Biological and Applied Environmental Research

Vol. 6(2): 192-203, 2022

https://doi.org/10.51304/baer.2022.6.2.192

ISSN: 2002-6153
Biol. Appl. Environ. Res.
www.baerj.com
editor@baerj.com

Evaluating the Water Quality of Al-Chibayish Marsh, Southern Iraq by Using the Canadian Index CCME-WQI

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Abstract: Al-Chibayish Marsh is one of the most important marshes located in southern Iraq. Many sewage plants discharging into the marsh and affect its water quality. The present study aims at evaluating the water suitability for drinking, irrigation and other domestic uses. Water samples were collected monthly from six stations in the marsh during August 2018 to July 2019. Twenty variables were monitored to apply the Canadian index, there are including water temperature, pH, turbidity, electrical conductivity, total suspended solids , total dissolved solids, dissolved Oxygen, biological oxygen demand, total hardness, Calcium, Magnesium, Nitrate, active Phosphate, Sulfate, Chloride, Sodium, Potassium, Sodium adsorption ratio, Boron and fecal coliform bacteria. The findings showed that the water of Al-Chibayish Marsh was marginal to poor for general uses, while it was poor for drinking or irrigation at all stations. The Iraqi Marshes Protection Law against pollution must be enforced to prevent the obvious deterioration of the marsh water to improve its quality.

Keywords: Iraqi marshes, Water assessment, Water quality, CCME-WQI

Introduction

Water quality assessment has become a central issue in many countries that have begun to take measures for water shortages. The population increase in recent decades and the development which may coincide in the future (economic and social aspects) has increased the demand for surface water sources to meet the various corresponding needs for this increase causing contamination of freshwater sources (Mohammed & Abdulrazzaq, 2018; Al-Sudani, 2021).

As a result of the improper and unsafe use of water resources, many countries are concerned about water resources. Therefore, water quality assessment has become a sensitive process, especially with the awareness that freshwater will be a limited resource in the future (Alazawii et al., 2018; Chabuk et al., 2020).

Traditional methods of estimating water quality were based on comparing the values of specific experimental variables with existing local standard values, and here it does not use water quality indices to give a global view of the spatial and temporal direction of total water quality (Nasirian, 2007; Al-Ani et al., 2019; Qzar et al., 2021).

Received May. 10, 2022, accepted May. 15, 2022

Any water quality index such as the Canadian index is a mathematical model that is efficient in determining water quality. It can summarize many water quality data and convert them into data that decision-makers and administrators can easily understand and interpret (CCME, 2001). The objective of the index is to transform complex water quality data into understandable and usable information by the public (Alazawii et al., 2018). The concept of the index is based on the comparison of a set of water quality variables with permitted limits according to standards and specifications that result in specific values of 0-100, which represents a certain level of water quality status (Rosemond et al., 2009; Shaawiat et al., 2019). The Canadian model tends to be the most accurate model to determine surface water quality for different water uses (Al-Hejuje, 2014; Hanna et al., 2019).

The aim of the present study is to assess water quality of Al-Chibayish Marsh through determining the concentration of certain physical, chemical and biological variables affecting water quality by applying the Canadian model CCME-WQI to predict its condition compared to global and Iraqi environmental scale and showing its suitability for different uses.

Materials and Methods

Study Area

Marshes constitute an important part of the wetland area of Southern Iraq and an important source of fisheries, reeds, agricultural and animal products. Al-Chibayish Marsh is one of these marshes located in the middle of the central marshes which exposed to the discharge of untreated domestic wastewater that contain considerable concentration of nutrients and toxic chemicals. Water samples were collected monthly from six stations in the Al-Chibayish Marsh during the period from August 2018 to July 2019 (Table 1).

Table 1: GPS coordinates of sampling sites.

