study the hydrochemical characteristics of the water along the southern sector of the Al-Massab Alam canal and to determine the factors causing the change in the water properties.

2. Materials and Methods

Fifteen water samples were collected at about 30 cm depth from the Al-Massab Al-Aam canal - southern sector (Figure 1). These water samples are kept in clean plastic containers with an airtight lid during several field trips started on September, 2019. These water samples are analyzed for their hydrochemical properties at the laboratories of the University of Babylon. Samples were analyzed for their main ions Na, K, Ca, Mg, Cl, SO4, HCO3 and the trace elements Fe, Pb, Hg, Co, Cu concentrations as well as the total hardness (TH) using standard procedures according to standard methods of the American Public Health Association [8 and 9]. The physical properties such as pH, EC, TSS, and TDS are measured using digital Siemens instruments during the field trips (Tables 2 and 3).

Table 2- Physical properties and total hardness (TH) for Al-Massab Al-Aam water samples.

sample No.	pH	EC (ms/cm)	TDS (ppm)	TSS (ppm)	TH (ppm)
1	6.60	16.50	13383	2513	5576
2	6.62	20.20	17296	3110	7603
3	7.09	18.50	15753	2870	5840
4	6.90	19.20	16470	3312	5290
5	7.05	19.90	18643	3953	6382
6	7.11	20.80	17686	4703	6005
7	7.04	20.70	22933	3816	6445
8	7.14	25.50	20076	3940	7484
9	7.22	28.50	23423	3723	12343
10	6.83	41.50	36536	6946	13328
11	7.07	42.30	32816	6286	10094
12	7.12	43.70	33573	5340	8877
13	7.33	42.00	33740	6546	14786
14	7.19	42.50	33860	7133	16208
15	7.08	50.20	46253	8296	19952
Max.	7.33	50.20	46253	8296	19952
Min.	6.60	16.50	13383	7.33	5290
Mean	7.02	31.10	26592.8	4264	9089

Table 3- the hydrochemical properties analysis (mg/l) for Al-Massab Al-Aam water samples.

sample No.	Na^+ (mg/l)	K^- (mg/l)	Mg^{2+} (mg/l)	Ca^{2+} (mg/l)	$SO4^-$ (mg/l)	Cl^- (mg/l)	$HCO3^-$ (mg/l)
1	3466	115.75	903	745	4128	5530	256.20
2	4967	124	1216	995	6600	10844	244.00
3	3972	116	947	778	4458	6522	207.40
4	3764	95.5	726	842	4210	7090	170.80
5	4064	89.3	1128	697	5014	8791	183.00
6	4167	98.5	983	785	4677	8508	97.60
7	5365	135.75	1213	582	4874	8508	158.60
8	4864	146.3	1298	858	5583	10351	195.20
9	6364	155.75	2445	914	6643	11911	219.60
10	8964	216	2947	1282	8348	18434	244.00
11	6662	166.6	1874	954	6367	11273	268.40
12	5966	116	2542	943	7057	9926	268.40
13	8965	197.5	2335	872	6816	15739	256.20
14	7466	195.2	2187	1285	4887	15456	256.20
15	9968	296	3913	1542	9232	20632	268.40
Max.	9964	296.00	3913	1542	9232	20632	268.40
Min.	3466	89.30	726	582	296	5530	97.60
Mean	6024	923.19	1816	952.82	5252	11510	215.29

3. Results and Discussion

The Physical properties

All the results of physical properties and total hardness (TH) for Al-Massab Al-Aam water samples are tabulated in Table 2.

The pH values range from 6.6 to 7.33, with an average value of 7.02 (Figure 2A). The results reflect that the pH values vary between acidity and alkalinity, while the majority are moderate and fall within the permissible limits of the international standard [10].

The Electrical conductivity (EC) values range from 16.5 to 50.2 ms/cm with an average value of 31.1 ms/cm. The results reflect that the EC values increase toward the south and reach their maximum near Shatt Al- Basra (Figure 2B).

