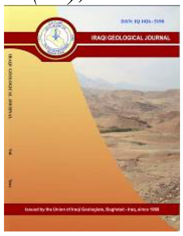
Iraqi Geological Journal

Journal homepage: https://www.igj-iraq.org



Application of Organic Indicators and Overall Index to Assess the Level of Water Pollution in Habbaniya Lake, Iraq

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Received: 28 March 2021; Accepted: 29 April 2021; Published: 31 July 2021

Abstract

The present investigation took place at Habbaniya lake to assess the level of pollution as an overall index besides organic directories. Dissolved Oxygen, Biological Oxygen Demand and Chemical Oxygen Demand were calculated for 16 samples of lake water in addition to parameters of Overall Index Pollution. The lake water content of Dissolved Oxygen is excellent and unpolluted according to Biological Oxygen Demand, and Chemical Oxygen Demand values (Dissolved Oxygen varied from 9.100 mg l^{-1} to 13.600 mg l^{-1}, Biological Oxygen Demand varied from 2 mg l^{-1} to 7 mg l^{-1}, and Chemical Oxygen Demand varied from 30 mg l^{-1} to 73.667 mg l^{-1}). Overall Index Pollution was useful and helpful in determining lake water quality. The situation of the lake was better compared to the year 2014. The health status of the lake varied from acceptable to slightly polluted due to having Overall Index Pollution values ranges from 1.632 to 2.677, and it supports aquatic life in it. The map of Overall Index Pollution shows that the values in the northwestern part of the lake are lower than in the southeastern part due to the continuous renewal of water in the first part because it represents a water inlet. This map is almost identical to a distribution map of Dissolved Oxygen, Biological Oxygen Demand, and Chemical Oxygen Demand. In general, Habbaniya lake is non-polluting and not dangerous to the environment now, but it may face the risk of pollution, based on the results obtained. Thus, the present study concluded that the use of the Overall Index Pollution technique with organic indicators is very suitable for assessing the level of water pollution in Habbaniya lake.

Keywords: Organic indicators; Overall index; Water pollution; Habbaniya; Lake; Iraq

1. Introduction

Residents of the area are greatly dependent on Habbaniya lake for many uses. Thus, it is imperative to protect our water resources to ensure that adequate quantities of high-quality water are available for generations to come. It is necessary to evaluate water in the term of quality to make optimal use of that water (Awadh, 2018). One of the most important ways to ensure the sustainability of water for a long time is to evaluate it continuously and ensure that it is free from all pollutants (organic and inorganic). Water protection is an important part of managing natural resources in the Middle East region in general and Iraq, in particular, Al-Dabbas et al. (2020). The natural factors and factors resulting from human activity that influence the chemistry of water determine the possibility of using that water in different fields (Al-Kilabi, 2018). Reduced water flow (drainage) leads to future droughts, deterioration of its

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quality, an increased level of pollution in it, (Awadh and Al-Kilabi, 2016). Consequently, the decline in water levels affects the sustainability of that water and the life of the organisms that live in it, such as fish. It is important to study climate change in the region because it is closely related to water quality and quantities, (Al-Kubaisi and Al-Kubaisi, 2018). Many studies are examining Habbaniya lake, including a study that was presented by Kassim et al. (2006) studied the distribution of phytoplankton with the depth of the lake (vertical distribution). (Al-Kathily, 2014) focuses on the purification of water by direct filtration of Habbaniya lake water. Levels of heavy metals of Habbaniya lake were studied by Khazaal et al. (2019). Al-Kubaisi (2020) presented a study in which the study evaluated the lake's water in terms of its quality. Lakes, in general, are graduating to become bad and polluted water as a result of the addition of many materials in them, such as nutrients, organic materials, toxic chemicals, etc., whose sources are from activities of agricultural and industrial. The pollution level of a given lake or any water body can be inferred by measuring Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) (Manahan, 1992; Kolo et al., 2010). The Overall Index of Pollution (OIP) is considered one of the most promising tools in studying changes in the chemistry of water and its quality in general (Al-Mayah and Rabee, 2018). Organic indicators, (DO, BOD, and COD) and the Overall Index of pollution were used to know the level of pollution in the Habbaniya lake.