Stations	GPS Coordinates	
St. 1	E: 46° 59’ 55.0’’	N: 30° 58’ 13.9’’
St. 2	E: 46° 59’ 48.2’’	N: 30° 58’ 35.8’’
St. 3	E: 46° 59’ 54.6’’	N: 30° 59’ 00.7’’
St. 4	E: 47° 00’ 05.6’’	N: 30° 58’ 36.1’’
St. 5	E: 47° 00’ 18.0’’	N: 30° 59’ 04.2’’
St. 6	E: 47° 00’ 24.0’’	N: 31° 00’ 13.4’’

Sample Analysis

Water temperature, pH and electrical conductivity (EC) were measured in situ by using Multimeter type Multi 350 i SET 5. Water turbidity was measured in the field by turbidity meter type TURB 355 IR WTW. Fecal coliform bacteria (FC) samples were collected in tightly stopper polyethylene sterilized containers (60 ml), preserved and stored in ice box according to APHA (2005), until further analysis using filtration method. Total suspended solid (TSS) and Total dissolved solid (TDS) were gravimetrically measured according to APHA (2005) at the laboratory.

Azid modification Winkler method according to Lind (1979) was followed to determine the level of dissolved oxygen (DO) and biological oxygen demand (BOD_5). Titrimetric method as described in Bartram & Ballance (1996) was applied to determine the sulfate ions (SO_4), while Total Hardness (TH), Calcium (Ca^{+2}) and Chloride (Cl^-) were determined according to APHA (2005). Magnesium (Mg) was calculated according to total hardness and Calcium hardness values.

Spectrophotometer (model v-1100d EMC.LAB/ Germany) was used to determine the Boron ions (B^{+3}) by using Curcumin method, while the colorimetric method was used to measure nitrite ion (NO_3^-) according to Ultra Violet Method (APHA, 2005). Reactive phosphates (PO_4) were determined according to the Ascorbic acid method (Strickland & Parsons, 1972).

Sodium (Na^+) and Potassium (K^+) were measured by Flame photometer instrument according to APHA (2005), while Sodium adsorption ratio (SAR) was calculated according to the equation:

$SAR=Na / \sqrt{[(Ca + Mg) /2]}$.

The water quality index for general use (GWQI) was calculated based on nine variables including DO, FC, pH, BOD_5, turbidity, TH, PO_4, EC and NO_3, whereas drinking water quality index (DWQI) was calculated according to 13 variables including DO, FC, pH, BOD_5, SO_4, turbidity, TH, Cl, EC, NO_3, Mg, Na and Ca. For Irrigation water quality index (IWQI), ten variables (B, EC, Cl, SO_4, pH, Na, K, SAR, TSS and TDS) were used to calculate the water suitability for irrigation.

The Canadian water quality guide (Canadian Council of Ministers of Environment) and the Iraqi standard limits has been implemented as CCME (2001) index:

F1= [Number of failed variables/ Total number of variables] * 100

F2= (Number of failed tests/ Total number of tests) * 100

F3= nse/ (0.01 * nse + 0.01)

The normalized sum of excursion (nse) was calculated as follows:

nse =Σ excursion/ total number of tests.

Calculation of deviation (excursion): The number of times that the value of the test is exceeded represents higher than the value of the standard set, calculated according to the following equation:

The excursion= (failed test value/ objective)-1, or the value of the test is less than the value of the standard set, depending on the following equation:

The excursion= (objective/ failed test value)-1

$WQI_{CCME}= 100- (\sqrt{(F1^2+F2^2 +F3^2)}/ 1.732)$

Then, the value was compared with the WQI designation (Table 2).

Table 2: WQI Designations (CCME, 2001).

Designation	Index value	Description
Excellent	95-100	The water is well protected and free from pollution as it approaches the ideal water.
Good	80-94	Water is less protected and rarely strays from ideal specifications.
Fair	65-79	Water is often protected but sometimes contaminated and sometimes far from ideal.
Marginal	45-64	Water is frequently contaminated and is often far from ideal.
Poor	0-44	Water is always polluted and far from ideal at all times.