The total dissolved solids (TDS) values range from 13383 to 46253 ppm, with an average value of 26592.8 ppm. The results reflect that the TDS values increase southward and reach their maximum near Shatt Al- Basra (Figure 2C). The water along the southern sector of the Al-Massab Alam canal is classified as saline water according to Todd, 1980 classification (Table 4) [11, 12 and 13]. However, it is noticed that there is a direct relationship between the electrical conductivity and dissolved salts, as the conductivity increases with the increase of the dissolved salts [11, 12 and 13].

Table 4- Classification of groundwater based on TDS according to Todd, 1980 classification [13].

Total dissolved salts (ppm)	Water class
0-1000	Fresh
1000-10000	Brackish
10000-100000	Saline
>100000	Brine

The total suspended solids (TSS) values range from 7.33 to 8296 ppm, with an average value of 4264 ppm. The results reflect that the TSS values increase southward and reach their maximum near Shatt Al-Basra (Figure 2D).

It is known that the suspended solids in the water are a result of the erosion of unstable canal banks due to the rainfall as well as the effect of the sand and dust storms that increase the water turbidity southward, especially within Basra Governorate [12].

The Total Hardness (TH) values are ranging from 5290 to 19952 ppm with an average value of 9089 ppm. The results reflect that the TH values increase southward and reach their maximum near Shatt Al-Basra, (Figure 2E). It is known that the TH in the water is a result of the presence of calcium and magnesium high concentrations in water southward, especially within Basra Governorate [9]. The water along the southern sector of the Al-Massab Alam canal is classified as very hard water according to Boyd, 2000 and Todd, 2007 classifications [14 and 15].

