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Evaluation of Irrigation Water Quality Index (IWQI) for Habbaniya Lake in Anbar Governorate, Iraq

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Abstract. A study was conducted to estimate the Irrigation Water Quality Index (IWQI) for Habbaniya Lake in central Iraq for irrigation purposes. The samples were taken at sixteen stations in October 2019. Studied samples were examined for ten Physico-chemical parameters Hydrogen Number (pH), Electrical Conductivity (EC), Temperature (T °C), Total Dissolved Solids (TDS), Total Hardness (T.H.), Turbidity (NTU), Sodium Absorption Ratio (SAR), Na^+, Cl^-, and HCO_3^-. The results showed that 68.75% of the study water samples fall within the low restriction category (LR) irrigation water in eleven stations (which is dominant in all parts) and 25% of the search region falls under the no restriction category (NR) irrigation water in four stations (which is dominant in the northwestern part at station 5-8). Meanwhile, a small part of the study area represents 6.25% of the water samples is classified as a moderate restriction (MR) irrigation water in one station (in the central part). Accordingly, these categories are suitable to use only with the soil having low to moderate permeability with a plant of some kind for specified tolerance of moderate salts content. The IWQI is homogeneous and suitable for irrigation in all parts, especially the northwestern part which represents the entrance waters through Warar Canal that fed principally from the Euphrates River.

1. Introduction

Water quality studies are essential for lake water, as they are an important water resource for domestic water supply, irrigation of crops, and industrial uses, as well as, to support human and animal life. Lake is gradually becoming polluted due to the addition of different materials, such as organic matter, plant and animal origin, nutrients, and toxic chemicals. The major sources of these pollutants are urban, agricultural, and industrial activities [1]. The quality of water depends on the situation quantity and the type of the salts that have been dissolved in it, which is highly variable and depends upon its purpose. Climate change has a significant impact in influencing the relationship between rainfall and evaporation that contribute to increasing or decreasing water in the area thus its quality changes [2]. In a simplified concept, the IWQI is a method for condensing complex data on water quality into a single statement or value [3]. Many different integration techniques are used to determine whether water is suitable for irrigation. Researchers established the standards diagrams for irrigation water at the United States Salinity Laboratory [4] and [5]. Many researchers in modern years used IWQI as a method for controlling the quality of groundwater like [6], [7], and [8]. In addition to researchers concerned with environmental studies and biological studies to assess Habbaniya lake [9];

[10]; [11]; [12]; [13]. The study aims to determine whether the water quality is suitable for irrigation, using (IWQI) and the RockWare-16 software to display this index's spatial dispersion.

1.1. Site Description

Habbaniya Lake is located in central Iraq, southeast of Ramadi Figure 1. It is bordered by longitudes 43° 19′ 40.6″- 43° 36′ 34.4″ E and latitudes 33° 10′ 37.7″ –33° 22′ 20.8″ N at an elevation range between 43–45 m above sea level (a.s.l.) with an area covering about 420 km^2. It has a depth of 9 - 13 meters, a length of 35kilometers, a maximum width of 25kilometers, and a storage capacity of 3.260 x 10^9 m^3. [9]. Because of the effect of fluctuating water levels, the lake is oligotrophic [14].

