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EVALUATING WATER QUALITY INDEX OF AL HAMMAR MARSH, SOUTH OF IRAQ WITH THE APPLICATION OF GIS TECHNIQUE

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Abstract

This study concerns the water quality index of the Al Hammar marsh. The water quality of station M1, also termed Al-Hamedy, located in the middle of the marsh and related to the Al-Basra governorate, was evaluated from 2011 to 2015, using 12 selected parameters. The parameters include pH, Phosphate (PO4), Nitrate (NO3), Magnesium (Mg), Calcium (Ca), Total hardness (TH), Sodium (Na), Sulphate (SO4), Chloride (Cl), Total dissolved solids (TDS), Alkalinity (Alk.) and Electrical conductivity (EC). The Arithmetic Weighted Index was employed to ascertain the water quality index (WQI) in the Al-Hammar marsh. The findings from this research have been linked to the ArcGIS 10.4.1 software, to produce layers that represent the nature of the spatial distribution of the WQIs, as coloured maps. The results revealed that the marsh quality fell below the class of poor water quality, and the marsh water was brackish due to the high concentration of totally dissolved solids flowing in from the estuaries of the feeding channels coming from the river Euphrates, as well as from the tidal phenomenon via river Shatt Al-Arab.

Keywords: Al-Hammar marsh, Geographical information system (GIS), Water quality index (WQI), Wetlands.

1. Introduction

Ranked high among the most productive ecosystems on Earth, wetlands provide several significant services to mankind [1]. Besides their historical and cultural value, the marshlands are also characterised by supporting unique floating buildings, and their traditional lifestyles. The most vital economic activities include agriculture, fishing and hunting, although more recently, oil exploration has been initiated around the marshes. The Al Hammar marsh is one among the three marshes that constitute the formerly extensive and biodiverse Mesopotamian marshlands of southern Iraq, which have now been selected as Ramras sites and are under international conservation management. The marshes offer important regulatory services, like water storage, purification, flood control, and climate regulation, besides being the habitat for the reed warbler of Basra and the marbled duck, which are globally endangered species [2].

Al-Shammary et al. [3], after assessing the restoration, investigated the water quality in the east Hammar marsh using CCME WQI, at two stations situated in the Al Hammar marsh from Sep. 2003 to Sep. 2009. The index calculations involved 12 selected environmental factors, which include oxygen demand, BOD_5, NO_2, NO_3, PO_4, TDS, TSS, salinity, turbidity, pH, water temperature and transparency. Between 2003 and 2004, the general historian was less than the marginal assessment of the first station, while the second station was fair. In this study, the water quality index was below the level of fair assessment in the two stations, respectively.

Al-Saboonchi et al. [4] applied the Canadian Water Quality Index (CCME WQI) to assess the water quality of the Al-Hammar marsh in three sampling stations in the East Hammar marsh from November 2012 to October 2013. Water Temperature, Salinity Transparency, pH, Dissolved Oxygen, reactive Nitrate and Phosphate were the variables selected to calculate the index. The results revealed that the WQI was in the range of 28.2 to 49.6 and 40.7 to 62.7, depending respectively on the historical studies prior and post drainage, and classified as poor to marginal. The study revealed that the water quality in the east of the Al Hammar marsh had improved after three years of restoration.

Al-Saboonchi et al. [5] performed their study adopting the Canadian Water Quality Index (CCME) in their assessment of the east Hammar marsh water quality. The model was applied from two approaches based on the old data and CCME guidelines for aquatic life as its objective. The variables included in the research calculations included, dissolved oxygen, water temperature, pH, salinity, total nitrogen, nitrate, ammonia, sodium and phosphorus. For both approaches, the analysis revealed that the east Hammar marsh water quality was in the poor category, based on the data drawn from 2005 to 2006, which implies that the marsh conditions normally departed from the desirable or natural levels, mostly with respect to the nitrogenous and sodium compounds, implying that the marsh had not as yet recovered.

Al-Saad et al. [6] conducted a water quality survey on the southern Iraqi marshes from Nov. 2005 to Sep. 2006 at six sites, four of which, were in Al-Nagara, Al-Baghdadia 1 and 2, and Al Barga, while the two other locations were in the Al-Hwaaiza marsh (Um Al-Neiach and Um Al-Warid). The sampling sites were selected so that they covered the contaminant distribution in these marshes. The analysis included the Biological Oxygen Demand, Dissolved Oxygen, Turbidity, Total Hardness, Total Dissolved Solids, Total Suspended Solids, Electrical Conductivity (EC), pH, Temperature, Salinity and Nutrients NO2. The seasonal variations of these parameters were monitored throughout this study. The results revealed some degree of fluctuation during the different seasons at different sites in the marshes. This survey provided the data and baseline for restoration works in the future and also offered reasonable evidence for successful restoration.