2. Study Area

Habbaniya lake in general is one of the largest bodies of water in Iraq and is considered an important body of water in the south of Ramadi city in particular (about 11 km south of Ramadi city). It is located on the right bank of the Euphrates River, from which its waters feed. Locally, the lake has two outlets and one water inlet, the Majara and Theban canal, and the Warrar canal, respectively. The lake has latitude and longitude coordinates: 33˚10′37.71″–33˚22′20.81″ and 43˚19′40.61″– 43˚36′34.41″ respectively. Its area is about 365.2 km^2, it is existing on almost flat terrain, and its elevation above sea level ranges from 43.3 to 45.2 meter (Fig.1).

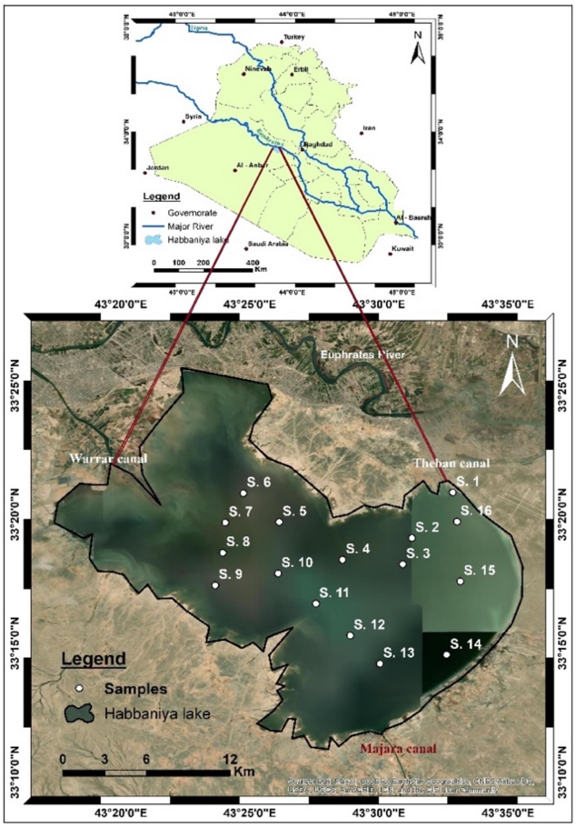

Fig. 1. Map of the Habbaniya lake and the sites of the selected samples

3. Materials and Methods

3.1. Field and Laboratory Practices

In October 2019, water samples from different sites of Habbaniya lake were collected by polyethylene bottles. The depth from which the samples were collected is 30 cm. To avoid any problems related to handling samples in the field (in-situ) or laboratory analyzes, the containers were washed appropriately. Also, samples are carefully measured directly in the field such as temperature (T) by °C, DO by mg l^{-1}, pH is measured unitless, total dissolved solids (TDS) by mg l^{-1}, and turbidity by NTU (nephelometric turbidity units). As for the rest of the parameters, they were measured in the laboratory of the AWD (Anbar Water Directorate) after they were transferred from the field.

3.2. Calculating the OIP Method

OIP was developed to be used as a guide or tool to simplify and understand water quality easily and clearly (Sargaonkar and Deshpande, 2003). A score can be obtained from OIP used for assessing the water quality of lakes and rivers based on measurements of TDS, turbidity, pH, DO, BOD, total hardness (TH), sulfate, and nitrate. From this technique or tool, water is classified into 5 categories based on Economic Commission for Europe (ECE) standard (UNECE, 1994) and Indian standard. These classes are C1 is excellent (not contaminated at all and use it to drink after disinfection and without treatment), C2 is acceptable (used in the shower and needs some disinfection before using it), C3 is slightly polluted (needs conventional treatment (filtration) in addition to disinfection before use) C4 is polluted (in addition to disinfection, needs special treatment), and C5 is heavily polluted (highly contaminated and it can only be used for controlled waste disposal and industrial cooling). This method can be expressed mathematically by the equation below (Sargaonkar and Deshpande, 2003).

$$Overall\ Index\ of\ pollution\ (OIP) = \sum_{i=1}^{n} \frac{P}{n} \quad (1)$$

Where: P is an index of pollution for each parameter. It can be extracted from the mathematical equations for each parameter (Table 1). n is the number of parameters that have been used.