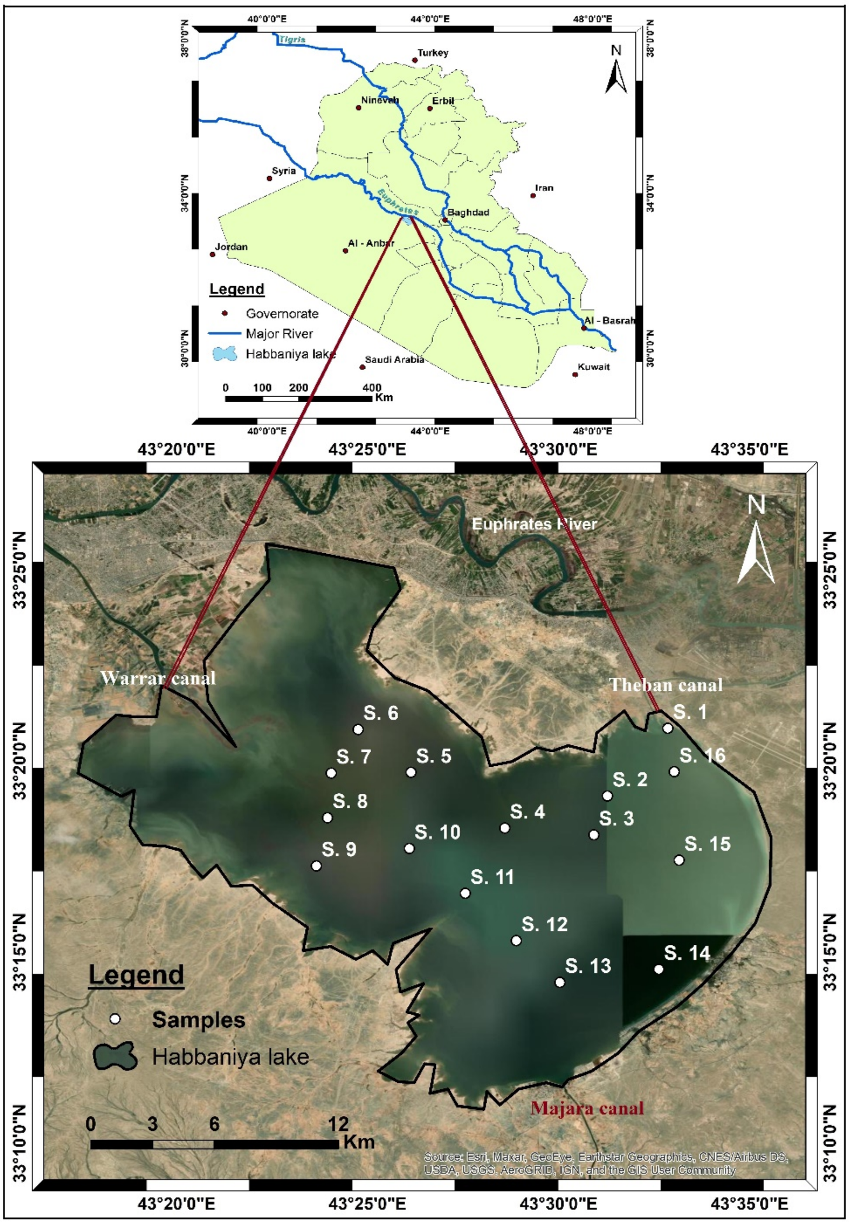

Fig. 1. The study area's location and sampling stations

The bottom was sandy in the southern part of the lake to a depth of 8 m. Gravel and clay were also found in some places. The sediments in the deeper parts (40–50 cm thick) had a low content of organic matter were a thick layer of watery loam. In the northern part of the lake where water depth did not exceed 8 m, the bottom sediments were loamier over the whole area [15]. The Habbaniya Lake is a natural shallow lake within Anbar, west of Baghdad, Iraq. The water is fed mostly by the Euphrates

River through Wararr Cannal, and it has 2 outlets: The Majjara Cannal empties into Razazza Lake, and the Thebann Cannal discharges into the Euphrates River once more. Tectonically, Habbaniya Lake represents a depression that was located in the west part of the Mesopotamia Zone. This depression may be tectonically controlled by the N-S trending Tharthar fault line and the NW-SE trending Euphrates Boundary Fault [16]. The amount of dissolved oxygen, pH, salinity, biological and microbiological activity in water are all affected by temperature fluctuations. The level of dissolved oxygen in a water body is related inversely to the temperature of the water. The temperature varied from 12. 5 ºC to 32. 1ºC with a mean temperature of 21. 3ºC. Temperatures reached their highest point in June, and their lowest value during January month [17].