Al-Mosewi [7] in their study on the Al Hammar marsh water quality in different locations investigated the diversity of certain water parameters. Ten water samples were analysed, and their results were discussed to clarify the reasons for the changes observed in these parameters in the sites along the marsh. The results demonstrated that the concentrations of Dissolved Oxygen and Biochemical Oxygen Demand for the use of agriculture and drinking fell within the acceptable range. The Dissolved Oxygen concentration did not drop below 6 ppm. Also, from the analysis it was evident that the Electrical Conductivity (EC) and Total Dissolved Solids (TDS) had high concentrations both at the beginning and end of the marshes, whereas these parameters were low in the middle of the marsh. Also, the total suspended solids (TSS) were low in concentration along the marsh, and principally dependent upon the water velocity in the marsh. When the velocity in this region was low and the sulphate concentration crossed the limits stipulated for drinking water by WHO (400 mg/L), this concentration was attributed to the organic matter burning in the soil after drainage. Recently, GIS has been used based on data drawn from the water quality index method to produce coloured maps of the water quality being investigated, in several countries including Iraq [3] and [8-13].

This study was done to evaluate the Al Hammar marsh water quality using the weighted arithmetic water quality index method based on the European standards EEC 440 for the surface water quality; besides, coloured maps were created for the marsh using ArcGIS 10.4.1 depending upon the findings obtained.

2. Area of Study

The Al Hammar marsh includes the large wetlands of Iraq, which are part of the system of the Tigris and Euphrates. Formerly, the permanent wetlands occupied by the Al Hammar marsh area was calculated to be approximately 2,800 km^2 and extending to above 4,500 km^2 [5]. Situated to the right of the river Euphrates between 634,272 to 3,413,985 m East and from 758,945 to 3,383,833 m North in zone 38 N, as seen from Fig. 1. [14], the marsh extends from the city of Nasiriyah in the West to the suburbs of Al Basra on the river Shatt Al-Arab in the East. The marshes are about 120 km long and around 25 km wide, having a maximum depth of 1.8 to 3 m [15].

The Al Hammar marsh can be distinguished into two regions; the first one is in the city of AL-Nasiriyah, receiving its waters from many rivers, while the second part lies within the Al-Basra city and is fed by the tidal phenomenon across the river Shatt Al-Arab. The eastern and western regions of the marsh are detached by the Al Hammar Dike. Future plans are in place to construct the Al Hammar Barrage and thus, connect both parts of the Al Hammar marsh. Several natural and artificial features abound in the marsh, including islands, waterways, railways, and several dykes, which surround the marsh, as well as extend within it and Fig. 2 shows these obstructions. According to Abdul-Raheem [16], the feeding and outlet river system are somewhat complex, as most of these rivers function as feeders at times and as outlets at other times depending upon the water level present in the marsh and in these rivers.

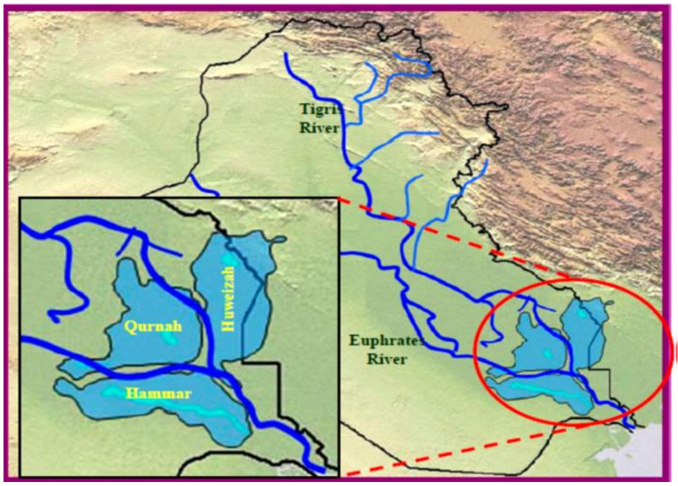


Fig. 1. The location of marshes south of Iraq [14].

Fig. 2. Al Hammar marsh [15].