Statistical Analysis

Analysis of variance (ANOVA test -one way) used by applying the statistical analysis program Minitab (version 16.1) to mention the temporal and spatial variations in the values of variables below the moral level ($p<0.05$) and the correlation coefficient (r) was calculated between the different variables depending on the Pearson's correlation coefficient. Principal component analysis (PCA) was performed by using XLSTAT 2015 program to identify the most important physical, chemical and biological water quality variables and its impact on water quality index values.

Results and Discussion

The obtained results showed increasing some water variables (Table 3) compared to the permissible values mentioned by Ayers & Westcot (1985), US-EPA (2012) and WHO (2018) for irrigation purposes, general used and drinking water supply (Table 4).

General Water Quality Index (GWQI)

The results gave a clear indication of the nature of temporal and spatial variability in the water quality of the Chibayish Marsh, as the water of the studied area was classified into two categories: poor or marginal (Table 5). Autumn was the most degrading season in water quality for all stations, as water classified as category 5 (poor) due to the decrease in water discharge from the Euphrates River and the increased concentration of untreated sewage pollutants discharged to the marsh, which increased salinity, electrical conductivity, fecal coliform and phosphates, as well as a decrease in the values of dissolved oxygen due to increased concentration of organic pollutants (Al-Asadi & Al-Hejuje, 2019). Effective nitrates and pH values remained within the limits of permitted values, whereas relative improvement in the values of other variables (turbidity, dissolved oxygen, phosphates, total hardness and fecal coliform) make most stations to be classified in the fourth category (marginal). This may be due to increase discharging rates of water from the Euphrates River to these stations. This finding is in agreement with Al-Musawi et al. (2018), while, the first and fourth stations have no improvement and stilled classified in the fifth category (poor).

As for the spatial differences, the first and fourth stations have a significant decrease in the values of the index in all seasons. This may be due to the fact that these two stations are receiving untreated sewage owing to their location near sewage treatment stations as well as a considerable input of pollutants from domestic and agricultural sources. The sixth station exhibited the highest values of the index because it is located far from sources of pollution.

The results of PCA analysis showed that magnesium, nitrate, sodium, calcium, sulfates, pH and conductivity are the most influential on the value of the index, followed by dissolved oxygen, total hardness, BOD_5, chloride and fecal coliform bacteria (Figure 1).

Drinking-Water Quality Index (DWQI)

Low values of DWQI during the present study classified central marshes water in the fifth category (poor) in all stations and seasons (Table 5). The sharp decrease in the values of the index indicates significant deterioration in the quality due to the impact of sewage plant water that discharged into the marshes in large quantities without treatment. The lowest values of the guide were recorded during the fall in all stations due to high values of some variables (TH, FC, turbidity, chloride, sodium, calcium, sulfates and electrical conductivity) from its standard specifications, excluding pH and nitrates that remained within the permissible limits, which may be due to lower water quantities input to the marshes and increased evaporation rates due to high temperatures and increased concentrations of pollutants without treatment, resulting in increased values of most of the permitted variables. The on-site changes recorded the first and fourth stations with the lowest water quality index values for drinking. This is due to the number of pollutants reaching these stations from untreated sewage stations that increase the concentration of many of the measured variables. The results of PCA showed that magnesium, nitrate, sodium, calcium, sulfates, pH and EC are the most influential factors on the index value (Figure 2).

Table 3: Variables ranges at the studied stations during the studied period.