Table 1. Calculation of the pollution index (P) for each parameter using mathematical equations

Variables[1]	Values	Equations
TDS	Smaller or equal to 500	$P = 1$
	From 500 to 1500	$P = ((y - 500)/721.50)$
Turbidity	From 5 to 10	$P = y/5$
	From 10 to 500	$P = ((y + 43.9)/34.50)$
pH	Smaller or equal to 7	$P = (7.0 - y)/1.0820$
	Greater than 7	$P = (y - 7)/1.0820$
Do	Smaller than 50	$P = -(y - 98.330)/36.067$
	From 50 to 100	$P = -(y - 107.580)/14.667$
	Greater or equal to 100	$P = ((y - 79.543)/19.054)$
BOD	Smaller than 2	$P = 1$
	From 2 to 30	$P = y/1.50$
TH	From 75 to 500	$P = (y + 42.50)/205.580$
	Greater than 500	$P = (y + 500.0)/125.0$
SO_4^{2-}	Smaller or equal to 150	$P = 1$
	From 150 to 2000	$P = ((y/50.0) + (0.3750)/2.5121)$
NO_3^-	Smaller or equal to 20	$P = 1$
	From 20 to 50	$P = (y - 145.160)/76.280$

[1] All variables are in milligrams per liter except turbidity is by NTU, DO by %, and pH is unitless

4. Results and Discussion

The results of ecological parameters of Habbaniya lake are listed in Table 2. According to ECE standard, Habbaniya lake waters fall within the second and third category (C2 and C3) due to it has pH values of 7.640 as a minimum and a maximum of 8.500 with an average of 8.178. Thus, needs conventional treatment (filtration) in addition to disinfection before use. It is also low-enriched water with salts because the electrical conductivity of water (EC) values is less than 1500 µS/cm (Subba Rao et al., 2012). Lake water is called freshwater because it has values for total dissolved salts ranged from 455.220 to 811.730 mg l^{-1}, where it is <1000 mg l^{-1} (USSL, 1954).

One of the factors affecting the aquatic environment is the temperature of the water. Changes in water temperature affect pH, salinity, level of DO, as well as, the activity of microbial and biological in the water. The temperature of the waters of Habbaniya lake changes from 28.300 to 30.500 °C. Turbidity is caused by an increase in the amount of cloudiness that occurs in the water. Its values can vary from water filled with mud (high turbidity) to completely clear water (it does not contain mud and other materials). It represents the extent of the visibility through the water. Turbidity leads to damage to taps and valves by filling the pipes and tanks with silt and mud. Based on ECE standards the lake water turbidity is within the excellent range and use it to drink because it has a turbidity of <5 NTU.

Table 2. Summary ecological parameters result of Habbaniya lake

Ecological parameters	Units of parameters	Mean	Maximum	Minimum
TDS	(mg l^{-1})	650.495	811.730	455.220
Turbidity (Turb.)	(NTU)	1.849	4.140	1.300
pH	Unitless	8.178	8.500	7.640
DO	(mg l^{-1})	11.994	13.600	9.100
BOD	(mg l^{-1})	4.206	7	2
TH	(mg l^{-1})	341.579	403.312	276.640
SO_4^{2-}	(mg l^{-1})	237.989	304.921	158.000
NO_3^-	(mg l^{-1})	4.200	6.200	2.300
T	Celsius (°C)	29.381	30.500	28.300
EC	(µS / cm)	853.191	1037.718	603.865
COD	(mg l^{-1})	52.458	73.667	30

4.1. Organic Indicators (DO, BOD, and COD) of Pollution

4.1.1. Dissolved oxygen (DO)

Several factors determine the amount of DO in water, these factors may be chemical, physical, or biological such as wind (aeration), algae, the velocity of water flow, atmospheric pressure, salt contents, temperature, organic compounds, etc. (Zhang, 2007). The balance between the atmosphere and the water controls the abundance of DO in river or lake water. Where its abundance supports the life of Organisms in that the lake or river. The DO content is inversely proportional to the abundance of organic matter in the lake. The death of fish and organisms living in a lake may occur due to a sharp decrease in the amount of DO especially if it is less than 2 mg l^{-1} (Sisodia and Moundiotiya, 2006). Habbaniya lake recorded DO values of 9.100 mg l^{-1} as the minimum value and 13.600 mg l^{-1} as the highest value with an average of 11.994 mg l^{-1}. According to ECE standard, the lake water content of DO is excellent because it has a DO of greater than 7 mg l^{-1} (Fig. 2). Using the GIS (ArcMap 10.4.1) program, the distribution of DO values in Habbaniya lake was drawn to give a clear picture of its (Fig. 3).