3. Methodology and Calculations

The data used in this research for the 2011-2015 time period were recorded at the M1 station, located in the middle of the Al Hammar marsh, known as Al-Hamady, (with the coordinates 46° 40'14.9" E and 30° 49' 39.5" N), and as part of the Al-Basra governorate. The data for the 2011-2012 period was collected from the Marsh Restoration Centre/Ministry of Water Resources, while the data for the 2013-2015 period were collected from the Ministry of Health and Environment. In order to calculate the water quality index, 12 parameters were selected, based on the data available at the M1 station. These parameters include the pH value, Orthophosphate (PO_4), Nitrate (NO_3), Calcium (Ca), Sodium (Na), Magnesium (Mg), Total Hardness TH), Sulphate (SO_4), Chloride (Cl), Total Dissolved Solids (TDS), Alkalinity (Alk.) and Electrical Conductivity (EC.). Using the arithmetic weighted formula, the WQI was calculated [17], while Eq. (1) was employed to calculate the quality rating scale for each parameter (q_i):

$$q_i = \left(\frac{c_i}{s_i}\right) * 100 \tag{1}$$

where q_i is the rating scale of quality, and c_i is the estimated concentration of i^{th} parameter, and S_i is the standard value of i^{th} parameter

A quality rating scale q_i was computed for each parameter by dividing its observed concentration value in each water sample by its standard value S_i and multiplying the result by 100. Eq. (2) was used to find the relative weight w_i for the corresponding parameter as a value inversely proportional to the standard value S_i:

$$W_i = \frac{1}{S_i} \tag{2}$$

Then, using Eq. (3) the Water Quality Index (WQI) was calculated by aggregating the quality rating scale q_i with the unit weight w_i:

$$\mathrm{WQI} = \sum w_i * q_i \tag{3}$$

where *qi* is the quality of the *ith* parameter, and *wi* is the unit weight of the *ith* parameter, and *n* is number of the parameters considered.

Generally, the WQI is discussed for any specific and intended use of water. Finally, using Eq. (4) the overall WQI was calculated:

$$WQI = \frac{\sum q_i * w_i}{\sum w_i} \tag{4}$$

Table 1 was used to classify the WQI of the Al Hammar marsh, where the water was classified under six classes, ranging from excellent water quality to highly polluted water. The recommended standard value of S_i is the European Standard EEC, No. 440, for surface water quality.

Table 1. Water quality classification based on WQI value [13].

WQI value	Water quality
<50	Excellent
50 - 100	Good
100 - 200	Poor
200 - 300	Very poor
300 - 400	Polluted
> 400	Very polluted

4. Results and Dissection

In Iraq, as water quality standards for the surface water in the marshes are not available, the development of a water quality index for various types of usage for the marshland water is important for the assessment of environmental effects.

4.1. Water quality index

In this research, the Al Hammar marsh water quality index (WQI) has been calculated using the weighted arithmetic index method with the 12 selected parameters, adopting the European standards for surface water quality. In Table 2, the procedure followed to calculate the water quality index, as well as the overall water quality index based on Eqs. (2) to (4) is clearly shown.

Table 3 presents the classification of the overall WQI of the Al Hammar marsh calculated for the 2011-2015 period. From the results shown in Table 3, the Al Hammar marsh water is evidently generally poor in quality.

Figure 3 reveals the water quality variations occurring in the Al Hammar marsh during the study period, based upon the results of Table 3.

Table 2. Water quality calculation for Al Hammar marsh during 2011.

Parameters	*Ci*	*Si*	*Wi*	*qi*	*Wi*qi*
pH	7.36	7.5	0.13333	98.13333	13.08444
PO_4	0.52	0.7	1.42857	74.28571	106.1224
NO_3	8.66	50	0.02	17.32	0.3464
Ca	1067.55	150	0.00667	711.7	4.744667
Mg	454.77	100	0.01	454.77	4.5477
TH	1950	500	0.002	390	0.78
Na	1352.75	40	0.025	3381.875	84.54688
SO_4	1831.22	250	0.004	732.488	2.929952
Cl	2204.11	200	0.005	1102.055	5.510275
TDS	6569.33	1000	0.001	656.933	0.656933
EC	7033.6	1000	0.001	703.36	0.70336
Alk.	231.87	500	0.002	46.374	0.092748
Sum			1.63857		224.0658
Overall WQI					136.7446

Table 3. WQI classification for Al Hammar marsh from 2011 to 2015.