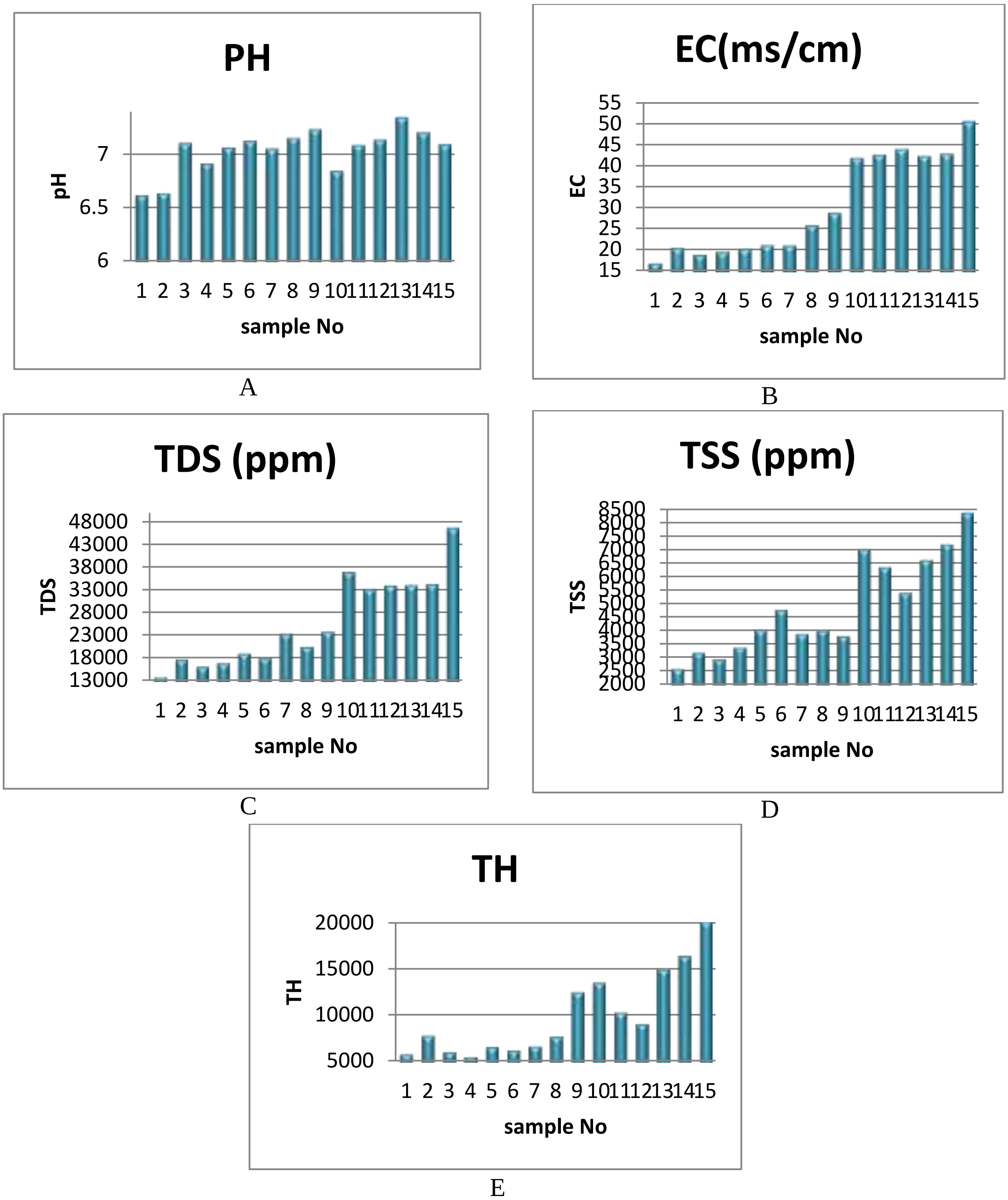


Figure 2- the histograms of the physical properties of the water samples of the Al-Massab Al-Aam channel, (A) pH, (B) EC, (C) TDS, (D) TSS, and (E) TH.

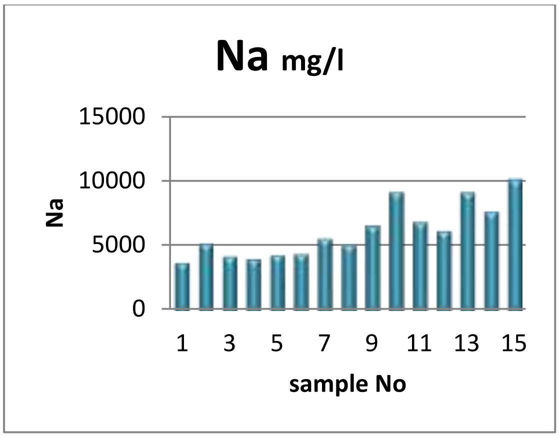
Hydrochemical properties A. The Cations

All the results of the concentration and averages of major ions of the Al-Massab Al-Aam channel water samples are tabulated in Table 3.

The sodium (Na) values range from 3466 to 9964 mg/l with an average value of 6024 mg/l. However, Halite is the major source of sodium in water due to its high solubility and the clay minerals through ionic exchanging [16]. The results reflect that the Na values increase southward and reach their maximum near Shatt Al- Basra (Figure 3A).

The potassium (K) values range from 89.3 to 296.0 mg/l with an average value of 923.13 mg/l. However, evaporate rocks and clay minerals are the major sources of potassium in water and weathering

of orthoclase rocks and biotite [17]. The results reflect that the K values increase southward and reach their maximum near Shatt Al- Basra (Figure 3B).
The magnesium (Mg) values range from 726 to 3913 mg/l with an average value of 1816 mg/l. However, ferromagnesian minerals such as the olivine and pyroxene are the major source of magnesium in water and weathering of carbonate rocks and chlorides [18]. The results reflect that the Mg values increase southward and reach their maximum near Shatt Al- Basra (Figure 3C).
The calcium (Ca) values range from 582 to 1542 mg/l with an average value of 952.82 mg/l. However, limestone and dolomite rocks are the major source of calcium in water and the decomposition of the organic matter due to high temperatures [19]. The results reflect that the Ca values increase southward and reach their maximum near Shatt Al- Basra (Figure 3D).



