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Assessment of Water Quality at Al-Hammar Marsh before and after Flow Improvement

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ABSTRACT

Marshlands have been considered among the most productive ecosystems on Earth. Marshlands existing in Mesopotamia are recently acknowledged by the United Nations as one of the international heritage sites. The current research highlights the deterioration level in the water quantity of the Al Hammar marsh which is one of the famous marshes in the south of Iraq. Recently, pipe culverts were constructed to reduce the salinity of the Al Hammar marsh. Data on Total Dissolved Solids (TDS), Electric Conductivity (EC), and Power of Hydrogen (pH) from February 2019 to February 2020 at five stations (distributed within Al Hammar marsh) were used to assess the water quality before and after the construction of pipe culverts. Two standards were used in the assessment: the Iraqi Water Quality Standard (IWQS, No.417) and the World Health Organization (WHO) Standards for drinking, irrigation, and aquatic life. In addition, the quality of ecological health in the Al Hammar marsh was assessed by using the Canadian Water Quality Index. Results show that the quality of water in the Al Hammar marsh is not recommended to be used for irrigation while the aquatic life is at a threat level.

Key words: *Marsh, WQI, Assessment, Irrigation, Aquatic life*

Introduction

Wetlands are low-lying land areas with hydric soils, and many types of plants are flooded permanently or seasonally. Wetlands are commonly found in many forms, such as marshes, bogs, swamps, etc. A wetland may be dry for long periods, but when the water table level is above the land surface it may be wet and can sustain aquatic plants. The populations of plants and animals that grow and respond to these conditions vary from those contained in strictly marine (lakes, rivers) or dry land ecosystems. Depending on the form, wetland can be mainly made up of plants, grasses, shrubs, or moss (Haslam, 2003; U.S. Department of interior, 2021).

Marshes and wetlands are part of the water system and naturally connected with rivers and it can help in polishing water quality in different ways. The inflow from rivers to the marshes and wetlands usually carry dissolved pollutants and sediment. Since the flow velocity inside the marshes and wetlands is significantly reduced, it resulted in the settling of sediment by gravity. However, the plants inside the marshes and wetlands adsorb some dissolved contaminants. Healthy marshes and wetlands can remove harmful bacteria and pathogens from the water before it is discharged to the rivers again.

Like every other instrument, indexes are used for assessing water quality levels. Awareness of water quality values and basic concepts will help to indicate the seriousness of relevant problems (Chougule *et al.*, 2009). Evaluation of water quality is vital for diagnosing the health of aquatic habitats in water systems (Yisa and Jimoh, 2010; Panda *et al.*, 1991). Evaluation includes two elements, water quality parameters calculation and comparison to benchmark metrics such as recommendations and change assessment targets. The value of water quality can be evaluated in space and/or in time (De Resemand *et al.,* 2009).

Fathi *et al*. (2016) determined the Water quality index (WQI) for Choghakhor International Wetland, Iran, based on eleven parameters (Nitrate, Ammonium-Nitrite, Amm-N, Alkalinity, Hardness, Turbidity, Conductivity, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), pH and Biochemical Oxygen Demand (BOD_5) and by using the analyses of variance (ANOVA). The method revealed significant differences between different sampling periods ($p<0.01$), and they recommended using the method to assess water quality in wetlands. The quantity and quality of water in Iraqi rivers that feed the marshes are declined due to the construction of many dams upstream (Al-Ansari and Ali, 2014). Accordingly, water pollution has been observed in many locations along rivers Tigris and Euphrates. Therefore, monitoring and evaluation of water quality parameters are essential in controlling the water quality of the rivers. Based on a limited number of samples, various studies were conducted to assess the water quality of Al Hammar Marsh (Al-Shammary *et al*., 2015). Nawar *et al*. (2018) applied ArcGIS 10.4.1 software to determine the spatial distribution of WQI in Al Hammar marsh using water data from 2011-2015. The data was measured at Al-Hamedy station or M1, located in the middle of Al Hammar marsh at the Al-Basrah governorate. However, Hashim *et al*. (2020) used Landsat-8 data to predict and evaluate the salinity's spatial variation and map distributions by selecting SO_4 and $CaCO_3$ as a representative parameter within Al-Hawizeh marsh during two seasons only in 2017.