Year	Overall WQI	Class
2011	136.745	Poor
2012	130.317	Poor
2013	114.911	Poor
2014	140.122	Poor
2015	105.451	Poor

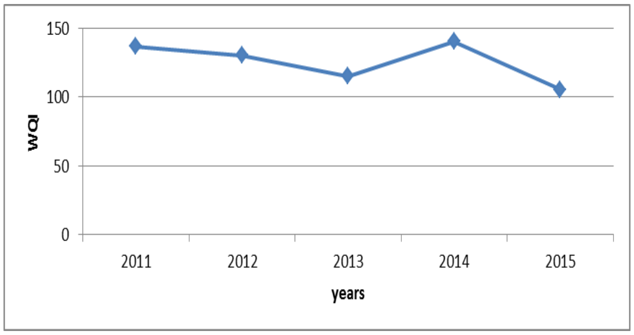
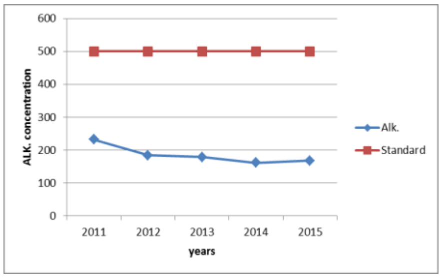


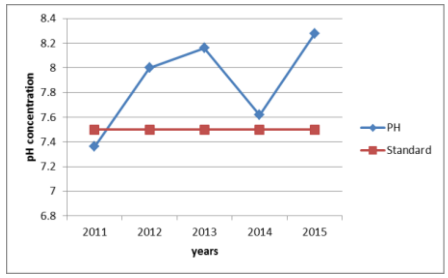
Fig. 3. WQI variation with time (2011-2015).

The pollution parameters under investigation was analysed in order to identify the one responsible for the deterioration of the water quality of Al Hammar marsh. Figure 4 shows the variations of the different water parameters measured. Alkalinity measurements fell within the permissible levels of the European standard for surface water and the pH value demonstrated that the water was within the basic values, depending upon the type of the dissolved salts. Figures 4(c) and (d) indicated that the phosphate (PO_4) and Nitrate (NO_3) concentrations were low because these nutrients are readily consumed by the aquatic plants growing in the marsh.

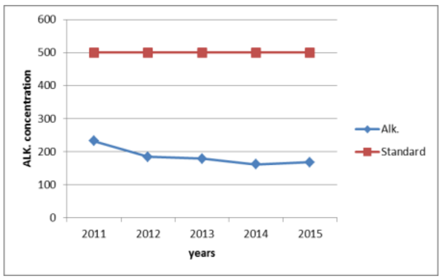
Other parameters listed in Figure 4 indicate the high ionic concentrations of Ca, Mg, Na, SO_4, and Cl, which are related to salinity pollution. Rivers flowing through limestone and gypsum soils may contain Ca and Mg levels in the 30-100 mg/L range, which contribute to raising the degree of water hardness. Chloride and sodium affect agriculture, as well as add a salty taste to the water. In the surface water, the sulphate may be found in concentrations in the range of a few milligrams to above several thousand. The presence of sulphate (SO_4) also influences the water taste. The high WQI value obtained is due to the high degrees of total hardness (TH), electrical conductivity (EC), and the total dissolved solids (TDS) in the marsh, as shown in Figs. 4(g), (k) and (l) respectively. This can be imputed to the various human activities that occur in the marsh, and the hardness is closely related to the nature of the marsh soil. Obviously, the high levels of these parameters in the marsh may have come in from the feeders to the marsh that receives its water from the river Euphrates; the tidal phenomenon via the Shatt Al-Arab may also be another source for the high concentrations of these parameters. As explained by AL-Shammary et al. [3] and Al-Saboonchi et al. [5], the findings from this study correspond to the results of the earlier studies.



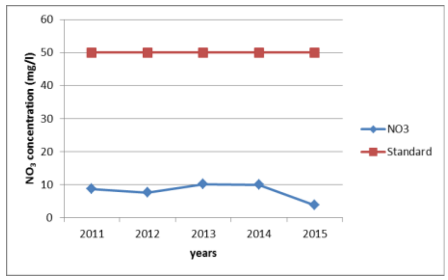
(a) Alk. concentration.



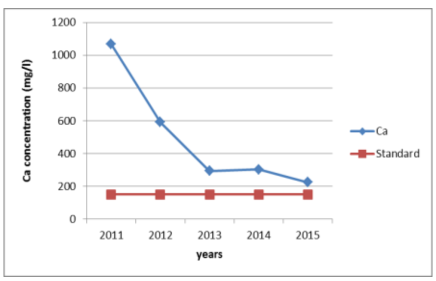
(b) pH value.