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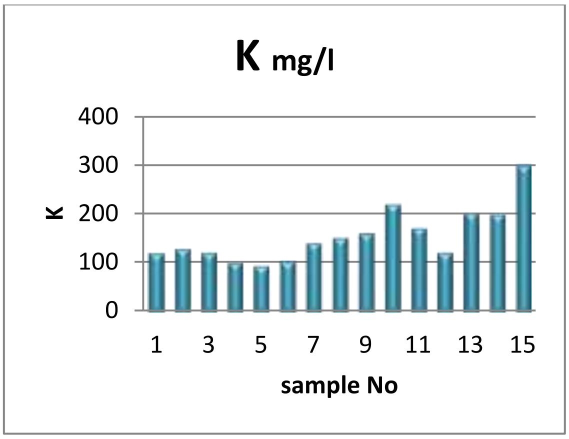

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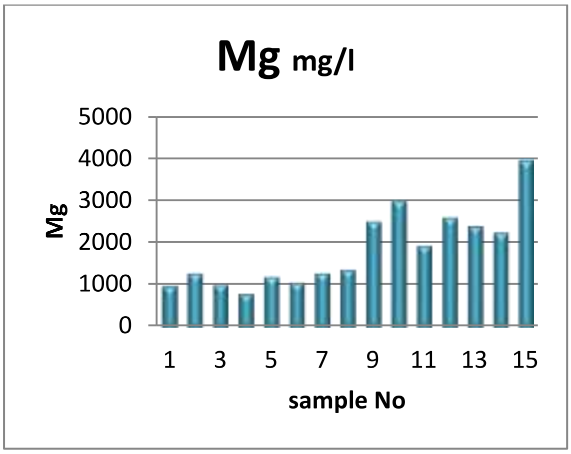

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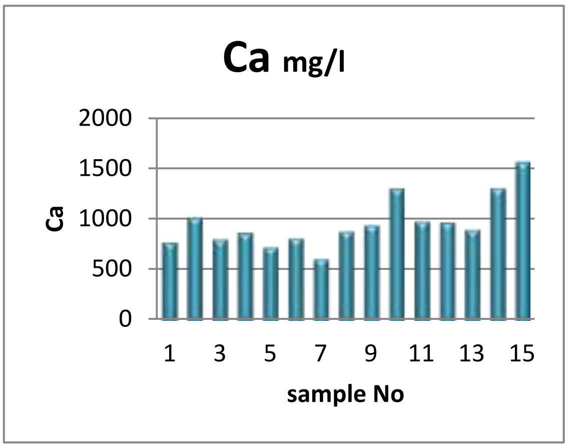