2. Materials and Methods

Sixteen water samples from Habbaniya Lake during October 2019 Figure 1 were collected in 2L polythene water and samples were examined according to conventional protocols, and essential precautions were taken to avoid contamination [18]. Each of the Habbaniya Lake water, total of ten parameters were examined in the samples; Temperature (T°C) is determined by the thermometer, Turbidity (NTU) by turbidimeter, pH and EC is determined by pH meter, conductivity meter, Total Hardness (TH), and Total Dissolved Solids (TDS) are calculated using an indirect approach. The (SAR), Na^+, HCO_3^- and Cl^- are determined by titrimetric in the chemical laboratory (Anbar Water Directorate's laboratory) Tables 1 and 2. In the present study, 5 parameters; the Electrical Conductivity (EC), Sodium (Na^+), Chloride (Cl^-), Bicarbonate (HCO_3^-), and (SAR) have been used for the evaluation of irrigation water quality according to (IWQI) model.

The IWQI calculations include three successive steps [19], [20], and [21]. The first step includes the parameters that are more suitable for the use of irrigation, the second step, a definition of aggregation weights (Wi) and quality of the parameter (Qi) measurement values and presented in Tables 2 and 3. Finally, the third step is to determine qi (quality rating) by the equation that follows:

$$(Qi) = qi_{(max)} - [(x\,i\,j - x\,inf) * qi_{(amp)})/ x_{(amp)}] \quad (1)$$

$qi_{(max)}$: (is the maximal value of the qi for the classes). x i j: (is the spotted value for parameters). x inf: (is the value that corresponds to the minimum limit of the category to which each parameter belongs). qi_{amp}: (is the category amplitude). x_{amp}: (is the category ampleness to each parameter belongs).

Table 1. Physical parameters measurements in the Habbaniya Lake; Temperature (T), Hydrogen Number (pH.), Electrical Conductivity (E.C.), Turbidity (NTU), Total Hardness (T.H.), and Total Dissolved Solids (TDS.)

Samples no.	T. (°C)	pH.	EC.(µS / cm)	TDS. (mg/l)	T.H (mg/l)	Turb. (NTU)
S. 1	29.40	8.45	1037.72	726.40	403.31	4.14
S. 2	29.20	8.33	850.06	630.66	342.52	2.50
S. 3	28.30	8.36	956.89	725.54	364.00	1.50
S. 4	29.50	8.35	934.60	740.33	280.08	1.30
S. 5	29.20	7.64	678.19	532.24	320.68	2.10
S. 6	30.50	8.20	615.94	455.22	276.64	1.90
S. 7	29.70	7.82	603.86	489.67	287.56	1.30
S. 8	29.90	7.76	640.10	502.88	289.02	1.60
S. 9	29.70	7.87	642.88	499.12	291.20	1.80
S. 10	29.50	7.81	785.02	612.35	331.24	1.30
S. 11	29.70	8.12	923.45	675.18	358.54	1.30
S. 12	29.40	8.35	991.27	745.78	374.92	1.40
S. 13	28.40	8.43	1012.63	811.73	395.30	1.80
S. 14	29.20	8.50	967.11	780.55	400.40	2.60
S. 15	29.70	8.40	1009.85	746.62	378.56	1.35
S. 16	28.80	8.46	1001.49	733.65	371.28	1.70

Table 2. Statistical summary of chemical parameters of water samples in Habbaniya Lake and the computed IWQI for each station in October 2019.

Samples no.	**Na^+ (meq / l)**	**HCO_3^- (meq / l)**	**Cl^- (meq/ l)**	**SAR**	**IWQI**	**Water use restrictions**
S. 1	4.04	0.80	5.22	2.01	77.02	LR
S. 2	3.09	0.88	4.02	1.67	72.76	LR
S. 3	3.96	0.72	4.87	2.07	80.15	LR
S. 4	3.83	0.80	4.60	1.98	67.15	MR
S. 5	2.26	1.08	3.16	1.35	91.57	NR
S. 6	2.04	0.75	2.74	1.26	87.90	NR
S. 7	2.09	1.16	2.88	1.23	94.15	NR
S. 8	2.26	1.08	2.90	1.33	92.35	NR
S. 9	2.26	0.92	2.96	1.32	81.80	LR
S. 10	3.13	1.02	3.92	1.72	82.40	LR
S. 11	3.78	0.80	4.38	2.00	79.68	LR
S. 12	4.35	0.88	4.52	2.24	75.28	LR
S. 13	4.65	1.28	4.98	2.34	81.99	LR
S. 14	4.87	0.56	5.03	2.43	81.27	LR
S. 15	4.48	0.64	4.87	2.30	80.26	LR
S. 16	4.43	0.72	4.71	2.30	78.64	LR
Max	4.87	1.28	5.22	2.43		
Min	2.04	0.56	2.74	1.23		