The main objective of the present study is to assess the water quality of the West Al Hammar marsh by using many tools such the Water Quality Index (WQI), Iraqi Water Quality Standard (IWQS) no.417 (Council of Ministers, 2009), and World Health Organization Standards for drinking, irrigation, and aquatic life. The assessment will be used to check the suitability of West Al Hammar marsh as an aquatic habitat. This study is an effort to help the decision-makers to control the salt concentration in the marsh (WHO, 2011).

Materials and Methods

History, location, and description of the study area

Historically and since 4th Millennium BCE, many marshes/wetlands were existing in southern Mesopotamia which formed what was called previously as cradle of civilization. Some of the marshes still exist in the South of Iraq. Recently, the marshes are acknowledged by the United Nations as one of the international heritage sites. It is also known as the Mesopotamian marshes or the Iraqi marshes. The Iraqi marshes or marshlands are mainly composed of the separate but adjacent marshes such as Al Hawizeh, central and Al Hammar marshes. The marshlands are the largest rare aquatic landscape in the desert and provide habitat for the marsh Arabs and important populations of wildlife. The Focus in this study will be on the water quality of Al Hammar marsh only. Most of the marshlands are mostly located within southern Iraq and it is originally covering an area of 20,000 km^2 and divided into three major groups, the first group of marshes are called central marshes and located between Rivers Tigris and Euphrates, while the second group of marshes are called Al Hammar marsh and located south of the Euphrates. The third group of marshes are called Al Hawizeh marsh and it is the bound east of the Tigris river. In this study, the Al Hammar marsh and is taken as a case study. Figure 1 shows the location of the marshes. Al Hammar marsh is located between two governorates Nasiriyah and Basrah, South of the Euphrates River and the West of Shatt Al Arab. The marshes form a permanent surface area of 2,800 km^2 of but during period of flooding it can extend to 4,500 km^2. Al Hammar marsh is the largest water body within the marshlands with depths ranging between 1.8 m and -3 m. In the summer, large portion of the marsh is exposed and forming many islands within Al Hammar marsh and these islands are used by the population living in the marsh for agriculture. Based on feeding flow rates, Al Hammar marsh is subdivided into Western and Eastern marshes. Flow rates to Al Hammar marsh are mainly coming from

Euphrates, and Main Outfall Drain (MOD) (Al-Ansari *et al*., 2012). To prevent the transfer of salty water from the Al Hammar marsh to Shatt Al Arab, the Center for the Restoration of the Iraqi Marshlands and Wetlands (CRIMW) has constructed a dyke in 2010 (CRIMW, 2010).

Fig. 1. The location of marshlands

The railway line is passing through the marsh and there are few box culverts that allow the water to move from the west part to the east part within the marsh. The inhabitants and the government are facing the problem of increasing salinity of the water in the marsh. The high evaporation rate and the high salt content in the feeding water are the main source of salinity of the marsh. A number of pipe culverts are constructed to improve the flow and reduce the salinity level in the marsh. The salinity was monitored through five different locations. Figure 2 shows the system of the marsh including the feeding sources and new outlet to MOD.

The Ecology of Al Hammar marsh

The flooded grasslands and savannas eco-region constitute the Al Hammar marsh where the seasonal and permanent marshlands are dominated by aquatic plants as shown in Figure 3.