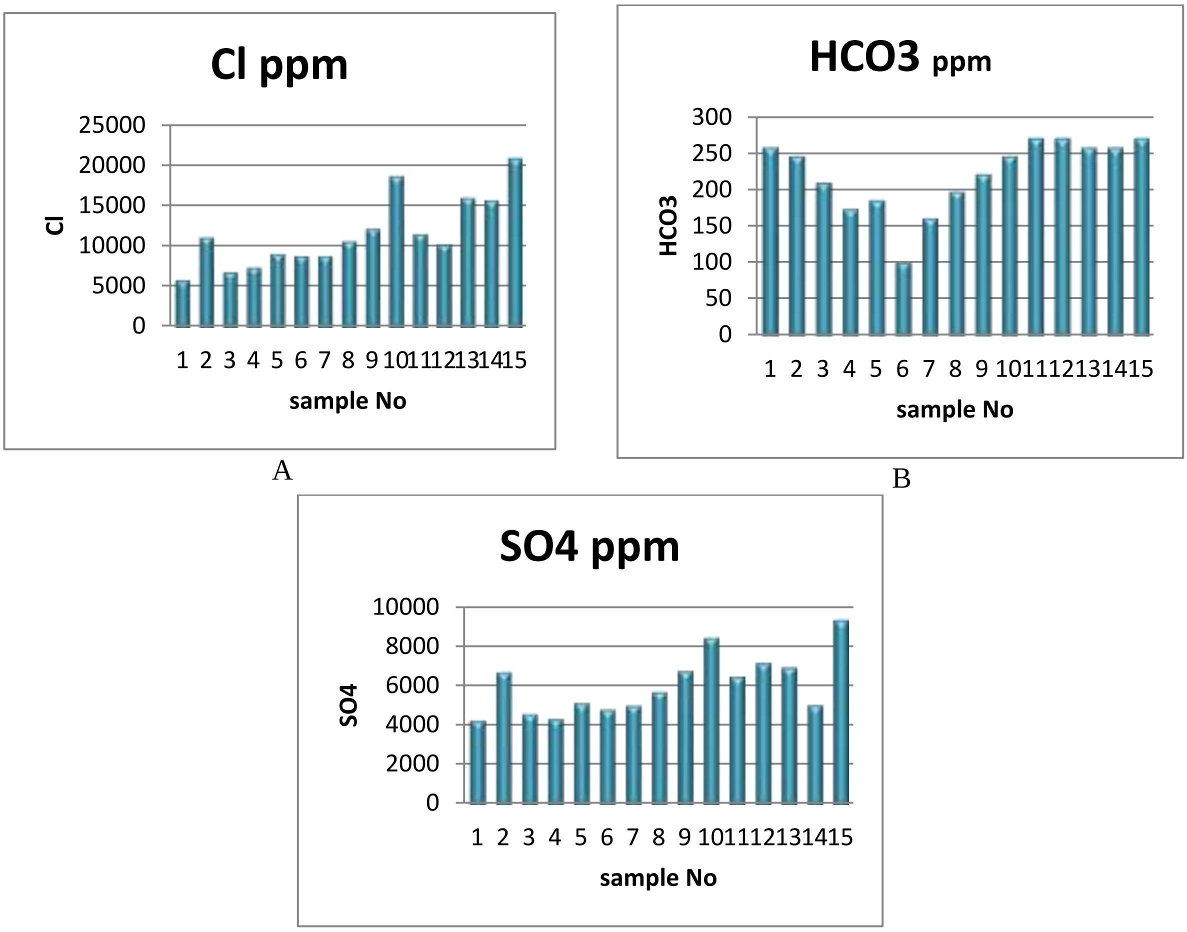
D

Figure 3- the histograms of the water samples of AL-Massab AL-Aam channel for (A) Na, (B)K, (C) Mg, (D) Ca .

B. The Anions

The chloride (Cl) values range from 5530 to 20632 mg/l with an average value of 11510 mg/l. However, Halite is the major source of chloride in water due to its high solubility as well as the contribution of the deep groundwater through faults [19, 20 and 21]. The results reflect that the Cl values increase southward and reach their maximum near Shatt Al- Basra (Figure 4A).
The bicarbonate (HCO_3) values range from 97.6 to 268.4 mg/l, with an average value of 215.29 mg/l. However, carbon dioxide is one of the sources of bicarbonate in water as well as the decomposition of the organic matter as a result of high temperatures [22]. The results reflect that the HCO_3values increase southward and reach their maximum near Shatt Al- Basra (Figure 4B).
The sulfate (SO_4) values range from 296 to 9232 mg/l with an average value of 5252 mg/l. However, evaporated rocks such as gypsum and anhydrite are the major sources of sulfate in water and fertilizers

[23]. The results reflect that the SO_4 values increase southward and reach their maximum near Shatt Al-Basra (Figure 4C).