Table 3. The IWQI parameters' weights according to [22].

Parameters	**Weight (Wi)**
EC	0.2110
Na^+	0.2040
HCO_3	0.2020
Cl^-	0.1940
SAR	0.1890
Total:	1.0000

The minimum limits shown in Table 4 have been planned by the UCCC (University of California Committee of Consultants) and the standards set forth by [23]. The uppermost limit $x_{(amp)}$, of each parameter's last category, was sighted as the highest value obtained of water samples. Lastly, The IWQI was determined using the equation below.:

$$IWQI = \sum_{i=1}^{n} Qi\, Wi \tag{2}$$

Table 4. Limiting values for parameters in quality measures (qi) calculations [23].

HCO_3^-	**Cl^-**	**Na^+**	**SAR**	**EC. (µS/ cm)**	***q_i***
	(meq/l)		**$(meq/l)^{1/2}$**		
1.0 ≤HCO_3< 1.50	1.0 ≤Cl < 4.0	2.0≤ Na < 3.0	2.0≤ SAR < 3.0	200.0≤ EC < 750.0	85.0 – 100.0
1.50 ≤HCO_3< 4.50	4.0≤Cl < 7.0	3.0≤ N < 6.0	3.0≤ SAR < 6.0	750.0 ≤ EC < 1500.0	60.0 – 85.0
4.50≤HCO_3<8.50	7.0≤Cl < 10.0	6.0≤ Na <9.0	6.0≤ SAR < 12.0	1500.0≤ EC < 3000.0	35.0 – 60.0
HCO_3<1.0 or HCO_3≥8.50	Cl <1.0 or Cl ≥ 10.0	Na <2.0 or Na ≥9.0	SAR <2.0 or SAR ≥12.0	EC < 200.0 or EC ≥ 3000.0	0.0 – 35.0

3. Results and Discussion

3.1. Results

The Dangers of Salinity

Table 1 shows the values, standard deviations, and medians of (EC) in Habbaniya Lake collected samples. The EC in the research area ranges from 1037.72 to 603.86 µS/ cm (stations 1 and 7 respectively), to the east, as well as the southeastern section of the study region, the EC value rises.

Danger of Infiltration

The area's spatial distribution of SAR under consideration is shown in Table 2. The SAR is varied from 2.43 to 1.23 (stations 14 and 7 respectively). Table 2 shows the SAR values which rise in the eastern and southeastern parts of the research area.

Specific Ion Toxicity

The concentration of sodium ion (Na^+) in water samples ranged from 4.87 meq/l to 2.04 meq/l. (stations 14 and 6 respectively). Table 2 shows the sodium ion (Na^+) concentration distributions in the examined area, where Na^+ values increase to the east. The other parameter defining the particular ion toxicity is chloride concentrations. The greatest and minimum chloride ion concentrations in the research area were 5.22 meq/l and 2.74 meq/l, respectively, according to chemical analysis of water samples (stations 1 and 6 respectively) Table 2. It is shown that only in sampling from stations St.1 and St.14 did the chloride ion concentrations reach reasonably high levels when compared to the value of good quality irrigation water (4.0 meq/ l). Meanwhile, the chloride ion concentrations relatively have good values in every water sample.