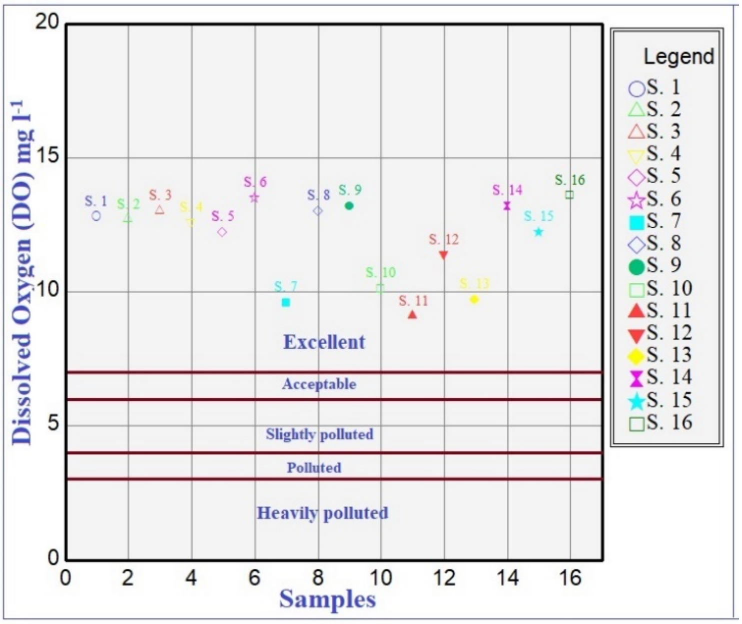

Fig.2. Classification of water depending on the DO according to ECE standard (UNECE, 1994)

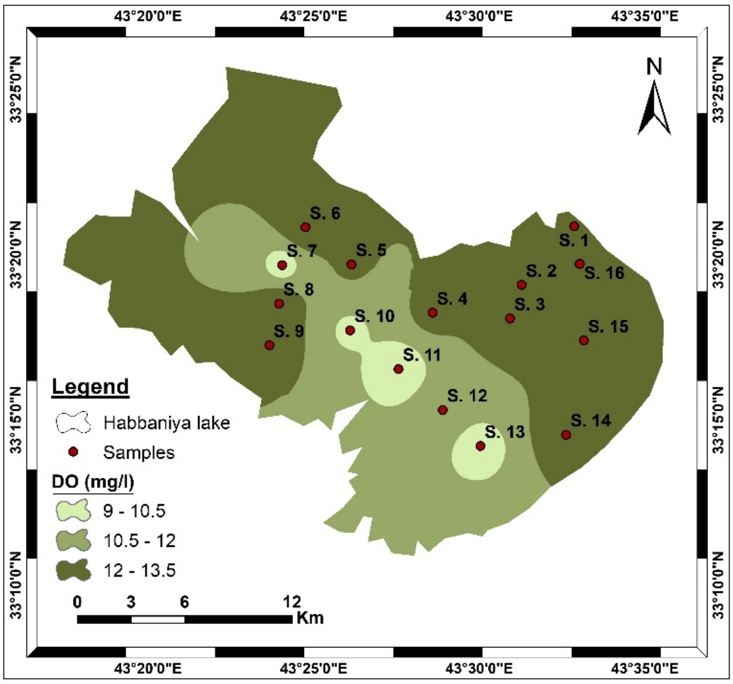

Fig.3. Spatial distribution of DO (mg/l) values in Habbaniya lake

4.1.2. BOD (Biological oxygen demand)

BOD refers to the effect of organic matter in the water, when organic matter (plants or animal remains such as fish) decomposes in a given amount or volume of water, it begins to consume the oxygen that has dissolved in the water (Weiner, 2000). It is also evidence of water, which has become anaerobic as a result of the depletion of oxygen. The value of BOD in water is inversely proportional to the amount of DO in it, with the high BOD the oxygen decreases and the water condition worsens. Habbaniya lake recorded BOD values of 2 mg l^{-1} as the minimum value and 7 mg l^{-1} as the highest value with an average of 4.206 mg l^{-1}. According to ECE standards, the lake water is not polluted because it has BOD values less than 10 mg l^{-1}. Using the GIS (ArcMap 10.4.1) program, the distribution of BOD values in Habbaniya lake was drawn to give a clear picture of it (Fig.4).