C

Figure 4- the histograms of the water samples of AL-Massab AL-Aam channel for (a) Cl, (b)HCO_3, (c) SO_4.

C. The Trace elements:

The trace elements in natural water are defined as those with a concentration of less than 1 ppm, which means that the trace elements are not considered in the calculation of the total dissolved salts in natural waters because their quantities are not significant compared with the total major ions. The Cu, Pb, Hg, Co and Fe were investigated. The concentrations of these trace elements are tabulated in Table 5. The results showed that the values of trace elements are less than the permissible limits [24].

The iron (Fe) values are ranging from 0.014 to 0.120 mg/l with an average value of 0.062 mg/l. Fe is found in the form of oxides and is widely distributed in soils [25]. However, the concentration of iron increases with the increase of the chemical weathering of clay and organic matter in the soil [26].

The copper (Cu) values are ranging from 0.004 to 0.018 mg/l with an average value of 0.010 mg/l. Cu is a common element in the Earth's crust, and its transport is linked to organic materials [27]. However, the copper concentration depends on the source rocks and the pH where it is transmitted in oxidation conditions [26].

The lead (Pb) values are ranging from 0.001 to 0.283 mg/l with an average value of 0.153 mg/l. The lead concentration is increasing near polluted areas [9].
The cobalt (Co) values are ranging from 0.001 to 0.054 mg/l with an average value of 0.021 mg/l. The source of cobalt in the Earth's crust is basal igneous rocks, and its presence coincides with the elements of iron and manganese in the geological cycle [28].
The Mercury (Hg) values range from 0.001 to 0.009 mg/l with an average value of 0.005 mg/l. Mercury is present in the environment through natural sources and anthropogenic activities. Natural sources include forest fires, ocean emissions and natural disposal of the Earth's crust [29]. Human activities include mining, mineral processing and fossil fuel combustion [30] .
Generally, it is believed that the analyzed trace elements are controlled by parent or source rocks, climatic conditions, pyogenic processes, and drainage where the soils and surface sediments of Mesopotamia terrains are immature with little modifications or alterations by pyogenesis and have undergone degradation by fluvial processes.

Table 5- The Trace elements concentrations (ppm) for Al-Massab Al-Aam water sample

sample No.	Cu	Pb	Hg	Co	Fe
1	0.010	0.229	0.003	0.026	0.022
2	0.013	0.209	0.005	0.018	0.017
3	0.005	0.150	0.004	0.003	0.014
4	0.018	0.158	0.004	0.001	0.033
5	0.009	0.172	0.001	0.019	0.036
6	0.004	0.203	0.007	0.022	0.028
7	0.008	0.231	0.004	0.054	0.027
8	0.011	0.189	0.002	0.038	0.055
9	0.008	0.001	0.003	0.007	0.090
10	0.013	0.001	0.002	0.008	0.101
11	0.017	0.003	0.008	0.003	0.120
12	0.005	0.028	0.005	0.001	0.085
13	0.008	0.274	0.009	0.022	0.094
14	0.010	0.189	0.007	0.045	0.098
15	0.014	0.283	0.009	0.039	0.105
Max.	0.018	0.283	0.009	0.054	0.120
Min.	0.004	0.001	0.001	0.001	0.014
Mean	0.010	0.153	0.005	0.021	0.062

Saturation indices

A mineral saturation index shows whether water will tend to dissolve or precipitate a particular mineral. Its value is negative when the mineral may be dissolved, positive when it may be precipitated, and zero when the water and mineral are at chemical equilibrium. The saturation index (SI) is calculated by comparing the chemical activities of the dissolved ions of the mineral (ion activity product, IAP) with their solubility product (Ksp). In equation form, SI = log(IAP/Ksp).
The Saturation indices of Anhydrite, Aragonite, Calcite, Dolomite, Gypsum and Halite were investigated, and the results are tabulated in Table 6. Moreover, the results of the saturation indices were plotted against the sulfate concentration, as shown in Figure 6 A, B, C, D, E, and F.