Miscellaneous Effects (Effects that aren't directly related to the main theme)

Water samples had bicarbonate ion (HCO_3-) concentrations ranging from 1.28 meq/l to 0.5 meq/l and increase to the east Table 2. Bicarbonate concentrations of less than 90.0 mg/ l (1.50 meq/ l) are regarded as optimum for irrigation [24].

Hydrogen Number (pH)

The water of Habbaniya Lake reveals that pH values tend to be slightly alkaline. The value ranges from 7.64- 8.50 and increases to the east Figure 2. These values were within the limits of [25] and [26] guidelines, for drinking water. The mean value of pH indicates that the water of Habbaniya lake is alkaline. Natural lake habitats have been found to have an acidity range of 4.50-6.50. Natural waters with high organic matter content have low pH levels [27]. There were no temporal and spatial variations in the values of pH of the lake water. The mean value of pH was in an agreement with that recorded by [28].

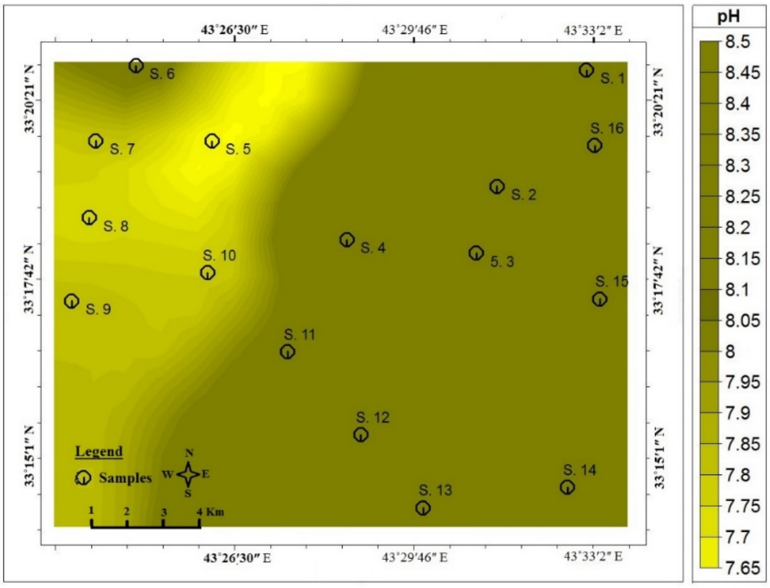

Fig. 2. The distribution map of water pH values in Habbaniya Lake.

The Total Dissolved Solids (TDS)

The TDS ranges between 811.73–455.22 mg/l in stations 13 and 6 respectively. Comparatively, the higher values of TDS were found in the eastern area of Habbaniya Lake Figure 3.

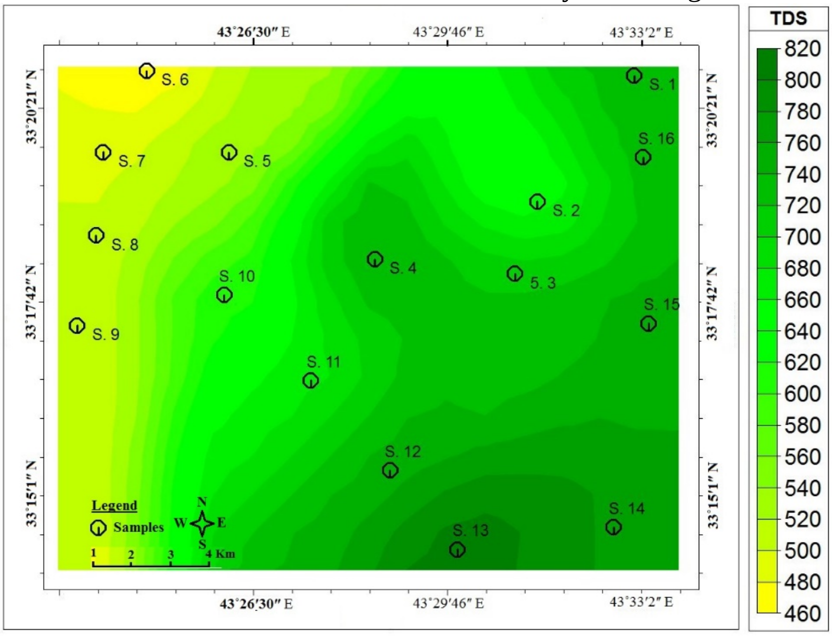

Fig. 3. The distribution map of water TDS values in Habbaniya Lake.