Fig. 3. The aquatic plants in Al Hammar Marsh

Also, Al Hammar marsh is home to a large number of birds (more than 40 species) as well as a stopover to many other migratory travelled birds from Siberia to Africa. In addition, several species of fish are found in Al Hammar marsh. Due to political reason, Al Hammar marsh as well as other marshlands were subjected to intensive draining from 1980-2003 in order to evict the population (marsh Arabs). Figure 4 and 5 show the marsh Arabs houses with their buffalos. It is estimated that about 90% of the marsh-

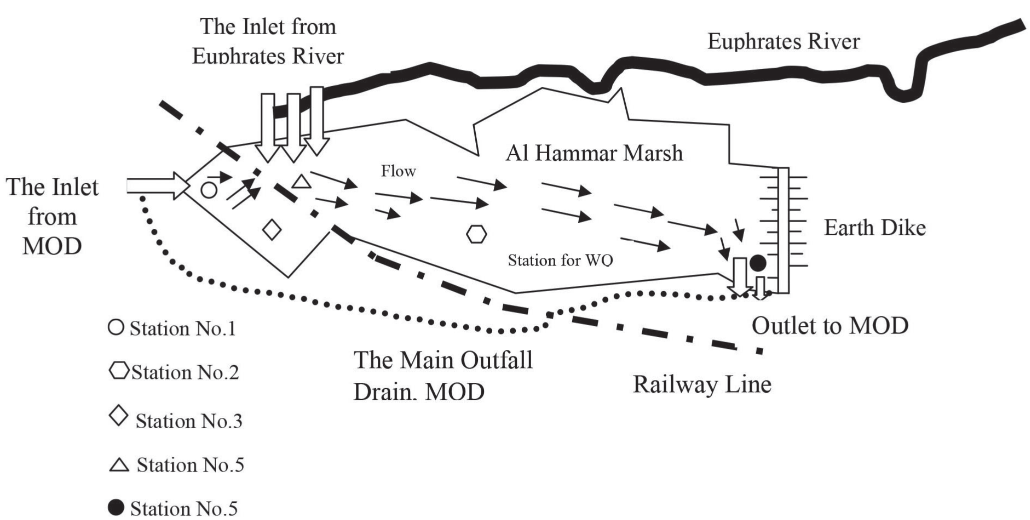

Fig. 2. Schematic sketch for Al Hammar marsh

lands were drained and this caused a significant decline in bioproductivity but after regime change in Iraq in 2003, the water that flow to the marshes restored and recovered the ecosystem. In 2016, the Mesopotamian marshes in South of Iraq have been listed as an UNESCO heritage site. The salinity of water in the marsh is decreased by constructing 87 pipe culverts; each one has a diameter of 1m to 1.2 m. These culverts are discharging to the MOD to ensure the circulation of water (Figure 2). Measurements at Station 5 showed that the circulation of water in the marsh is led to decrease the salinity from around 27000 mg/l to about 10000 mg/l, as shown in Table 1. In the study, the environmental condition of the Al Hammar marsh is assessed by focusing on the variation of selected parameters that are affecting the aquatic life in the marsh.

Data acquisition

Data from five different stations were collected to cover the variation of water quality in the west part of Al Hammar marsh. The stations are shown in Figure 2. The first Station is located at Al Khamissiya channel, and this channel was constructed in 2009 with a design discharge of 60 m^3/s and through the measurement period, the TDS of the channel water varied from 4000 to 9000 ppm. However, another two sampling stations are located on the both sides of the box culverts through the railway embankment inside the marsh. However, the remaining two sampling stations are located in the east part of the marsh but one of them is located near the pipe cul-

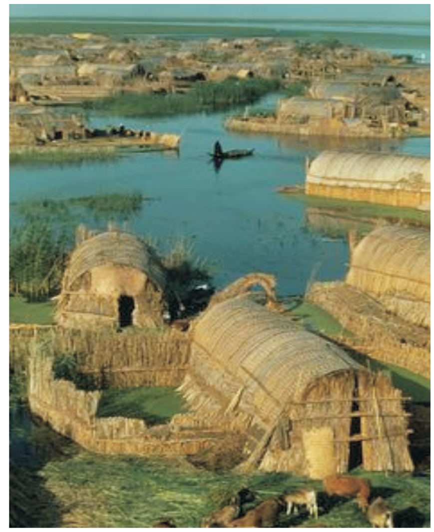

Fig. 4. Houses of marsh Arabs

Table 1. The measured data on water quality parameters for the period of (Feb. 2019 – Feb. 2020)

