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Monitoring of Main Outfall Drain and Southern Marsh in Iraq by Arithemitic Water Quality Index

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Abstract

This study set out to assess the ecological states to show that the Main Outfall Drain and the Southern Marsh are viable for irrigation use and the preservation of aquatic life. Water quality conditions at four sites were evaluated using the weight model. Samples were taken monthly to calculate the water quality index (WQI) for two seasons, summer of 2021 and winter of 2022. Twenty-six parameters were chosen to apply the WQI: Cl^-, CO_3^-, HCO_3^{2-}, Ca^{2+}, Mg^{2+}, pH, electrical conductivity (EC), NO_3, NO_2, NH_3, Na^+, K^+, dissolved Oxygen (DO), water temperature (WT), total dissolved solids (TDS), Mn, Ni, Pb, Fe, Cr, Zn, Cd, Cu, sodium absorption ratio (SAR), residual sodium carbonate (RSC) andsoluble sodium percent (SSP).

High levels of Cl, TDS, Cu and Pb were found in all sites during both seasons, and their concentrations were beyond the aquatic life protection criterion. Cl-, Mg2+, pH, EC, Na+, Cu and Cd were above the permissible limit for irrigation uses.

The results of the index for protection of aquatic life and irrigation uses ranged between 72.12–372.47 and 131.24–158.1 respectively. The WQI's ultimate rating ranged from very poor to unfit for both purposes. Therefore, only tolerant species may find this water quality acceptable which is insufficient to support the presence of diverse aquatic life.

Keywords: Monitoring, Aquatic life, Irrigation uses, WQI model, Main Outfall Drain, Southern Marsh.

مراقبة مياه المصب العام والاهوار الجنوبية في العراق بإستخدام مؤشر جودة المياه الحسابي

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الخلاصة

لإثبات أن المصب العام والاهوار الجنوبية صالحة للاستخدام للري ومعيشة الحياة المائية، وضعت هذه الدراسة لتقييم حالتها البيئية. تم تقييم ظروف جودة المياه في اربعة مواقع باستخدام نموذج الوزن. تم أخذ العينات شهريًا وحساب مؤشر جودة المياه لموسمين (صيف 2021 وشتاء 2022). تم اختيار ستة وعشرين عامل لتطبيق مؤشر جودة المياه المعتمد على الطريقة الوزنية: الكلورايد، الكاربونات، البيكاربونات، الكالسيوم، المغنيسيوم، الاس الهيدروجيني، التوصيلية الكهربائية، النترات،النتريت، الامونيا، الصوديوم، البوتاسيوم،الاوكسجين المذاب، درجة حراة المياه، المواد الصلبة الذائبة، المنغنيز، النيكل، الرصاص، الحديد، الكروم، الزنك، الكادميوم، النحاس، نسبة الصوديوم الممدص، كاربونات الصوديوم المتبقية ، ونسبة الصوديوم الذائب.

تم تسجيل مستويات عالية من الكلورايد والمواد الصلبة الذائبة والنحاس والرصاص في جميع المحطات في كلا الموسمين وقد كانت تركيزاتهم اعلى من الحدود السموح بها لمعيشة الاحياء المائية. بينما كان مستوى كل من الكلورايد والمغنيسيوم و الاس الهيدروجيني والتوصيلية الكهربائية والصوديوم والنحاس والكادميوم ونسبة الصوديوم الذائبة اعلى من الحدود المسموح بها لإستخدامات الري.

تراوحت قيم مؤشر جودة المياه لحماية معيشة الاحياء المائية والاستخدام الزراعي بين 72.12– 372.47 و 131.2– 158.1 على التوالي. والتقدير النهائي لمؤشر جودة المياه قد تراوح بين نوعية مياه رديئة جدا الى نوعية غير مناسبة لأي استخدام. ولذلك، تعتبر نوعية مياه هذين المسطحين غير مشجعة لوجود الاحياء المائية وربما يمكن ان تكون مقبولة لبعض الانواع المقاومة. ولذلك، فإن الأنواع المقاومة فقط هي التي قد تجد نوعية المياه هذه مقبولة لمعيشتها؛ حيث ان نوعية المياه هذه غيرملائمة لتعزيز وجود حياة مائية متنوعة.

1. Introduction

Water resource management and conservation are major worldwide issues, particularly in areas like Iraq which is facing ecological difficulties. The Water Quality Index (WQI) has taken a significant step in monitoring the Main Outfall Drain and Southern Marsh in Iraq in response to the urgent demand for efficient water quality monitoring [1].

As one-third of the population lives in rural areas and relies on agriculture for their livelihoods, agriculture is one of the primary sources of employment in these areas. Given the importance of crop production to Iraq's economy, 75% of the country's farmers largely depend on it for their primary source of income. This emphasizes how vitally dependent a sizable segment of the populace is on the productivity and sustainability of agricultural activities. Furthermore, the agricultural industry in Iraq employs around 20% of the labour force, making it the country's second-largest employer after the oil and gas industry. The vital socio-economic role that agriculture plays in the nation is not just as a means of subsistence for farmers but also as a significant employer of labour. Despite the oil industry's dominance in terms of GDP (Gross Domestic Product) contribution overall, the agriculture sector continues to play a crucial part in Iraq's overall economic landscape [2]. However, several issues in Iraq are impeding this goal including decaying infrastructure, inadequate system upkeep and operation, a lack of strong government support and a lack of national regulatory policies [3].

Environmental degradation is one of the biggest issues facing contemporary human society [4]. The dissolution of metals in water during weathering of rocks can contribute to the presence of heavy metals in rivers. Still, the primary human-caused sources of trace metals in aquatic environments are industrial emissions, mining, smelting, and agricultural practices like using pesticides and phosphate fertilizers [5, 6]. Fossil fuel combustion also leads to the emission of heavy metals into the environment [7]. Due to their toxicity, heavy metals create various health issues and are persistent in the environment and food systems [4].