Variables	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Water Temperature °C	10-28	11-30	11-31	12-31	13-33	14-32
pH	7.45-8.55	7.7- 8.25	7.32-8.05	7.43-8.16	7.33-8.05	7.4-8.0
Turbidity NTU	4.16-26.9	15.1-51.5	2.40-88.85	6.78-63.4	1.7-107.9	1.61-12.25
Conductivity mS/cm	3.60-5.42	2.5-4.71	2.76-4.49	2.56-4.53	2.74-4.48	2.91-6.0
TSS mg/l	10.7-46.8	16.9-83.9	5.6-130.1	8.6-63.2	5.3-107.7	6.1-18.3
TDS mg/l	2346-4036	1917-3128	2069-3383	2087-3132	2120-3238	2237-3224
DO mg/l	0.6-5.5	3.9-8.4	2.2-6.7	2.1-7.9	1.8-7.45	2.75-5.65
BOD_5 mg/l	0.6-3.8	0.4-6.9	0.65-5.1	1.05-4.0	0.6-6.25	0.4-1.8
Total Hardness mg/l	840-1500	790-1300	820-1450	770-1400	860-1400	890-1530
Calcium Ca^{+2} mg/l	128.3-234.5	114.2-220.4	114.2-226.5	142.3-244.5	138.3-216.4	152.3-260.5
Magnesium Mg^{+2} mg/l	156.7-300.4	143.6-252.6	154.4-300.9	138.0-287.3	158.6-286.3	165.6-297.5
Nitrate NO_3^- mg/l	2.10-7.92	1.8-8.65	1.79-8.26	2.76-6.71	2.12-8.02	3.16-6.23
Active Phosphate PO_4^{-2}	0.73-10.35	0.3-2.76	0.25-2.49	0.40-9.24	0.16-2.54	0.127-0.825
Sulfate SO_4^{-2} mg/l	652.8-1430.4	528.0-1420.8	96.0-1219.2	211.2-1344	201.6-1305.6	676.0-1099.6
Chloride Cl^- mg/l	749.8-1624.5	574.8-1374.6	624.8-1274.6	599.8-1324.6	524.8-1124.7	599.8-1899.4
Sodium Na^+ mg/l	577.5-806.2	436.6-779.3	478.9-777.8	507.0-834.9	450.7-825.2	606.9-887.3
Potassium K^+ mg/l	9.4-38.4	8.2-25.3	8.8-27.3	8.2-35.6	6.47-30.57	9.42-32.66
Sodium Adsorption Ratio	39.59-60.97	31.3-60.47	31.86-61.82	36.53-62.5	33.82-58.95	39.70-55.59
Boron B^{+3} mg/l	0.124-0.922	0.1-0.8	0.092-0.759	0.116-0.654	0.068-0.79	0.163-0.602
Fecal coliform bacteria FC CFU/100ml	444-1889	444-2000	333-2222	1000-5889	222-1889	111-556

Table 4: Variables ranges at the studied stations as compared to the permissible values.

Variables	Units	WHO (2018)	US-EPA (2012)	ISRM (2011)	Ayers & Westcot (1985)	The present study
Water Temperature	°C	-	-	-	20-30	10-33
Dissolved Oxygen	mg/l	5	-	>5	-	0.6-8.4
BOD_5	mg/l	5	-	<3	-	0.4-6.9
TDS	mg/l	-	500	-	-	1917-4036
EC	mS/cm	-	0.25	-	0.7	2.53-6.0
pH	-	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.4	7.32-8.55
TH as $CaCO_3$	mg/l	NG*	100	-	-	770-1530
Ca	mg/l	-	100	-	-	114.23-260.52
Mg	mg/l	-	30	-	-	137.98-300.85
Turbidity	NTU	5	5	<5	-	1.61-107.9
TSS	mg/l	-	-	50	-	5.3-130.14
NO_3	mg/l	50	10	15	5	1.79-8.65
Reactive PO_4	mg/m^3	-	40	400	-	0.127-10. 35
B	mg/l	2.4	-	-	0.7	0.068-0.922
SO_4	mg/l	-	250	200	250	96.0-1430.4
Cl	mg/l		250	200	250	524.84-1899.41
Na	mg/l	50	30-60	-	200	436.62-887.32
K	mg/l	-	-	-	12	6.47-38.39
SAR	-	-	-	-	3	31.32-62.50
Fecal Coliform (FC)	CFU/100 ml	ZERO	200	-	-	111-5889