No:	Parameters	Date (2019 to 2020)															
		Feb.	Mar.	Apr.	May	JUN	July	Aug.	Sep.	Oct.	Nov	Des	Jan	Feb	Min.	Max.	Avg.
Station 1	TDS	6911	8606	4485	3450	6214	6828	6070	6140	6610	4350	5227	5119	5220	3450	8606	5786.9
	EC	10.063	13.24	6.521	5.447	9.561	10.536	9.344	9.45	10.017	6.71	8.041	7.802	7.988	5.447	10.536	8.82
	PH	7.3	7.9	7.9	7.6	8.1	8.3	8.3	8.3	8.2	8.1	8	8.1	8.2	7.3	8.3	8.02
Station 2	TDS	8400	7477	7982	4119	4346	3835	5360	4260	5979	2861	3100	3129	3105	2861	8400	4919.4
	EC	13.01	11.51	12.052	6.34	7.776	6.012	8.27	6.51	7.925	4.001	4.35	4.815	5.098	4.001	13.01	7.5
	PH	7.3	7.8	8.1	8.1	8.2	8.5	8	8.3	8	7.9	7.9	7.9	8.1	7.3	8.5	8
Station 3	TDS	4093	4634	4026	3075	3044	2407	2496	2765	3492	3019	3134	2624	2614	2407	4634	3186.3
	EC	6.297	7.128	6.179	4.731	5.507	4.309	5.398	4.9	4.824	4.038	4.017	6.297	7.128	4.017	7.128	4.98
	PH	7.1	7.8	8.1	7.6	8.1	8.3	8	8.1	7.9	8	7.4	7.8	7.9	7.1	8.3	7.8
Station 4	TDS	7212	7284	7740	4001	4270	3586	4780	3867	5899	2600	3770	3095	3040	2600	7740	4703.3
	EC	11.89	11.21	12.012	6.211	7.692	5.61	7.35	6.711	8.112	3.911	5.82	4.916	4.678	3.911	12.012	7.39
	PH	7.2	7.9	8	7.9	8.5	8.4	7.9	8.2	8.2	8.1	8	7.9	8	7.2	8.5	8.01
Station 5	TDS	27881	27300	22650	22160	23949	22190	24395	16450	15200	11200	12900	11100	9950	9950	27881	19025
	EC	43.564	42.656	35.405	34.625	37.42	34.67	38.116	25.70	23.75	17.5	20.15	17.34	15.39	15.39	43.564	29.71
	PH	8.3	8.2	8.1	8.3	8.4	8.6	8.4	8	7.1	6.9	7.5	7.2	7.2	7.1	8.6	7.86

Fig. 5. The Buffalo in the marshlands

verts discharging outlet to MOD (Figure 2). The collected data covered the period from February 2019 to February 2020. The average monthly values of the selected parameters are shown in Table 1. In Table 1, each value is taken as the average of three different measurements. Table 2 shows the values of the selected water quality parameters.

Water Quality Index (WQI) for Al Hammar Marsh

In this study, the Weighted Arithmetic of the Canadian Water Quality Index Method has been used to assess the water quality in the Al Hammar marsh by using the affected values of water sample parameters collected from 5 stations within the marsh area. The most important measured water quality parameters were TDS, EC, and pH. The weighted arithmetic water quality index was shown in Table 3). However, the main steps for deriving WQI are summarized as below (Marine, 1999):

F1= [Number of failed variable/ Total number of variable] × 100 .. (1)
where F1 is the scope criterion.

F2= [Number of failed tests/ Total number of tests] ×100 .. (2)

where F2 is the frequency measure, which means that the percentage of exams are not passing objective criteria after several exams.