Soil salinization is one of the leading causes of cultivated soils losing productivity. Approximately 10 million ha of agricultural land are lost to salt buildup worldwide yearly. Climate change, excessive groundwater use (especially if close to the sea), rising low-quality water use for irrigation, the widespread introduction of irrigation associated with intensive farming and poor drainage [8], and untreated sewage water disposal in nearby canals in urban areas [9] are all factors that can speed up this rate.

The Main Outfall Drain (MOD) suitability for irrigation and aquatic life was assessed using multiple criterion decision-making methodologies. Water quality indices have been established to represent and make the data on water quality more understandable. The WQI is an excellent tool to transfer the huge data obtained from the monitoring program into a simple expression. It is a tool for communicating data on water quality [10].

This project aimed to comprehensively assess and ensure the sustainability of the water bodies in the region by the following: (i) to recognize and classify the salt-affected soils in the study area into the usual groups of salt-affected soils, (ii) assess the quality of the water used for aquatic life and irrigation, and (iii) provide baseline data on the resources of pollutants that affect the MOD.

2. Material and methods

2.1 Study sites

Main Outfall Drain created by Iraqi government in 1992 and is primarily used to dump agricultural effluents from both sides in the middle and southern regions of Iraq and industrial waste discharge and transport [11, 12]. It stretches approximately 565 kilometres from Al-Shaklawiya in Baghdad north to Khor Al-Zubair in the south [11].

The main Outfall Drain's south sector (study area), which is divided into three sectors (North, Mid, and South), stretches for around 165 km from the end of the mid sector to Shatt Al-Basarah in the south. This sector's average annual water discharge is 220 m3/sec [12]. This sector had a new branch built with a 7 km length that fed into the marshes south of Al-Nassiriya city.

Site 1 (St.1) was located in the middle of Al-Nassiriya city, next to the Al-Holandee Bridge and on the major road. Separated from the first site by 20 km was the second site (St. 2). Site 3 (St.3) served as the new branch's beginning. The Al-Sanaf Marsh represented the fourth site (St. 4) (Figure 1).

Water samples were collected from the MOD and Al-Sanaf Marsh during the summer 2021 (Jun, July, August) and winter 2021-2022 (December, January, and February). Field measurements included pH, dissolved oxygen (DO), water temperature (WT) and electrical conductivity (EC) by using a portable device (Model H19811 Manufacture Company HANA). Experimental Measurements included chloride (Cl^-), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), calcium (Ca^+), magnesium (Mg^{+2}), nitrate (NO_3), ammonia (NH_3), sodium (Na^+), potassium (K^+), total dissolved solid (TDS) and nitrite (NO_2). Additionally, some heavy metals: manganese (Mn), nickel (Ni), lead (Pb), iron (Fe), chromium (Cr), zinc (Zn), cadmium (Cd) and copper (Cu) were also determined using atomic absorption spectrophotometer. All mentioned parameters were determined according to APHA [13].

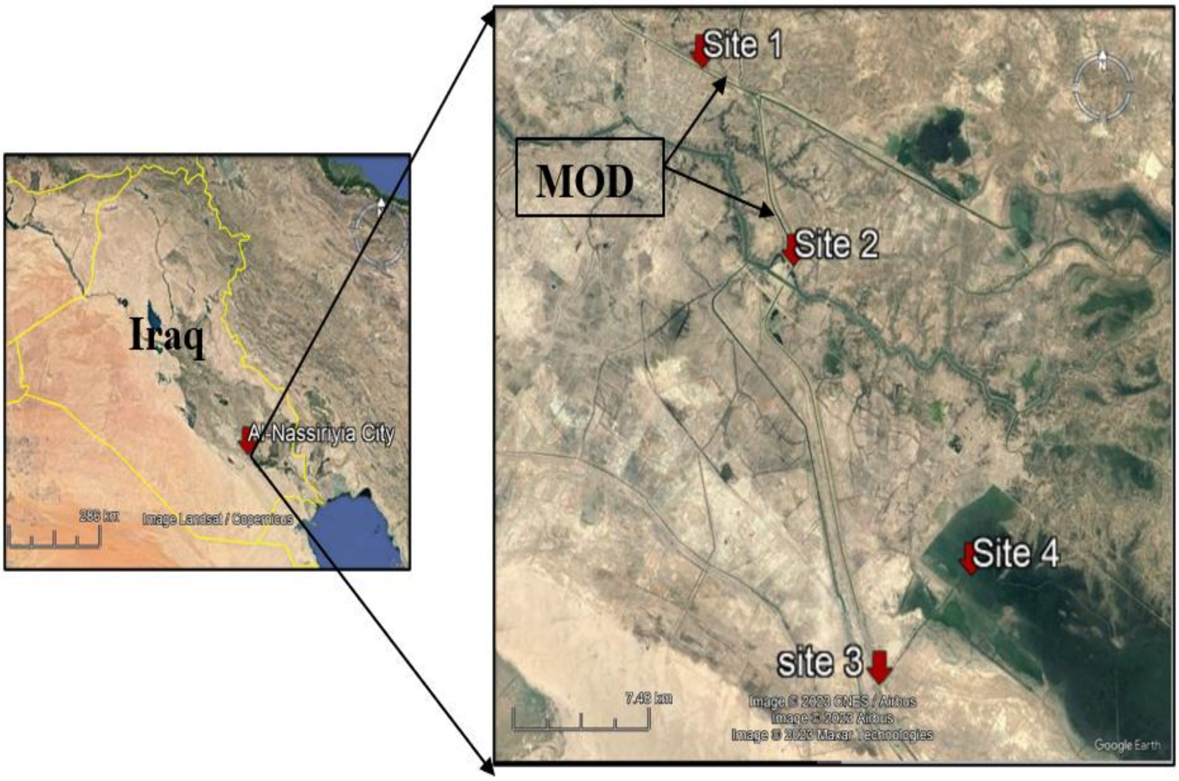

Figure 1: Sampling sites (Source: Google Earth, 2023)

2.2 WQI Calculation

Twenty-two parameters (the Canadian water quality guidelines for aquatic Life [14] and guidelines for irrigation water uses [15]) were used to calculate the water quality index for irrigation uses and aquatic life. Table 1 displays the water quality score which resulted from the final WQI computation using the arithmetic index model suggested by Brown *et al*. [16], as shown in equations 1-3.