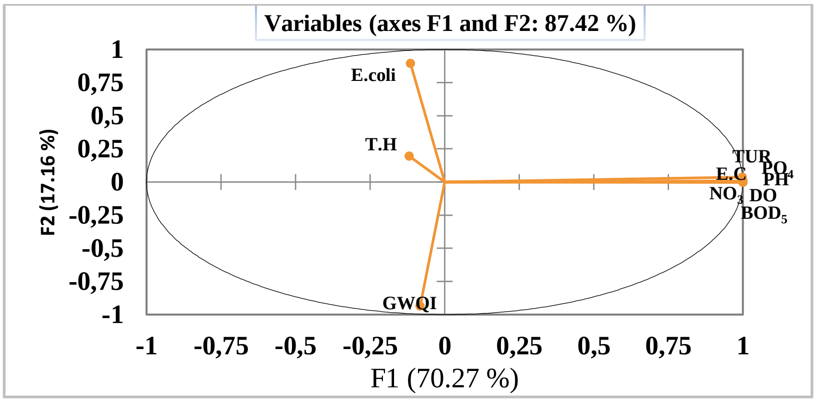

Figure 1: General water quality variables responsible by Principal Component Analysis (PCA).

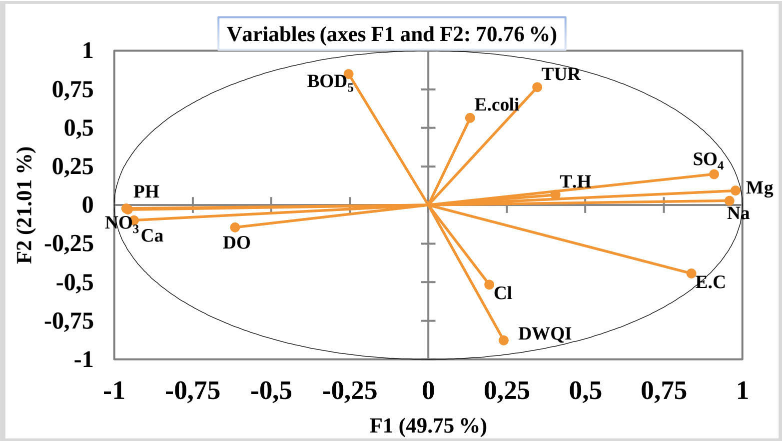

Figure 2: Drinking water quality variables responsible by Principal Component Analysis (PCA).

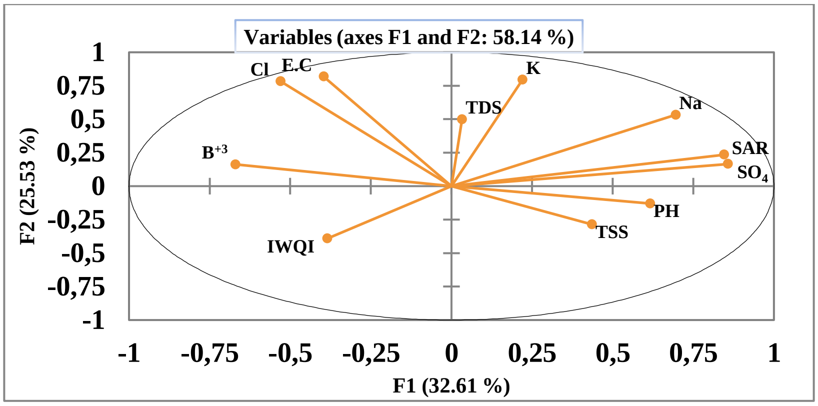

Figure 3: Irrigation water quality variables responsible by Principal Component Analysis (PCA).

Irrigation Water Quality Index (IWQI)

Water of the middle marshes falls under the fifth category (poor) for irrigation (Table 5), as it recorded low values in all seasons and stations. This is due to the rise of most variables responsible for the quality of water for irrigation purposes, including the decrease of water levels in the marshes, rising temperatures which increased concentrations of ions such as chlorine, sulfate, sodium, SAR and TDS in addition to increased concentrations of pollutants from various sources, including sewage plants.