3.2. Discussion

Figure 4 shows the steps to find a consequence of the geostatistical analysis, the final map of IWQI was created by overlapping the theme maps (SAR, EC, Cl, Na, and HCO_3) and was thought to be a good map for supplying irrigation water from the Habbaniya Lake.

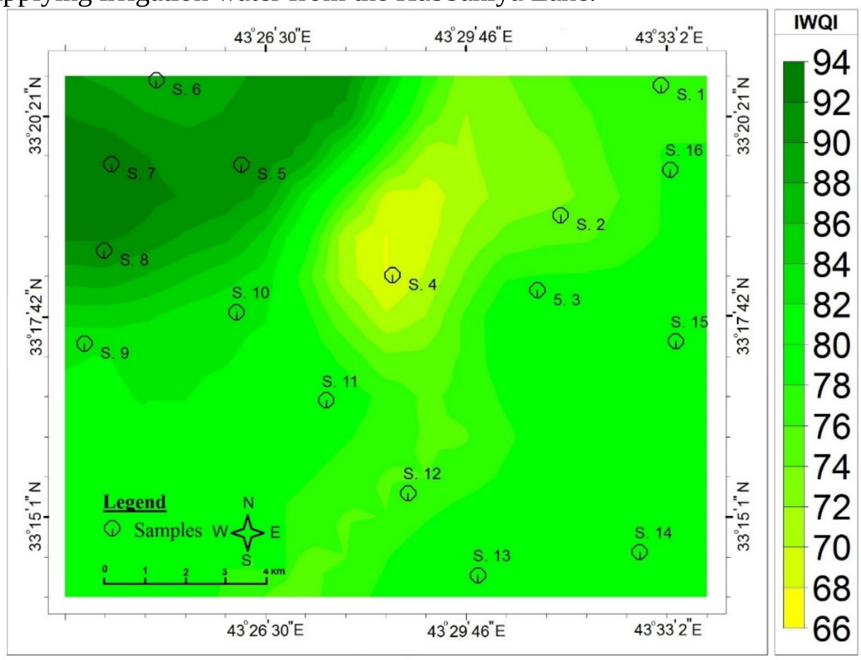

Fig. 4. IWQI map of Habbaniya Lake.

The values of weight (Wi) of each chemical parameter used in the IWQI have been suggested by [22] as specified in Table 3 where the restrictions have been proposed on the water categories used after calculating the total value of the indicator as shown in Figure 5. IWQI values for irrigation classes are divided into five classes ranging from (zero to one hundred) which are not dimensional parameters, the higher the values indicate better water quality. It was defined based on problems of the hazard of salinity, reduction of infiltration of soil water, as well as plant toxicity as noted in the proposed classifications of [29] and [30].