Step one: The following equation was used to determine the quality rating or sub-index (Qn):

$$Qn = 100(Vn - Vio)/(Sn - Vn) \quad \text{……….(eq... 1)}$$

Where:

Qn = Quality rating for the nth water quality parameter.

Vn = Estimated value of the nth parameter at a given sampling point.

Vio = Ideal value of $_n$th parameter in pure water.

Sn = Standard permissible value of the nth parameter.

Step two: The suggested standard value Sn of the related parameter was used to determine the unit weight using a value that was inversely proportionate to it.

$$Wn = K/Sn \qquad \text{………………. (eq... 2)}$$

Where:
Wn = Unit weight for the nth parameter.
K = Constant for proportionality.
Sn = Standard value for the nth parameter.

Step three: by adding up the quality rating (Qn) and unit weight (Wn) using a linear formula, the total WQI was determined.

$$WQI = \sum qnWn/\sum Wn \qquad \text{…………………………(eq... 3)}$$

Where:
WQI = Water quality index.
qn = Quality rating for the nth water quality parameter.
Wn = Unit weight for the nth parameter.

Table 1: Water quality score [16].

Rank	Categorization
0-25	Excellent
26-25	Good
51-75	Poor
76-100	Very poor
100>	Unfit for use

Sodium absorption ratio (SAR) was calculated using the equation below (eq. 4), where ionic Na, K, and Mg2+ concentrations were expressed in meq/L. higher SAR value indicated a greater Na hazard [3].

$$SAR = \frac{Na}{\sqrt{0.5\,([Ca^{2+}]+Mg^{2+}])}} \qquad \text{………………………..(eq... 4)}$$

The soluble sodium percent (SSP) was determined using equation (eq. 6) and expressed in meq/L [17]:

$$SSP = \frac{NA}{Ca+Mg+NA} \times 100 \qquad \text{……………………..(eq… 6)}$$

RSC is calculated as follows(eq. 5)and expressed in meq/L [18]:

$$RSC = [HCO3 + CO3] - [Ca + Mg] \qquad \text{……………..(eq…5)}$$

3. Results and Discussion

3.1 WQI results

The WQI is a good tool as it grew out of the necessity to organize communication with the public on water monitoring. Secondly, it relates to the need for broad methods of classifying and contrasting various bodies of water in the region [19]. WQI is calculated based on a series of physical and chemical characteristics that serve as indicators to reflect the health of the aquatic system [11]. The mean values of the physical and chemical properties of the MOD are illustrated in Tables 2 and 3. Twenty-two parameters, selected for their importance for irrigation, were used to build the WQI for agricultural irrigation uses. The appropriateness of water for agricultural irrigation use is referred to as water quality for irrigation, and the composition and concentration of dissolved components in water may be used to assess this quality. The TDS/EC (salinity) and chloride/sodium concentration in proportion to the level of calcium and magnesium or SAR have a significant impact on the appropriateness of water for irrigation [20]. The results for the 4 sites were 135.80, 131.24, 137.68, 146.57 during winter, and 135.78, 137.13, 143.77, 158.10 in summer respectively. These values strongly indicated that MOD was unfit (polluted) for irrigation uses. Cl^-, Mg^+, EC, Na, Cu, Cd, Ni, and SSP indexes fell in winter, while Cl^-, Mg^+, EC, Na, Cu, Cd, and SSP during summer. Improper irrigation management and poor irrigation water quality, salinization of irrigated fields could be a major issue.

Twelve parameters chosen to calculate WQI for the aquatic life protection are shown in Tables 4 and 5. The 4 sites' results are as follows: 237.10, 193.75, 123.57, and 86.00 during winter, and 372.47, 324.11, 95.45, and 72.12 in summer respectively. WQI rank ranged from very poor to unfit for use (polluted). In the same manner, the MOD were not found to be suitable for aquatic life. The parameters that caused the indexes fall were Cl^-, TDS, NO_3, NH_3, Ni, Zn in winter, DO, WT, Cl^-, TDS, NO_2, NH_3 pH and Zn in summer.

Table 2: The physical-chemical characteristics and WQI (Winter season) of MOD for irrigation uses.

Parameter		Observed Mean Values				Standard Value (Sn)	Unit Weight (Wn)
		St.1	St.2	St.3	St.4		
1	Cl^- (mg/L)	**1896.8**	**1803.1**	**1940.6**	**1806.8**	1000	0.0000079
2	CO_3^{2-} (mg/L)	0.00	0.00	1.20	0.00	3	0.0026232
3	HCO_3^{2-} (mg/L)	32.34	34.16	34.90	37.83	610	0.0000129
4	Ca^{2+} (mg/L)	294.58	327.7	286.9	273.74	401	0.0000196
5	Mg^{2+} (mg/L)	391.23	301.7	340.9	292.31	60.8	0.0001294
6	pH	7.83	7.85	7.85	7.70	7.5	0.0010493
7	EC (µs/cm)	7190.0	7430	6820	6795.0	3000	0.0000026
8	NO_3	7.75	0.00	9.30	5.98	45	0.0001749
9	NH_3 (mg/L)	2.43	2.53	1.34	0.94	6.08	0.0012944
10	Na (mg/L)	1325.0	1310	1360	1215.0	920	0.0000086
11	K (mg/L)	29.00	27.00	29.00	29.50	78	0.0001009
12	Mn (mg/L)	0.03	0.03	0.02	0.04	0.2	0.0393485
13	Ni (mg/L)	0.53	0.18	0.02	0.20	0.2	0.0393485
14	Pb (mg/L)	0.06	0.14	0.07	0.08	5	0.0015739
15	Fe (mg/L)	0.08	0.07	0.11	0.07	5	0.0015739
16	Cr (mg/L)	0.08	0.09	0.09	0.10	0.1	0.0786969
17	Zn (mg/L)	0.01	0.03	0.02	0.03	2	0.0039348
18	Cd (mg/L)	0.01	0.02	0.02	0.02	0.01	0.7869694
19	Cu (mg/L)	0.02	0.04	0.04	0.04	0.2	0.0393485
20	SAR	2.41	2.72	2.74	2.75	18	0.0004372
21	RSC	0	0	0	0	2.5	0.0031479
22	SSP	64.96	66.62	67.43	67.11	50	0.0001967
							ΣWn=1.0
	WQI	135.80	131.24	137.68	146.57	-	

Note: Values in bold indicate they exceeded the limits.