F3 is the amplitude of measurement, which is calculated based on the following three steps:

Step 1: Excursion Calculation

The excursion is the number of times an individual's focus reaches (or falls below, depending on the situation). The target is a minimum then the goal. Where the test value must not be greater than the goal:

Excursion= [Failed test value i / objective j]-1 (3)

When the measured value must not be less than the goal:

Excursion= [objective j / Failed test value i]-1 (4)

Step 2: Calculation of the Normalized Total of Excursions

The normalized sum of excursions, Nse, is the cu-

Table 2. The standard values of water quality parameters

Parameter		Standard value	References
Symbol	Meaning		
EC (ds/m)	Electric Conductivity	Upper Limit (4)	Fipps (2003)
pH	Power of Hydrogen	6.5-8.4	Akter *et al*. (2019)
TDS	Total dissolve solid	2000–3000	Ewaid *et al*. (2020)

Table 3. The categories of water quality index (WQI)

No.	Suitability	Description	WQI	Reference
1	Excellent	The situation is very similar to natural, and there isn't any sign of pollution in the water.	100-95	
2	GOOD	The water is well protected and managed	94-80	
3	FAIR	Water is welfare preserved, although it is occasionally endangered	79-65	Marine (1999)
4	MARGINAL	Water quality has reached its max allowable. Frequently threatened or poor, values sometimes decline below normal or required standards.	64-45	
5	POOR	This range represents the level of water quality threatened or poor; usually, conditions fall outside normal or preferred levels.	44-0	

mulative amount of excursions. Nse is computed according to the following equation

$$Nse = \left(\sum_{i=1}^{n} excursion \right) / \text{Number of tests}$$

(5)

Step 3: Calculation of F3

F3 is determined based on the following equation:

F3=Nse/ (0.01 Nse + 0.01) .. (6)

Then WQI is calculated as:

$$WQI = 100 - \left(\sqrt{F_1^2 + F_2^2 + F_3^2} / 1.732 \right) \quad .. (7)$$

Table 3 shows the values of WQI after it was classified into five categories.

Results and Discussion

Three important parameters have been selected in this study to evaluate the quality of water in the Al Hammar marsh. These parameters are Total Dissolved Solids (TDS), Electrical Conductivity (EC), and Power of Hydrogen (pH). The main reason for choosing TDS as an indicator in the water quality index is that it represents three different forms of existing solids in water, and these are suspended, volatile and dissolved solids that may contain organic and inorganic matters (Ali *et al*., 2018; Rabee *et al*., 2011). As shown in Table 1, the values of TDS at various locations of Al Hammar marsh were varied from less than 3000 ppm to more than 27000 ppm. The highest values were recorded at station 5 (Fig. 2). Still, after September 2019, the values were significantly decreased due to the construction of 87 pipe culverts that were hydraulically connected the Al Hammar marsh with MOD. The values of TDS obtained from field and laboratory works are compared with the Iraqi standard (IWQS no.417) and World Health Organization for drinking, irrigation and aquatic life. The values were found out of range. Figures 6, 7 and 8 show the monthly variation of TDS, EC and pH at all the stations, respectively.

The Electric Conductivity (EC) is considered an important parameter since it directly correlates with other parameters such as temperature, pH, and total dissolved solids, as well as it is affected by the type of soil on which the flow of water passes. In this study and based on the location, the EC values had been ranged between 4000 to 43000 µS/cm. The highest values of EC and TDS were found at the same locations (station number 5). After the standard values of aquatic life were checked with specifications, it is found that the critical EC value of 5000 µS/cm was found in many locations. Generally, the critical value of EC is exceeded if the water in the marsh is intended to be used for drinking and irrigation, while in many locations, it complies with the limits of EC recommended for aquatic life.

The power of Hydrogen (pH) is another important parameter that influences the suitability of water for different purposes. The pH value for aquatic life is suggested as an indicator for assessing the