The results of the saturation index analysis showed that the relationship between the sulfate concentration and the mineral saturation coefficients tends to increase their solubility for most minerals.

Such results confirm that some water samples are oversaturated or close to equilibrium calcite, dolomite, anhydrite, and gypsum in contrast to aragonite, anhydrite, and halite due to geological rock composition and due to reaction between water and bedrock (Figure 6 A, B, C, D, E, and F).

Table 6- saturation indices of Anhydrite, Aragonite, Calcite, Dolomite, Gypsum and Halite for the studied water samples (mmole/kg) for Al-Massab Al-Aam canal.

No.	Ionic Strength	Percent Error	SI (Anhydrite)	SI (Aragonite)	SI (Calcite)	SI (Dolomite)	SI (Gypsum)	SI (Halite)	SO_4
1	0.290	4.311	-0.244	-0.437	-0.289	-0.195	-0.013	-3.501	43.000
2	0.541	3.274	-0.075	-0.430	-0.282	0.096	0.151	-3.004	79.166
3	0.323	2.464	-0.220	-0.039	0.108	0.604	0.011	-3.376	46.430
4	0.315	-4.561	-0.183	-0.266	-0.119	-0.001	0.048	-3.362	43.850
5	0.372	-8.411	-0.252	-0.202	-0.055	0.404	-0.022	-3.245	52.229
6	0.362	-6.193	-0.214	-0.354	-0.206	-0.010	0.015	-3.246	48.718
7	0.397	3.440	-0.361	-0.355	-0.208	0.211	-0.133	-3.141	50.770
8	0.436	-6.832	-0.165	-0.019	0.128	0.744	0.063	-3.103	58.156
9	0.574	5.723	-0.180	0.086	0.234	1.212	0.045	-2.935	69.197
10	0.826	2.261	0.027	-0.151	-0.004	0.681	0.247	-2.555	97.375
11	0.536	4.933	-0.143	0.060	0.208	1.024	0.083	-2.937	66.323
12	0.449	-7.966	-0.050	0.112	0.260	0.978	0.178	-3.117	73.510
13	0.690	3.730	-0.210	0.234	0.382	1.515	0.012	-2.667	71.000
14	0.650	3.143	-0.164	0.286	0.433	1.425	0.060	-2.752	50.906
15	0.909	4.229	-0.039	0.211	0.358	1.459	0.180	-2.549	75.330