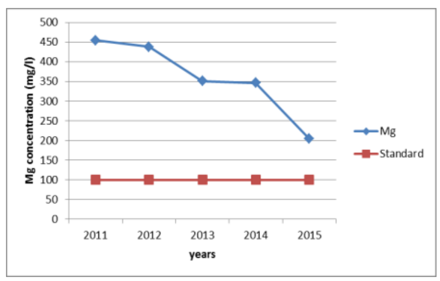
(c) PO_4 concentration.



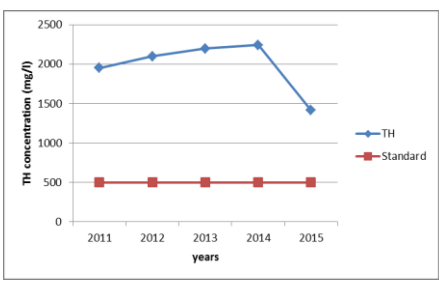
(d) NO_3 concentration.



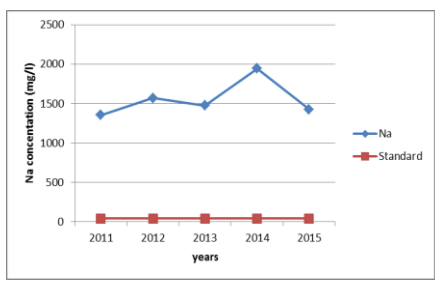
(e) Ca concentration.



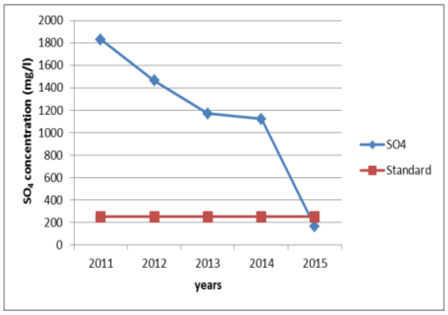
(f) Mg concentration.



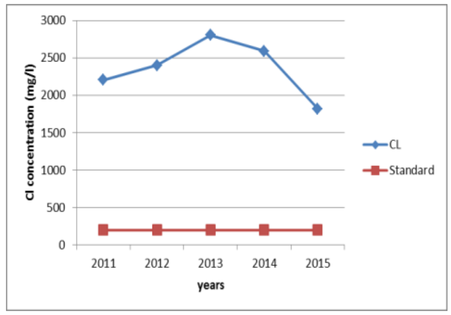
(g) TH concentration.



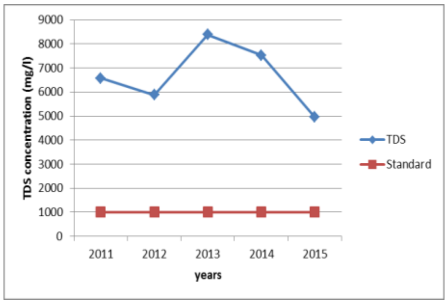
(h) Na concentration.



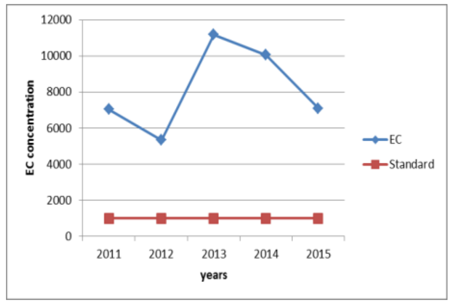
(i) SO_4 concentration.



(j) Cl concentration.



(k) TDS concentration.



(l) EC concentration.

Fig. 4. Variation of water parameters concentration with time (2011-2015).

4.2. Using GIS software

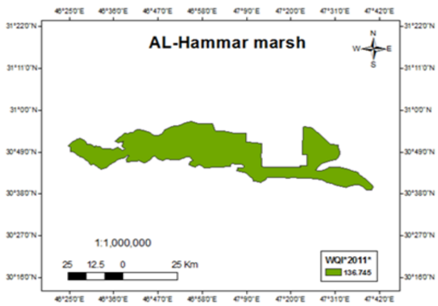
The results of this study have been linked with the ArcGIS 10.4.1 software to produce layers, which represent the nature of the spatial distribution of the WQIs as coloured maps to reveal the degrees of pollution of the Al Hammar marsh during the years of the study. Table 4 shows the colour indicator used in the GIS maps based on the WQI classification in Table 1.