Water affects soils and crops, particularly alkaloid soils, as sodium is one of the most important variables that have a direct impact on water use for irrigation purposes (Nishanthiny et al., 2010). Sodium adsorption ratio (SAR) is also effective in estimating the water quality index for agriculture (Zhang et al., 2012). Electrical conductivity also has effects on crop productivity due to the presence of some plant-toxic ions such as boron (B^{+3}), causing damage to the plant and public health (ISRM, 2011). The results of PCA analysis (Figure 3) showed that SAR, sulfates, boron, sodium, pH and chloride were the most influential factors on the value of the water index for irrigation purposes, followed by total suspended solids, potassium, electrical conductivity and total dissolved solids due to elevated values as compared with other studies (Shekha et al., 2017).

Table 5: The WQI CCME (GWQI, DWQI and IWQI) values and their descriptions at the studied stations during the studied period.

Stations	Seasons	GWQI	Description	DWQI	Description	IWQI	Description
St. 1	Autumn	29.82	Poor	14.84	Poor	38.51	Poor
	Winter	31.34	Poor	12.44	Poor	38.14	Poor
	Spring	31.86	Poor	13.89	Poor	38.40	Poor
	Summer	31.54	Poor	14.87	Poor	32.80	Poor
	Mean	31.14	Poor	14.01	Poor	36.96	Poor
St. 2	Autumn	27.79	Poor	13.41	Poor	33.69	Poor
	Winter	45.27	Marginal	20.37	Poor	38.81	Poor
	Spring	42.68	Poor	17.26	Poor	40.64	Poor
	Summer	41.06	Poor	15.10	Poor	39.74	Poor
	Mean	39.20	Poor	16.53	Poor	38.22	Poor
St. 3	Autumn	37.09	Poor	13.34	Poor	33.11	Poor
	Winter	47.18	Marginal	20.47	Poor	38.63	Poor
	Spring	46.85	Marginal	16.63	Poor	40.45	Poor
	Summer	37.33	Poor	16.71	Poor	35.79	Poor
	Mean	42.12	Poor	16.78	Poor	36.99	Poor
St. 4	Autumn	26.66	Poor	12.51	Poor	33.19	Poor
	Winter	41.65	Poor	19.48	Poor	38.35	Poor
	Spring	33.52	Poor	11.67	Poor	40.38	Poor
	Summer	32.35	Poor	16.44	Poor	40.53	Poor
	Mean	33.54	Poor	15.02	Poor	38.11	Poor
St. 5	Autumn	24.97	Poor	13.39	Poor	31.94	Poor
	Winter	48.13	Marginal	17.44	Poor	38.33	Poor
	Spring	48.11	Marginal	18.11	Poor	40.67	Poor
	Summer	35.65	Poor	16.73	Poor	36.07	Poor
	Mean	39.22	Poor	16.42	Poor	36.76	Poor
St. 6	Autumn	-	-	-	-	-	-
	Winter	45.60	Marginal	17.22	Poor	37.83	Poor
	Spring	50.5	Marginal	18.53	Poor	40.43	Poor
	Summer	49.26	Marginal	21.89	Poor	36.72	Poor
	Mean	48.47	Marginal	19.21	Poor	38.33	Poor

Conclusions

The current study showed a marked increase in the values of some of the measured variables (total hardness, BOD_5, turbidity, TDS, TSS, sodium, sodium adsorption ratio, chloride and magnesium) compared with the world permissible values. This is due to the domestic sewage that discharges directly, without treatment, to the marsh through Al-Ghameja and Al-Machri pumps stations. Large numbers of fecal coliform bacteria were recorded in all the studied stations, especially the first and fourth stations, which indicated an increase in household waste and sewage directly into the marsh. The study showed that the application of WQI is a useful tool in assessing the overall quality of water, which gave a straightforward interpretation of the monitoring data to help local people improve water quality.

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