Table 3: The physical-chemical characteristics and WQI (Summer season) of MOD for irrigation uses.

Parameter		Observed Mean Values				Standard Value (Sn)	Unit Weight (Wn)
		St.1	St.2	St.3	St.4		
1	Cl^- (mg/L)	**1419.40**	1734.40	1926.30	2171.70	1000	0.0000079
2	CO_3^{2-} (mg/L)	0.00	0.00	0.00	0.00	3	0.0026232
3	HCO_3^{2-} (mg/L)	38.44	31.18	31.24	38.56	610	0.0000129
4	Ca^{2+} (mg/L)	285.00	285.75	296.15	354.65	401	0.0000196
5	Mg^{2+} (mg/L)	324.70	362.05	408.80	403.70	60.8	0.0001294
6	pH	7.75	8.05	7.87	7.95	7.5	0.0010493
7	EC (µs/cm)	7059.5	10550.4	10383.1	11422.2	3000	0.0000026
8	NO_3 (mg/L)	10.85	8.86	34.99	9.97	45	0.0001749
9	NH_3 (mg/L)	1.90	1.11	1.94	1.63	6.08	0.0012944
10	Na (mg/L)	1235.25	810.00	855.00	720.00	920	0.0000086
11	K (mg/L)	52.50	60.00	55.00	65.00	78	0.0001009
12	Mn (mg/L)	0.04	0.04	0.03	0.04	0.2	0.0393485
13	Ni (mg/L)	0.04	0.04	0.05	0.06	0.2	0.0393485
14	Pb (mg/L)	0.09	0.05	0.03	0.02	5	0.0015739
15	Fe (mg/L)	0.10	0.10	0.10	0.09	5	0.0015739
16	Cr (mg/L)	0.02	0.03	0.02	0.05	0.1	0.0786969
17	Zn (mg/L)	0.03	0.04	0.04	0.03	2	0.0039348
18	Cd (mg/L)	0.02	0.02	0.02	0.02	0.01	0.7869694
19	Cu (mg/L)	0.06	0.07	0.06	0.06	0.2	0.0393485
20	SAR	2.58	1.57	1.51	1.21	18	0.0004372
21	RSC	0.00	0.00	0.00	0.00	2.5	0.0031479
22	SSP	65.10	53.37	52.94	46.65	50	0.0001967
							ΣWn=1.0
	WQI	135.78	137.13	143.77	158.10	-	

<u>Note:</u> Values in bold indicate they exceeded the limits.

Table 4: The physical-chemical characteristics and WQI (Winter season) of MOD for aquatic life.

Parameter		Observed Mean Values				Standard Value (Sn)	Unit Weight (Wn)
		St.1	St.2	St.3	St.4		
1	pH	7.65	7.61	7.59	7.4	7.75	0.0018136
2	DO (mg/L)	8.66	8.3	9	7.8	7.25	0.0019387
3	WT (C°)	15.4	15.8	16.8	16.7	15	0.0009370
4	Cl^- (mg/L)	1896.8	1803.15	1940.6	1806.8	250	0.0000562
5	TDS (mg/L)	5334.5	5012.5	5047.5	5063.5	500	0.0000281
6	NO_3 (mg/L)	7.7501	0	9.303	5.9805	13	0.0010812
7	NO_2 (mg/L)	0.4439	0.3289	0.1969	0.0325	0.06	0.2342585
8	NH_3 (mg/L)	2.4316	2.529	1.337	0.936	1.37	0.0102595
9	Mn (mg/L)	0.02815	0.0293	0.0243	0.0412	0.1	0.1405551
10	Ni (mg/L)	0.52885	0.1793	0.02034	0.2031	0.15	0.0937034
11	Fe (mg/L)	0.0766	0.0673	0.1066	0.068	0.3	0.0468517
12	Zn (mg/L)	0.01485	0.0298	0.0248	0.0336	0.03	0.4685170
							ΣWn=1.0
	WQI	237.10	193.75	123.57	86.00	-	-

<u>Note:</u> Values in bold indicate they exceeded the limits.

Table 5: The physical-chemical characteristics and WQI (Summer season) of MOD for aquatic life.

Parameter		Observed Mean Values				Standard Value (Sn)	Unit Weight (Wn)
		St.1	St.2	St.3	St.4		
1	pH	7.75	8.05	7.87	7.95	7.75	0.0018136
2	DO (mg/L)	6.36	6.36	6.35	0.95	7.25	0.0019387
3	WT(C°)	28.5	28	27	32	15	0.0009370
4	Cl^- (mg/L)	1419.4	1734.4	1926.3	2171.7	250	0.0000562
5	TDS (mg/L)	5103	6031	6809	6608.5	500	0.0000281
6	NO_3 (mg/L)	10.8535	8.86	34.99	9.9675	13	0.0010812
7	NO_2 (mg/L)	0.7896	0.64155	0.0658	0.01645	0.06	0.2342585
8	NH_3 (mg/L)	1.8966	1.1126	1.9394	1.6294	1.37	0.0102595
9	Mn (mg/L)	0.0389	0.03515	0.0345	0.0381	0.1	0.1405551
10	Ni (mg/L)	0.0363	0.0414	0.05075	0.0605	0.15	0.0937034
11	Fe (mg/L)	0.10395	0.10355	0.0985	0.09175	0.3	0.0468517
12	Zn (mg/L)	0.03385	0.04025	0.037	0.0339	0.03	0.4685170
							ΣWn= 1.0
	WQI	372.47	324.11	95.45	72.12	-	-

Note: Values in bold indicate they exceeded the limits.