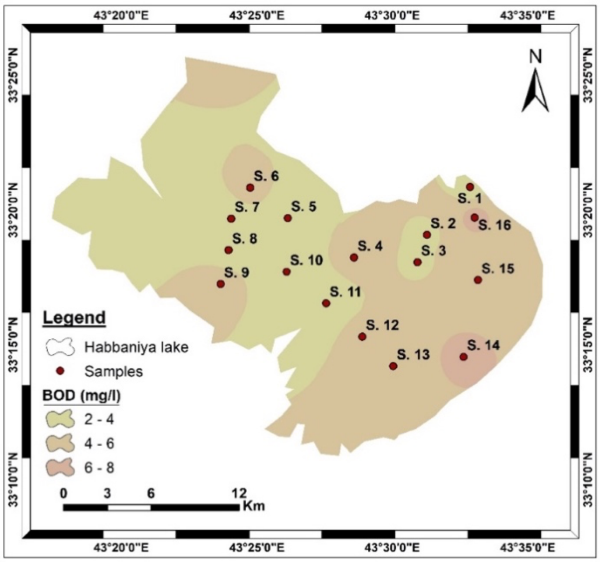

Fig.4. Spatial distribution of BOD (mg/l) values in Habbaniya lake

4.1.3. COD (Chemical oxygen demand)

COD refers to the effect of chemical oxidizer and its relationship with organic matter in the water when organic matter (plants or animal remains such as fish) oxidized to H_2O and CO_2 in a given amount or volume of water by a strong chemical oxidant, such as dichromate or permanganate, it begins to consume the oxygen that has dissolved in the water (Weiner, 2000). COD also as BOD is considered evidence of water pollution and degradation. Consequently, the increase in the amount of organic matter increases the concentration of COD in the water body. Habbaniya lake recorded COD values of 30 mg l^{-1} as the minimum value and 73.667 mg l^{-1} as the highest value with an average of 52.458 mg l^{-1}. According to ECE standard, the lake water is not polluted because it has COD values less than 80 mg l^{-1}. Using the GIS, ArcMap 10.4.1 software, the distribution of COD values in Habbaniya lake was drawn to give a clear picture of its (Fig.5).

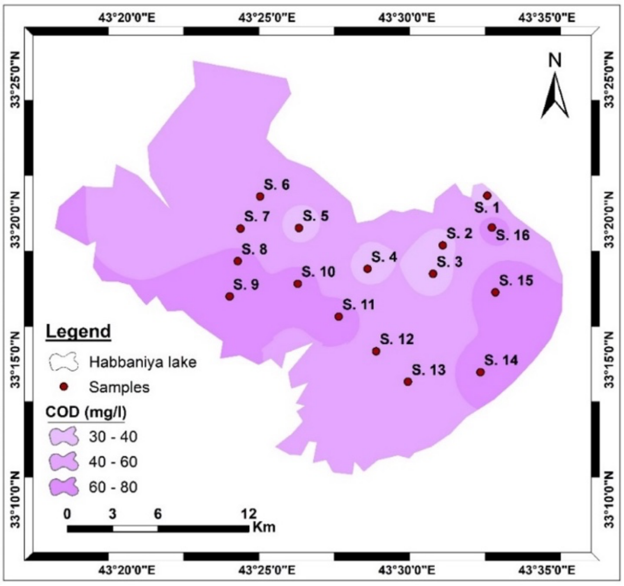

Fig. 5. Spatial distribution of COD (mg/l) values in Habbaniya lake

4.2. Comparison of Organic Indicators of Pollution with the Previous Studies

A previous study was conducted by Salah et al. (2014) to determine organic directories in Habbaniya lake. The results showed that the water is not organically contaminated based on organic indicators during the year 2014. The present study revealed results that better describe the situation of the lake than before the year 2014. Where the values of DO are higher on average than previous study. Besides, the BOD values were lower than the previous study, as shown in the comparison table below Table 3. Where the reason for this is attributed to the increase in the amount of water in the lake during the current study more than it was in the previous study.

Table 3. Comparison of organic indicators of pollution with the study of Salah et al. (2014)

Ecological parameters	Units of parameters	The study	Mean	Maximum	Minimum
pH	Unitless	This study	8.178	8.500	7.640
		Salah et al. (2014)	8.100	8.200	7.900
T	Celsius (°C)	This study	29.381	30.500	28.300
		Salah et al. (2014)	21.300	32.100	12.500
DO	(mg l^{-1})	This study	11.994	13.600	9.100
		Salah et al. (2014)	8.900	10.570	6.720
BOD	(mg l^{-1})	This study	4.206	7	2
		Salah et al. (2014)	7.530	11.160	2.860
COD	(mg l^{-1})	This study	52.458	73.667	30
		Salah et al. (2014)	33.470	40.330	26.830