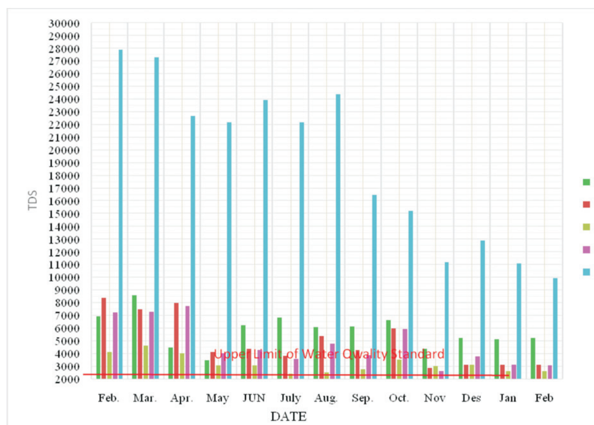

Fig. 6. Monthly variation of TDS in Al Hammar marsh

Table 3. The categories of water quality index (WQI)

No.	Suitability	Description	WQI	Reference
1	Excellent	The situation is very similar to natural, and there isn't any sign of pollution in the water.	100-95	
2	GOOD	The water is well protected and managed	94-80	
3	FAIR	Water is welfare preserved, although it is occasionally endangered	79-65	Marine (1999)
4	MARGINAL	Water quality has reached its max allowable. Frequently threatened or poor, values sometimes decline below normal or required standards.	64-45	
5	**POOR**	This range represents the level of water quality threatened or poor; usually, conditions fall outside normal or preferred levels.	44-0	

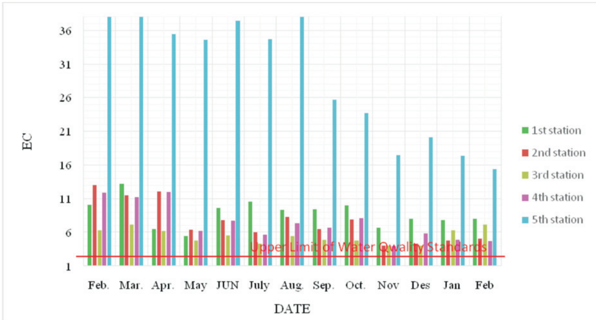

Fig. 7. Monthly variation of EC in Al Hammar marsh

pollution of the Al Hammar marsh (Rabee *et al*., 2011). The significance of pH as an indicator is due to the-direct correlation with the concentration of carbon. For example, higher pH values indicate changes in the physical-chemical state and decreases in the rate of photosynthesis activity throughout the absorption of carbon dioxide and bicarbonate (Bhateria and John, 2016). In this study, the pH values ranged between 7 and 8.6. The values are acceptable when compared with the Iraqi and WHO standards for aquatic life (Table 1). However, the high pH values in the Al Hammar marsh can be attributed to the fact that the main outfall drain is discharging into the Al Hammar marsh in addition to other discharging sources such as low-quality irrigation returns and sewage outfalls that are polluting the marsh.

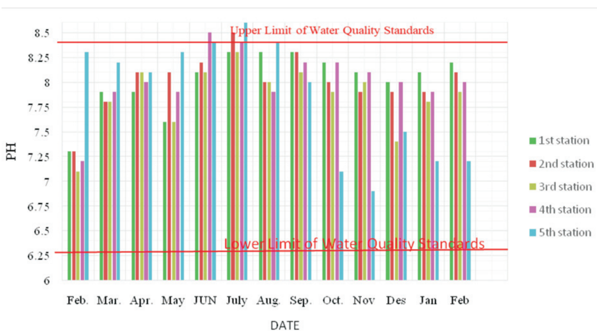

Fig. 8. Monthly variation of PH in Al Hammar marsh

In spite of all these polluting sources, the observation showed that the biodiversity (plants, fish, and birds) still exists in the Al Hammar Marsh, as shown in Figure 9.

Fig. 9. Observation of biodiversity in the Al Hammar marsh

WQI is one of the most useful tools for covering vast data of physical-chemical parameters and turning the complex characteristics of water into an easy and clear method (Al-Saffawi and Al-Sadar, 2018). The main benefit of WQI is giving an entire image of the overall quality of the water [Al-Rabee *et al*., 2011; Bhateria and John, 2016; Al-Saffawi and Al-Sadar, 2018; Etim *et al*., 2013).