3.2 Physical and chemical parameters

Dissolved oxygen, a very important factor for aquatic life, its value ranged from 0.95 - 6.36 and 7.8-9.0 mg/L in summer and winter respectively. According to Susilowati *et al.*[21], DO concentrations in water under 7.25 mg/L can cause oxygen deficiency in aquatic life bodies and affect metabolic activity and many life processes. It is clear from Tables 7 and 8 that, in contrast to winter, DO fell below the standard value in summer in all the sites. The decrease in summer was primarily due to to WT as mentioned previously in Tables 4 and 5, where the reading of WT ranged between 27-32°in summer. Their values were high in all sites and, hence, not withinstandard value’s range to protect aquatic life where the solubility of oxygen decreases as temperature increases [22]. Increase in the salts levels is the second factor that decreases the solubility of dissolved oxygen. Saltwater that holds about 20% less dissolved oxygen than freshwater [23] is considered brackish water as will be explained next.

EC and TDS are related to total ion concentrations [24]. In this study, EC was used to calculate WQI for irrigation purpose, and values ranged between 7430 - 6795.0 µS/cm in winter, 6795.0-11422.2 µS/cm in summer. All values exceeded the permissible limits (3000 µs/cm), according to [15]. Upon comparing the results with the modified classification of Thorne and Peterson proposed by the US Salinity Laboratory in 1954, as clarified in Table 6 [25], EC values were found to fall in the fourth category (very high salinity).

Table 6: Group of irrigation water proposed by US Salinity Laboratory [26].

Water Salinity Classification	EC(µs/cm)	Description	Salt Concentration
Low Salinity	0 - 250	Used for irrigation of crops on most soils.	<0.20
Medium Salinity	250 - 750	Used in case of a moderate amount of leaching occurs.	0.20–0.50
High Salinity	750 - 2250	Cannot be used in soil with restricted drainage.	0.50–1.50
Very high Salinity	2250 -5000	Used under special circumstances. The soils must be permeable, irrigation water must be applied in excess to provide considerable leaching, drainage must be adequate, and salt-tolerant crops should be selected.	3-5

TDS calculated QWI for aquatic life protection uses ranged between 5012.5 - 5334.5 mg/L in inter, and 5103-6809 mg/L in summer. All values exceeded the permissible limits (500 mg/L) according to guidelines[14], and according to the Classification in Catroll's report [27] of water quality, the water isclassified as brackish water when the TDS range is between 1001-10000 $mg.l^{-1}$. The high EC and TDS observed in winter could be attributed to agricultural activities that might have increased the concentration of ions. The high concentration of EC/TDS in the water indicates intense anthropogenic activities along the MOD course with high suspended matter concentration and dissolved minerals. MOD was designed to discharge the effluents from cultivated fields [28].

pH is one of the most important environmental parameters that can potentially restrict the spread of several species in an aquatic system. It also affects various biological and chemical processes in water [29]. pH ranged between 7.70 - 7.85 in winter and 7.75 - 8.05 in summer. These values slightly exceeded the permissible limits for both agricultural and aquatic life protection uses. Many factors, like the reduction of photosynthetic activity rate and the assimilation of carbon dioxide CO_2 and bicarbonates HCO_3 alongwith high water temperature during the summer months, are accountable for this increase of pH [30].

Chloride (Cl^-) is one of the factors that drove the WQI to an unfit situation where its values exceeded the permissible limits for agricultural and aquatic life protection uses in both seasons. Its value ranged between 1803.1 - 1940.6 mg/L in winter and 1419.40 - 2171.70 mg/L in summer. Many studies on watersheds have pointed to the increase of Cl^- levels as a pollution indicator in the water body. The Cl^- sources in water are positively related to anthropogenic activities like sewage from drainages and refuse, Cl^- entering a water course through softener discharge contamination [31], and fertilizers made from potashor mined salts. Potassium chloride (KCl) is the salt commonly utilized in potash fertilizer, where potassium is one of three major nutrients along with nitrogen and phosphorous that are added to raise soil fertility. Nevertheless, like phosphorous and nitrogen, chloride (Cl^-) can be leached from fertilized soils into streams and rivers [32].

Sodium (Na^+) values ranged between 1215.0 - 1360 mg/L in winter, and 720.0 - 1235.25 mg/L in summer, where most readings were above the limitation (Tables 5, 6). Na was high during winter in all sites and in St.1 during summer, with the highest value of 1360 mg/l in St.3 and the lowest value being 720.0 mg/L in St.1. High Na in irrigation water is not recommendable because Na overlap with the adsorption ratio of other ions leads to the separation of interchangeable cations (Ca^{+2} and Mg^{+2}) from soil minerals, leading to damaging soil structure and blocking the soil pores causing low water permeability. Soil fertility decreases in such situations. Na increase can refer to both natural and anthropogenic sources. Dissolution of silicate minerals releases Na, and runoff from precipitation may come into contact with the rock salt and surface, and then contribute to loading dissolved solids to rivers and streams [33].

Potassium (K) was in background value throughout the study, ranging between 27.0-29.0 mg/L during winter and 52.50- 65.00 mg/L in summer. K has many different roles in plant life, including being an enzyme ingredient and a regulator of drought tolerance. Chlorosis of the leaf margins can be caused by a K deficit [18].

Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ranged between 0.00-1.20 mg/L and 37.83-32.34 mg/L in winter, 0.0- 0.0 mg/L and 31.18-38.44 mg/L in summer respectively. HCO_3^- induces the precipitation of calcium in the form of calcium carbonate in the dry season, causing a higher SAR in water [2]. All sites in this study were considered suitable for irrigation for carbonate and bicarbonate as the values were within limits.