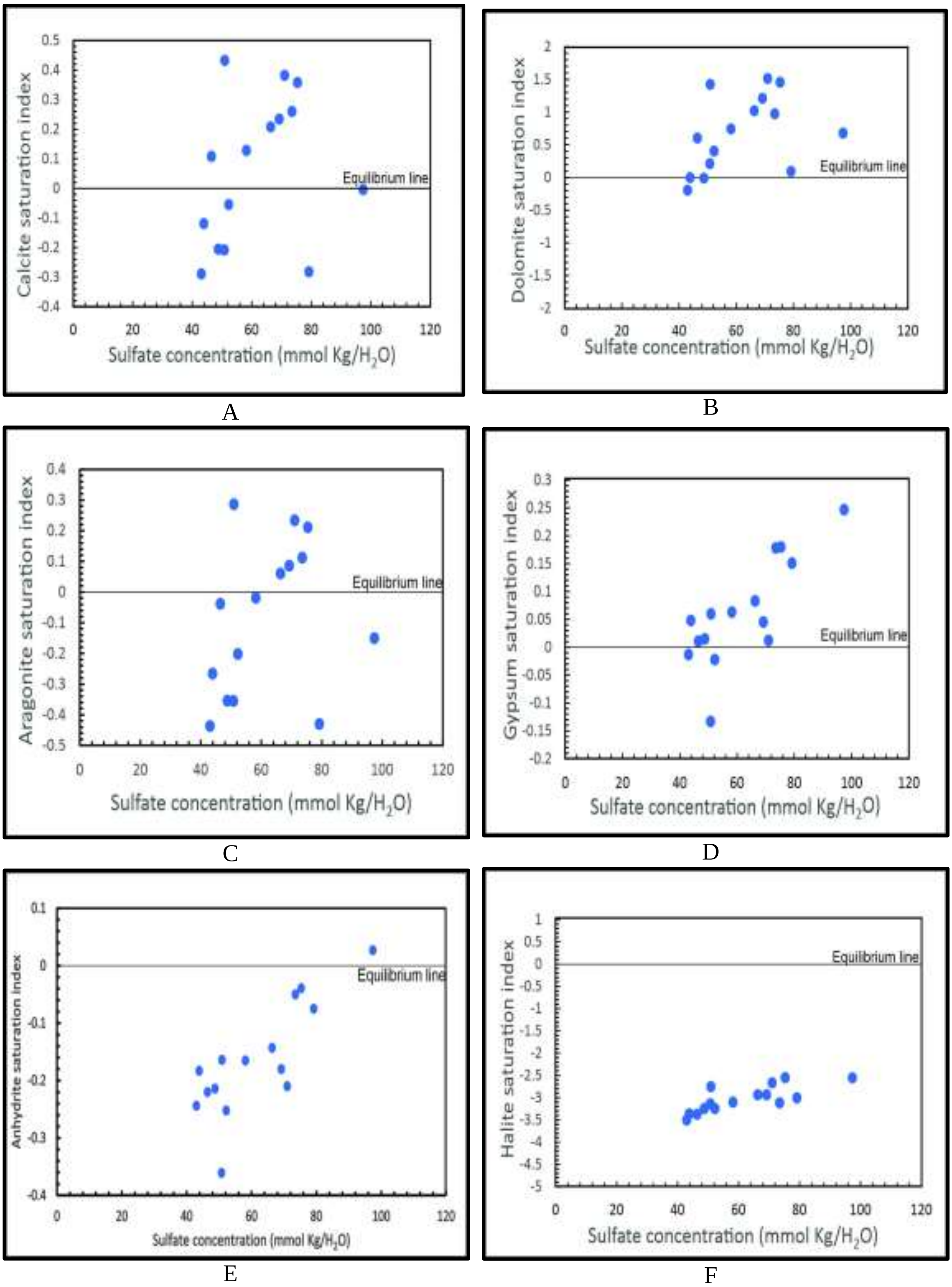


Figure 5- The Saturation indices of Anhydrite, Aragonite, Calcite, Dolomite, Gypsum and Halite were plotted against the sulfate concentration of the water samples of the Al-Massab Al-Aam canal, (A) the relationship between calcite saturation factor and sulfate concentration, (B) the relationship between dolomite saturation factor and sulfate concentration, (C) the relationship between Aragonite saturation factor and sulfate concentration, (D) the relationship between gypsum saturation factor and sulfate concentration, (E) the relationship between anhydrite saturation factor and sulfate concentration and (F) the relationship between halite saturation factor and sulfate concentration.

Moreover, comparing the current study results with previous studies' findings indicated that they are concordant and have the same conclusions [31, 32 and 33].

4. Conclusions

- The values of physical and chemical properties vary depending on the natural factors such as rainfall, temperatures and evaporation during summer and winter.
- It is noted that the percentage of dissolved solids is high and classified as saline water.
- The percentage of TH is very high, and the water is classified as very hard.
- The trace element values are less than the permissible limits.
- The results of the saturation indices confirm that some water samples are oversaturated or close to equilibrium, such as calcite, dolomite, anhydrite, and gypsum, in contrast to aragonite anhydrite, and halite due to geological rock composition and due to reaction between water and bedrock.
- By comparing the results of the current study with previous studies' findings indicated that they are in the concordance and have the same conclusions

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