By following the procedure of the Canadian method for determining WQI, values of F1, F2 and

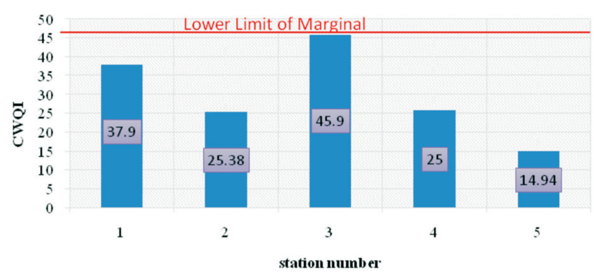

Fig. 10. Values of WQI for Al Hammar marsh

Table 4. Values of F1, F2, F3, and WQI at the locations of the five measuring stations

Station	Number of the failed variable	Total Number of variable	F1	Number of failed tests	Total Number of tests	F2	Nse	F3	WQI
Al Khamissiya	2	3	67	26	39	67	1.033	50.82	37.9
Security Barrage	3	3	100	27	39	69	0.77	44	25.38
Um Alwada	2	3	67	24	39	61.5	0.282	22	45.9
Near railway (Al-Hor)	3	3	100	27	39	69	0.733	42.3	25.7
Outlet sulain embankment	3	3	100	27	39	69	4.97	83.3	14.94

F3 were calculated using the data collected from five stations within the Al Hammar marsh. Equations (1) to (7) were applied, and the results are shown in Table 4 and Figure 10. In addition, the classification of water quality of Al Hammar marsh is based on the Canadian method for WQI assessment (Table 5). Based on the values of WQI of Al Hammar marsh categorized in Table 3, the Al Hammar marsh is under threat. The classification of water quality of Al Hammar marsh in all locations (at the five stations) falls into the fifth category (poor), except station number 3 (Umm Al-Wada) falls at the upper limit of the fourth category (MARGINAL)

Table 5. The classification of WQI at the measuring stations

Station	WQI	STATUS
1	37.9	POOR
2	25.38	POOR
3	45.9	MARGINAL
4	25.7	POOR
5	14.94	POOR

Conclusion

The water quality of the Al Hammar marsh has been studied based on local standards and the arithmetic method of the Canadian Water Quality Index. Different data sets from 5 measuring stations within Al Hammar marsh, have been used to assess the marsh water quality. In this study, three water quality parameters have been selected, and these are TDS, EC, and pH. According to Iraqi and World Health Organization Standards, results show that the water quality of the Al Hammar marsh is not suitable for drinking, irrigation, and for aquatic life. The highest concentration of TDS (more than 27000 mg/l) was clearly observed at station 5 (Sulain dyke), and this value was declined to more than 9000 mg/l after the construction of the CRMW outlet that is discharging the water from the Al Hammar marsh to the Main Outfall Drain (MOD). However, the value of TDS after the flow improvement is still high. The improvement in WQI of the Al Hammar marsh can be attributed to the reduction of low quality flow from MOD and increase the good quality flow from the Euphrates River, particularly near the location of station 5.

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Conflict of Interest

The authors confirm that there is no conflict of interest from publishing the present research work

References

Al-Ansari, N., Ali, A. and Knutsson, S. 2014. Present conditions and future challenges of water resources problems in Iraq. *Journal of Water Resource and Protection.* 6(12) : 1066-1098.

Al-Ansari, N., Knutsson, S. and Ali, A. 2012. Restoring the garden of Eden, Iraq. *J. Earth Sci. Geotech. Eng.* 2(1): 53–88.

Akter, T., Islam, M.K, Islam, M.S. and Monirul, M. 2019. Irrigation water quality assessment of Betagi Upazila under Barguna district in Bangladesh. *Arch. Agric. Environ. Sci.* 4(4) : 428–433.

Ali, H.L., Mohammed,T.A., Yusuf, B.B. and Aziz, A.A. 2018. A simplification of the Einstein equation for the calculation of suspended sediment transport in rivers. *International Journal of Hydrology Science and Technology*. 8(4) : 393-409.