In this study two odd situations arised for Mg^{2+} ion; Mg^{2+} ion exceeded the permissible limits for irrigation uses, and secondly Mg^{2+}ion concentration appeared higher than Ca^{2+}. This case is considered a unique phenomenon where in nature, the ratio of Ca: Mg is 5:3. The concentration of $Ca^{2+}$and Mg^{2+} ranged from 273.74 - 327.7, 292.31 - 391.23 in winter, 285.00 - 354.65, 324.70 - 408.80 mg/L in summer respectively. This increase in Mg^{2+} over the Ca^{2+} could be due to agricultural runoff that is fertilizer rich with magnesiumsulfate also known as epsom salt (containing 10% Mg^{2+} and 14% S) [34]. According to [35], if Mg^{2+}content exceeds the Ca^{2+} content, they will demonstrate equally toxic effects on soil characteristics and plant growth as the Na. Strawn *et al.* 2019 reported that at lower or equal Mg^{2+}concentration, Mg^{2+} acts like Ca^{2+} and higher Mg^{2+} like sodium, eventually led to dispersion of soil and decrease in the infiltration rate [36].

Nitrate (NO_3) exceeded recommended values by the guideline for the protection of aquatic life just once time in summer at St.3 where their concentration ranged between 0 - 9.303 mg/L in winter and 8.86 - 34.99 mg/L in summer. While Nitrite (NO_2) concentration ranged among 0.032 - 0.4439 mg/L in winter and 0.016 - 0.789 mg/L in summer. NO_2 exceeded the guideline continuously for the same use in St. 1, 2 and 3. Almost during the whole study period ammonia (NH_3) concentration ranged between 0.93 - 2.529 mg/L in winter and 1.112 - 1.9394 mg/L in summer which was above the recommended values for the guideline for the protection of aquatic life. This unmistakably demonstrated that human activity in the region of concern had considerably influenced surface water quality [37, 38, 39].

Heavy metals were also measured in this study. Mn, Ni, Pb, Fe, Cr, Zn, Cd and Cu were used for WQI irrigation calculation and Mn, Ni, Fe and Zn for aquatic WQI. Based on the guidelines for irrigation, Ni in St.1, 2 Cd and Cu in St.2,3,4 were out of limits in winter and Cd, Cu in all sites for summer in all sites. For aquatic life purposes, Ni in St.1, 2 and 4 exceeded the limits in winter and Zn in St.4. While in summer, only Zn exceeded the limit in all sites. In general, heavy metals can negatively affect the water and soil quality. Environmental pollutants of aquatic ecosystems and heavy metals are stable and persistent. Naturally occurring processes and contaminants from human activity contribute to their occurrence in the environment [39, 40, 41].

Three important factors, SAR, RSC and SSP, were calculated and inserted in the index for assessing the suitability of tMOD for irrigation usage [42]. SAR is a parameter for irrigation water quality that can be used to manage the effect of sodium in soils. It is a standard identification parameter to predict irrigation water sodium hazard to the soil [42]. SAR values were below the limitation limits and ranged between 2.41 - 2.75 in winter and 1.21 - 2.58 during summer [34].

RSC of irrigation water is utilized to report the hazardous effects of the alkalinity on soil. It is a good indicator of the suitability of the water for irrigation in clay soil particles with a great cation exchange capacity. If dissolved Na is high in water compared with dissolved Ca^{2+} and Mg^{2+}, clay soil undergoes dispersion or swells, drastically reducing its infiltration capacity [43]. RSC values stayed below the recommended limit in all sites and seasons in this study.

Being another factor for irrigation, SSP is yet another significant factor in studying the sodium hazard. A high sodium percentage can reduce the permeability of the soil and prevent plant growth [44]. According to Wilcox [45], irrigation water should be classified according to its SSP.

SSP levels <50 suggests adequate irrigation-quality water, while values >50 indicate unsuitable water [17]. SSP in this study was >50 all the time, and this increase referred to a rise in Mg^{2+} and Na concentrations in the first place which eventually led the index to fall to unsuitability.

4. Conclusion

The Main Outfall Drain and Southern Marsh in the southern region of Iraq were comprehensively ecologically assessed in this study. Water quality index indicated if the water was unsuitable both for the aquatic life and agricultural uses. The primary cause of the water's poor quality was due to the high concentration of salts in the MOD which eventually seeped into the marsh, severely damaging its biodiversity.

Conflicts of Interest

The author declares that they have no conflicts of interest.

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Reference

[1] R. A. Villar-Navascués , and M. C. Fragkou, “Managing Water Scarcity Futures: Identifying Factors Influencing Water Quality, Risk Perception and Daily Practices in

Urban Environments after the Introduction of Desalination," *Water*, vol. 13, no. 2738, pp. 1-15, 2021.URI:https://repositorio.uchile.cl/handle/2250/183598, DOI: 10.3390/w13192738.

[2] I. Alwan, H. Karim, and N. Aziz, "Investigate the Optimum Agricultural Crops Production Seasons in Salah Al-Din Governorate Utilizing Climate Remote Sensing Data and Agro- Climatic Zoning," *Iraqi Journal of Science*, vol. 60, pp. 2087–2094, Sep. 2019, DOI: 10.24996/ijs.2019.60.9.24.

[3] I. A. Alwan, H. H. Karim, and N. A. Aziz, "Groundwater aquifer suitability for irrigation purposes using multi-criteria decision approach in Salah Al-Din Governorate/Iraq," *AgriEngineering*, vol. 1, no. 2, pp. 303–323, 2019. https://doi.org/10.3390 /agriengineering 1020023

[4] Z. Z. Al-Janabi, F. M. Hassan, A. H. M. J. Al-Obaidy, "Heavy metals pollution profiles in Tigris River within Baghdadcity," *IOP Conf. Series: Earth and Environmental Science*, vol. 1088, pp. 1-8/012008, 2022. DOI:10.1088/1755-1315/1088/1/012008.