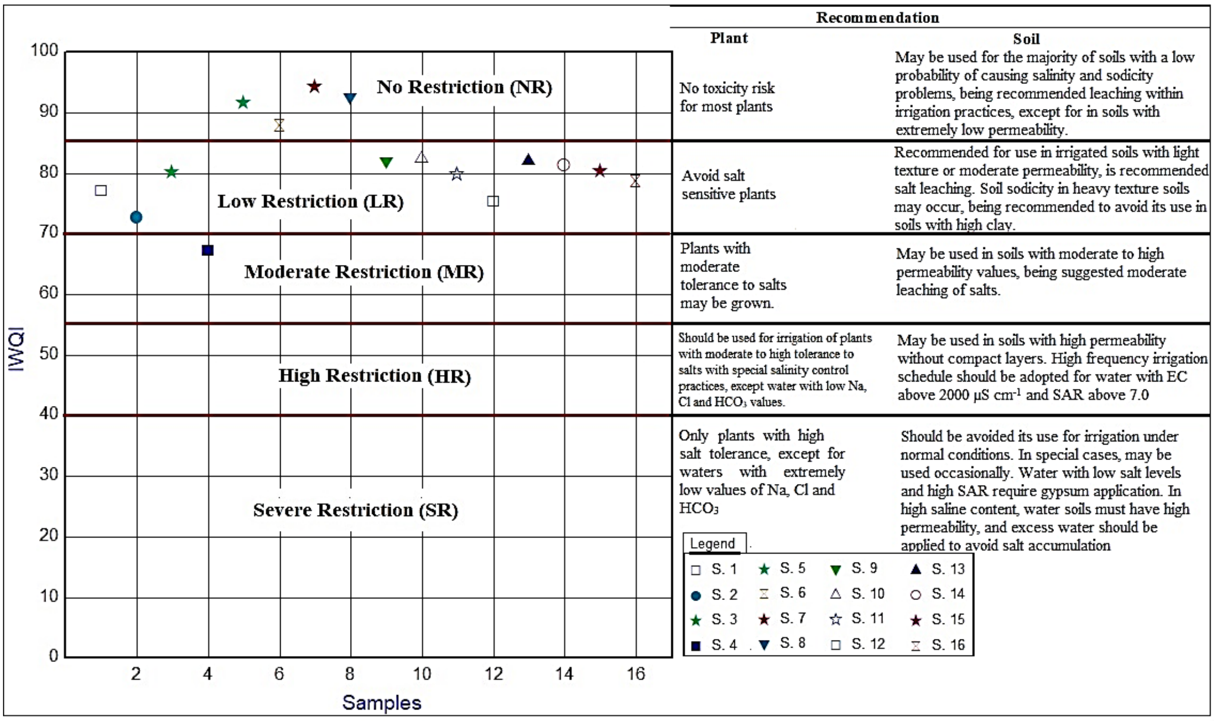

Fig. 5. Water Quality Index Categories [22].

The IWQI was calculated by using Equation 2, where the IWQI for all water samples is ranged from 67.15 to 94.15. The study area represents 68.75% of the water samples, which have a low restriction (LR) irrigation water in eleven stations. While the rest of the study area represents 25% of the water samples has no restriction (NR) irrigation water in four stations. A small part of the study area represents 6.25% of the water samples is categorized as a moderate (medium) restriction (MR) for irrigation water use in one station. Accordingly, this water is suitable to use with low to moderate permeability soils. Plants with the ability to tolerate moderate salt content can be grown. Consequently, the water quality was considered as homogeneous water varied from NR to MR for using irrigation water due to the short range of IWQI as shown in Figure 4.

Figure 4 depicts the IWQI spatial distribution in the research area, which varies from LR to NR Table 2. A broad area of low restricted water quality could be detected in all sections of the study area, as well as minor areas in the center. Because the EC, SAR, Sodium-ion, and Chloride-ion increased from west to east, the IWQI decreased in this direction, as seen in Figure 4. These forms of water should only be utilized with soil that has a high permeability, according to the recommendations in Figure 5. Fortunately, because the entire study area is located in Habbaniya Lake, which has extremely high permeability soil (sand), the water from the lake may be used to irrigate plants that are salt tolerant.

4. Conclusion

To determine the quality of the water in Habbaniya Lake for agricultural purposes in a precise and readable manner, the index of irrigation water quality was mapped, where all water samples are ranged from moderate restriction class to no restriction class. A small part of the study area is classified as a moderate restriction for using irrigation water and its value is close to the low restriction class, so it does not give importance to attention. RockWare-16 was used to map the spread of the indicator of irrigation water quality according to Eq. 2. IWQI values are indicated by the distribution map. Hence it gives the result that describes the state of the water in Habbaniya Lake and provides a comprehensive view of the distribution of the water quality index. It is concluded from the analysis of the irrigation water quality index map that water in Habbaniya Lake is suitable for irrigation. Where it is more suitable for irrigation in the northwestern part because it represents the entrance to the waters coming from the Euphrates River.

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