Figure 5 reveals the coloured maps drawn by the GIS technique for the 2011 to 2015 time period. The Al Hammar marsh water quality index for all the years hovered between 100 and 200, as evident from Table 3; therefore, all the maps are appearing green in colour, but in varying degrees of intensity, where an increase in the colour intensity implies an increase in the WQI value.

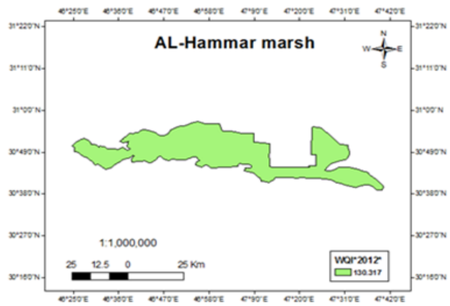
In this study, the use of GIS techniques facilitated connecting the collected data in such a manner that the data were organised in a scientific method. This enabled it to be spatially presented (in its true geographical location), accompanied by its related analysis, calculation, graphs and results, so that it became amenable to editing and easy for updating and reanalysis.

Table 4 Color indicator for the WQI in the GIS maps [13]

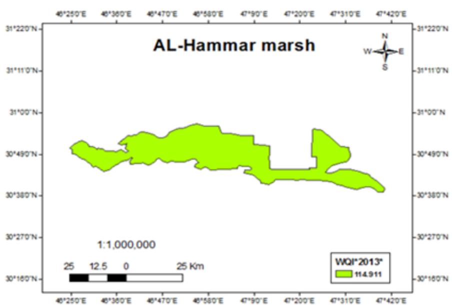
WQI value	Colour indicator
0 < WQI < 100	blue
100 < WQI < 200	green
200 < WQI < 300	yellow
300 < WQI < 400	orange
WQI > 400	red



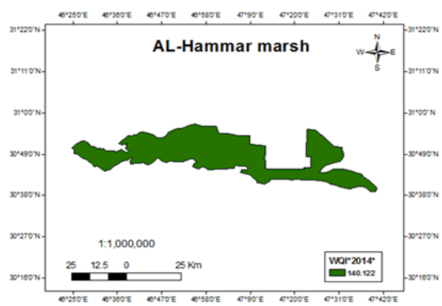
(a) WQI of Al Hammar marsh in 2011.



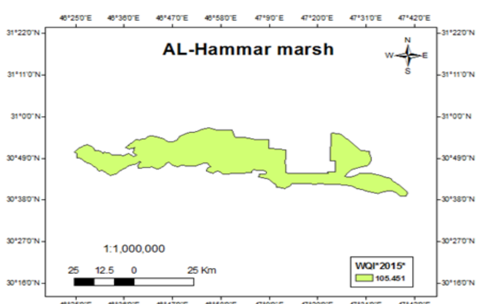
(b) WQI of Al Hammar marsh in 2012.



(c) WQI of Al Hammar marsh in 2013.



(d) WQI of Al Hammar marsh in 2014.



(e)WQI of Al Hammar marsh in 2015.

Fig. 5. Colored maps for Al Hammar marsh from (2011-2015).

5. Conclusions

- Based on the Water Quality Index, the Al Hammar marsh water is poor in quality; therefore, to improve it, more quantity of water must be supplied to the marsh.
- The PO_4 and NO_3 concentrations are low because these nutrients are readily consumed by the aquatic plants growing in the marsh.
- The high TDS levels (including the Ca, Mg, Na, SO_4, and C ions) may come in from the feeders, which receive their supply from the river Euphrates, as well as from the tidal phenomenon via the river Shatt Al-Arab.
- In this study, the use of GIS techniques enabled the collected data to be arranged in such a manner that the data were organised according to a scientific method, which made it easy to spatially present it (in its true geographical location).

Nomenclatures

Ca	Calcium
Cl	Chloride
Mg	Magnesium
Na	Sodium
NO_2	Nitrogen dioxide
NO_3	Nitrate
PO_4	Orthophosphate
SO_4	Sulphate

Abbreviations

Alk.	Alkalinity
BOD_5	Biological Oxygen Demand
CCME	Canadian Water Quality Index
EC	Electrical Conductivity
GIS	Geographical Information System
TDS	Total Dissolved Solid
TH	Total Hardness
TSS	Total Suspended Solids
WQI	Water Quality Index

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