[5] Muhammad Afzaal; Saman Hameed; Iram Liaqat; Amir Amanat Ali Khan; Hafiz abdul Manan; Raja Shahid; Muhammad Altaf, "Heavy metals contamination in water, sediments and fish of freshwater ecosystems in Pakistan," water Practice &Technlogy, vol. 17, pp. no. 5, 1253-1272, 2022. https://doi.org/10.2166/wpt.2022.039

[6] Z. Z. Al-Janabi, S. R. Zaki, J. S. AlHassany, A. H. M. J. Al-Obaidy, E. Awad, and A. A. Maktoof, "Geochemical Evaluation of Heavy Metals (Cd, Cr, Fe, and Mn) in Sediment of Shatt Al-Basrah, Iraq," Engineering and Technology Journal, vol. 37, no. 2, pp. 237–241, 2019. DOI: 10.30684/etj.37.2C.6

[7] H. Ali, E. Khan, and I. Ilahi, "Environmental chemistry and ecotoxicology of hazardous heavy metals: environmental persistence, toxicity, and bioaccumulation," *J Chem*, vol. 2019, 2019. https://doi.org/10.1155/2019/6730305

[8] R. Almeida and R. Serralheiro, "Soil salinity: effect on vegetable crop growth," *Management practices to prevent and mitigate soil salinization. Horticulturae*, vol. 3, no. 2, p. 30, 2017. DOI:10.3390/horticulturae3020030

[9] E.-H. Bhatti, M. M. Khan, S. A. R. Shah, S. S. Raza, M. Shoaib, and M. Adnan, "Dynamics of water quality: Impact assessment process for water resource management," *Processes*, vol. 7, no. 2, p. 102, 2019. https://doi.org/10.3390/pr7020102

[10] Z. Z. Al-Janabi, F. M. Hassan, A. H. M. J. Al-Obaidy, "A brief review of water quality indices and their applications," *IOP Conf. Series: Earth and Environmental Science*, vol. 779, pp. 1-12/012008, 2021. doi:10.1088/1755-1315/779/1/012088

[11] M. W. Alabdraba, Z. B. Mohammed, M. M. Hazaa, and S. A. Resheq, "Evaluation of the Tigris river water quality for domestic and irrigation uses near drinking water treatment plants through Baghdad city," in *Proceedings of ISER 13th international Conference, Singapore, 25th November*, 2015, pp. 63–68. https://www.researchgate.net /publication /285578161.

[12] H. Chlaib, "Evaluation of Quality of Main Outfall River Water According to some Standard Criterions in Dywinyia and Thi-Qar Governorates," vol. 8, p. 2019, Dec. 2021. https://www.researchgate.net/publication/357312564.

[13] E. W. Rice, R. B. Baird, and A. D. Eaton, "Standard Methods for the Examination of Water and Wastewater ed-23rd," *American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF), Washington DC*, 2017.

[14] CCME, Canadian Council of Ministers of the Environment. 2007. Canadian Water Quality Guidelines for the Protection of Aquatic. Excerpt from publication No. 1299.

[15] CCME, Canadian Council of Ministers of the Environment. 1999. Canadian water quality guidelines for the protection of agricultural water uses: Introduction. In: Canadian environmental quality guidelines. 1999, Canadian Council of Ministers of the Environment, Winnipeg. Avaiable at: https://www.scribd.com/document/516368137/Canadian-Water-Quality-Guidelines-for-the-Protection-of-Agricultural-Water-Uses-Introduction

[16] R. M. Brown, N. I. McClelland, R. A. Deininger, and R. G. Tozer, "A water quality index-do we dare," *Water Sew Works*, vol. 117, no. 10, 1970. Avaiable at: https://www.scribd.com/document/389699238/A-Water-Quality-Index-Do-we-dare-BROWN-R-M-1970

[17] S. Fang, H. Yang, G. Wei, T. Shen, Z. Wan, M. Wang, X. Wang, Z. Wu, "Potassium application enhances drought tolerance in sesame by mitigating oxidative damage and regulating osmotic adjustment." Frontiers in plant science, vol. 13, p. 1-13, 2022. https://doi.org/10.3389/fpls.2022.1096606

[18] K. K. Singh, Geeta T., and S. Kumar, "Evaluation of Groundwater Quality for Suitability of Irrigation Purposes: A Case Study in the Udham Singh Nagar, Uttarakhand" Journal of Chemistry, Article ID, 6924026, pp. 1–15, 2020. https://doi.org/10.1155/2020/6924026

[19] R. Thapa, S. Gupta, and H. Kaur, "Introducing an irrigation water quality index (IWQI) based on the case study of the Dwarka River basin, Birbhum, West Bengal, India," *Sustain Water Resour Manag*, vol. 6, no. 5, p. 86, 2020. https://www.researchgate.net /publication /344380435.

[20] S. Amrani, S. Hinaje, M. El Fartati, Y. Gharmane, and D. Yaagoub, "Assessment of groundwater quality for drinking and irrigation in the Timahdite–Almis Guigou area (Middle Atlas, Morocco)," *Appl Water Sci*, vol. 12, no. 4, p. 82, 2022. https://doi.org /10.1007/s13201-022-01609-3.

[21] S. Susilowati, J. Sutrisno, M. Masykuri, and M. Maridi, "Dynamics and factors that affects DO-BOD concentrations of Madiun River," in *AIP Conference Proceedings*, AIP Publishing LLC, 2018, p. 020052. https://doi.org/10.1063/1.5082457.

[22] M. Rajesh, and S Rehana, "Impact of climate change on river water temperature and dissolved oxygen: Indian riverine thermal regimes." Scientific reports vol. 12, no.1, p. 9222, 2022. https://doi.org/10.1038/s41598-022-12996-7.

[23] F. Giomi, A. Duarte, J. Booth, S. Agusti, V. Antion, D. Daffonchio and M. Fusi. "Oxygen supersaturation protects coastal marine fauna from ocean warming," *Sci Adv*, vol. 5, no. 9, p. eaax1814, 2019. DOI: 10.1126/sciadv.aax1814

[24] A. Gapparov and M. Isakova. "Study on the characteristics of water resources through electrical conductivity: A case study of Uzbekistan." *IOP Conference Series: Earth and Environmental Science*, vol 1142, no. 012057,page1-9, 2023. DOI:10.1088/1755-1315/1142 /1/012057

[25] D. W. Thorne and H. B. Peterson, *Irrigated soils*, vol. 78, no. 5. LWW, 1954. http:// dx.doi.org/10.1097/00010694-195411000-00021

[26] V. A. Kovda, Irrigation, drainage and salinity*: an international source book*. Hutchinson, FAO, UNESCO, 1973. https://unesdoc.unesco.org/ark:/48223/pf0000005702.