AL-Shammary, A.C., AL-Ali, M.F. and Yonuis, K.H. 2015. Assessment of Al-Hammar marsh water by uses Canadian water quality index (WQI). *Mesop. Environ. J.* 1(2): 26–34.

Al-Saffawi, A.Y. and Al-Sardar N.M. 2018. Assessment of groundwater quality status by using water quality index in Abu-Jarboaa and Al-Darrawesh villages, Basiqa subdistrict, Iraq. *In Sci. Tech. and Engineering*. 7(6): 6-12.

Bhateria, R. and Jain, D. 2016. Water quality assessment of lake water: a review. *Sustain Water Resour Manag.* 2(2): 161–173.

Chougule, M.B., Wasif, A.I. and Naik,V.R. 2009. Assessment of water quality index (WQI) for monitoring pollution of River Panchganga at Ichalkaranji. *Proceedings of International Conference on Energy and Environment.* Chandigarh, pp. 122–127.

Council of Ministers. 2009. Iraqi standard of drinking water No. 417: second modification. Central Organization for Quality Control and Standardization. Baghdad, Iraq.

CRIMW. 2010. Possibility of using the water of the Main Outfall Drain, MOD to restore Al Hammar marsh after operating the pumping station in Al Nassiriyah. Ministry of Water Resources. Baghdad, Iraq.

De Rosemond, S., Duro, D.C. and Dubé, M. 2009. Comparative analysis of regional water quality in Canada using the Water Quality Index. *Environ. Monit. Assess.* 156(1) : 223–240.

Ewaid, S.H., Abed, S.A., Al-Ansari, N. and Salih, R.M. 2020. Development and Evaluation of a Water Quality Index for the Iraqi Rivers. *Hydrology.* 7(67) : 1-14.

Etim, E.E., Odoh, R., Itodo, A.U., Umoh, S.D. and Lawal, U. 2013. Water quality index for the assessment of water quality from different sources in the Niger Delta Region of Nigeria. *Frontiers in Science.* 3(3): 89-95.þ

Fathi, P., Ebrahimi, E., Mirghafarry, M. and Esmaeili, O.A. 2016. Water quality assessment in Choghakhor Wetland using water quality index (WQI). *Iranian Journal of Fisheries Sciences.* 15(1): 508- 523.

Fipps, G. 2003. *Irrigation water quality standards and salinity management strategies.* Texas, USA.

Hashim, A., Hussain, A.J., Hayder, D., Hussain M.H. and Nadhir, A. 2020. Evaluation of water quality parameters in marshes zone Southern of Iraq based on remote sensing and GIS techniques. *Water Air Soil Pollut.* 231(183) : 1-11.

Haslam, S.M. 2003. *Understanding Wetlands: Fen, Bog and Marsh.* CRC Press, London.

Marine, N.R. G. 1999. Canadian water quality guidelines for the protection of aquatic life. Can. Counc. Minist. Environ. Winnipeg, Canada.

Nawar, O., Sura, K., and Fatima, M. 2018. Evaluating water quality index of Al Hammar marsh, South of Iraq with the application of GIS technique. *Journal of Engineering Science and Technology.* 13(12): 4118–4130.

Panda, R.B., Sahu, B.K., Garnaik, B.K., Sinha, B.K. and Nayak A. 1991. Investigation of water quality of Brahmani River. Indian. *J. Environ. Health.* 33(1) : 45–50.

Rabee, A.M., Abdul-Kareem, B.M. and Al-Dhamin, A.S. 2011. Seasonal variations of some ecological parameters in Tigris river water at Baghdad Region, Iraq. *J. Water Resources and Protection.* 3 : 262-267.

U.S. Department of Interior. 2021. Wetlands, Marshes and Swamps. National Park Service. Michigan, USA.

WHO. 2011. *Guidelines for Drinking-Water Quality*:4th Edtion. Volume 38. Geneva, Switzerland. Pages 104–108.

Yisa, J. and Jimoh, T. 2010. Analytical studies on water quality index of river Landzu. *Am. J. Appl. Sci*. 7(4): 453-458.