[27] D. Catroll, "Rain water as a chemical agent of geological process: a view," *USGS water supply*, vol. 1533, pp. 18–20, 1962. https://pubs.usgs.gov/wsp/1535g/report.pdf

[28] A. A. Maktoof, Z. Zahraw and M. G. Magtooph, "Concentrations of some trace metals in water and sediment of main outfall drain in Al-Nassiriyia city by using pollution indices".*AIP Conference Proceedings,* vol,2290, no 020013, p. 1-12, 2020. https://doi.org/10.1063/5.0028595.

[29] B. M. Saalidong, S. A. Aram, S. Otu, and P. O. Lartey, "Examining the dynamics of the relationship between water pH and other water quality parameters in ground and surface water systems," *PLoS One*, vol. 17, no. 1, p. e0262117, 2022. https://doi.org/10.1371 /journal.pone.0262117

[30] M. A. Arthur, "The chemical evolution of the atmosphere and oceans". Advancing Earth and Space Sciences, V. 67(1):pp.5-5, 1986. https://doi.org/10.1029/EO067i001p00005

[31] M. Shukla and S. Arya, "Determination of Chloride ion (Cl-) concentration in ganga river water by Mohr method at Kanpur, India," *Green Chemistry & Technology Letters*, vol. 4, no. 1, pp. 6–8, 2018. DOI:10.18510/gctl.2018.412

[32] W. Yue, X. Liu, L. Wang, H. Li, S. Zhang, J. Yang, N. Liu and X. Han, "Effects of Long-Term Application of Cl-Containing Fertilizers on Chloride Content and

Acidification in Brown Soil" *Sustainability*, vol,15, no 8801, p. 1-10, 2023. https://doi.org/10.3390 /su15118801

[33] F. D. Tillman, D. W. Anning, J. A. Heilman, S. G. Buto, and M. P. Miller, "Managing salinity in upper Colorado river basin streams: Selecting catchments for sediment control efforts using watershed characteristics and Random Forests models," *Water (Basel)*, vol. 10, no. 6, p. 676, 2018. https://doi.org/10.3390/w10060676

[34] O. Giday Adhanom, "Salinity and sodicity hazard characterization in major irrigated areas and irrigation water sources, Northern Ethiopia," *Cogent Food Agric*, vol. 5, no. 1, p. 1673110, 2019. https://doi.org/10.1080/23311932.2019.1673110

[35] N. Hussain, R. A. Jakhar, M. Tahir, R. Noreen, N. M. Hassan, and F. Mujeeb, "Impact of Ca/Mg Ratios of Irrigation Water on Soil Properties and Crop Yields," *Asian J Plant Sci*, 2002. DOI: 10.3923/ajps.2002.51.52

[36] Strawn DG, Bohn HL and O'Connor GA. 2019. Soil Chemistry. 5th ed., John Wiley - Blackwell, USA, pp: 376. https://www.wiley.com/en-sg/9781119515180

[37] H. J. Khadim and H. O. Oleiwi, "Assessment of Water Quality in Tigris River of AL-Kut City, Iraq by Using GIS," in *E3S Web of Conferences*, EDP Sciences, 2021, p. 04001. https://doi.org/10.1051/e3sconf/202131804001

[38] I.A.A. Al-Bahathy, Z.Z. Al-Janabi, R.R. Al-Ani and A.A. Maktoof. "Application of the Water Quality and Water Pollution Indexes for Assessing Changes in Water Quality of the Tigris River in the South Part of Iraq". *Ecological Engineering and Environmental Technology*, 2023, 24(5), pp. 177–184. DOI:10.12912/27197050/165901

[39] R.R. Al-Ani, A.M.J Al Obaidy and F.M. Hassan. "Multivariate analysis for evaluation the water quality of Tigris river within Baghdad city in Iraq".*Iraqi Journal of Agricultural Sciences*, 2019, 50(1), pp. 331–342. https://www.researchgate.net/publication/331598000.

[40] Nnabueze Darlington Nnaji, Helen Onyeaka*, Taghi Miri, Chinenye Ugwa, "Bioaccumulation for heavy metal removal: a review.," *SN Applied Sciences*, vol. 5, no. 125, p. 1-20, 2023. https://doi.org/10.1007/s42452-023-05351-6

[41] S. Mitra, A. J. Chakraborty, A. M. Tareq, T. B. Emran, F. Nain, A. Khusro, A. M. Idris, M. U. Khandaker, H. Osman, F.A. Alhumaydhi, and J.Simal-Gandara, "Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity," *Journal of King Saud University - Science*, vol. 34, no. 3, p. 101865, 2022. https://doi.org/10.1016/j.jksus.2022.101865

[42] S. H. Ewaid, S. A. Abed, N. Al-Ansari, and R. M. Salih, "Development and evaluation of a water quality index for the Iraqi rivers," *Hydrology*, vol. 7, no. 3, p. 67, 2020. https://doi.org/10.3390/hydrology7030067

[43] H.S. Öztürk , S. D. Saygin, N.K. Copty, E. İzci, G. Erpul, B. Demirel, A.K. Saysel, and M. Babae, "Hydro-physical deterioration of a calcareous clay-rich soil by sodic water in Central Anatolia, Türkiye," *Geoderma Regional*, vol. 33, pp. e00649, 2023. https://doi.org/10.1016/j.geodrs.2023.e00649

[44] G. Ondrasek *et al.*, "Salt Stress in Plants and Mitigation Approaches," *Plants*, vol. 11, no. 717, p. 1-21, 2022. https://doi.org/10.3390/plants11060717

[45] Lv. Wilcox, *Classification and use of irrigation waters*, no. 969. US Department of Agriculture,1955.https://ia803201.us.archive.org/10/items/classificationus969wilc/classificationus969wilc.pdf