4.3. Determine OIP for Habbaniya Lake

The OIP calculation aims to make it easier to judge the type of water by converting the enormous value of complex data into easy (clear) and understandable information. OIP is used as a technique or tool to determine the level of pollution in Habbaniya lake. According to Equation 1, the OIP ranges from 1.632 to 2.677, where the samples of the Habbaniya lake were acceptable water for the pollution level (31.25% of samples), while were slightly polluted water for the pollution level (68.75% of samples) (Fig. 6) and (Table 4). This little level of pollution is due to appropriate values of turbidity, pH, DO, BOD, TH, SO_4^{2-}, and NO_3^-, It is responsible for reducing the pollution level and improving the lake's water. Fig. 7 display the level of pollution as an overall index for Habbaniya lake, as it falls within the second and third classes of ECE standards. The OIP values in the northwestern part of the lake that appear in the distribution map to be lower than in the southeastern part. The reason for this is due to the continuous renewal of water in the first part because it represents the entrance to the lake (feeding the lake from the water of the Euphrates river). Thus, the water condition in this part is better and more acceptable than others. It is worth noting that this map is almost identical to a distribution map of DO, BOD, and COD (Figs. 3, 4, and 5), respectively.

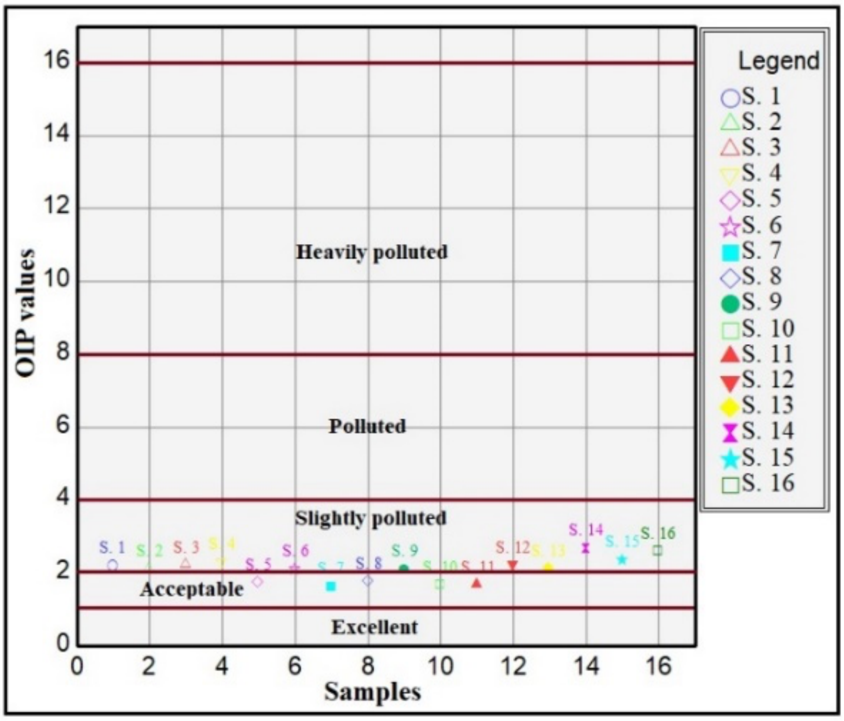

Fig.6. Categorization of OIP water depending on ECE standard (UNECE, 1994)

Table 4. Calculate P (index of pollution) for each parameter and OIP values for Habbaniya lake

Sample no.	P for TDS	P for Turb.	P for pH	P for DO	P for BOD	P for TH	P for SO_4^{2-}	P for NO_3^-	OIP values
S. 1	0.314	1.628	1.340	4.000	1.867	2.169	5.112	1	2.179
S. 2	0.181	1.3	1.229	3.936	2.467	1.873	4.865	1	2.106
S. 3	0.313	1.1	1.257	4.128	2.467	1.977	5.569	1	2.226
S. 4	0.333	1.06	1.248	3.872	3.400	1.569	5.713	1	2.274
S. 5	0.045	1.22	0.591	3.616	2.000	1.767	3.729	1	1.746
S. 6	1.000	1.18	1.109	4.447	3.067	1.552	3.309	1	2.083
S. 7	1.000	1.06	0.758	1.956	2.267	1.606	3.408	1	1.632
S. 8	0.004	1.12	0.702	4.128	1.933	1.613	3.713	1	1.777
S. 9	1.000	1.16	0.804	4.255	3.400	1.623	3.614	1	2.107
S. 10	0.156	1.06	0.749	2.275	1.933	1.818	4.347	1	1.667
S. 11	0.243	1.06	1.035	1.637	1.333	1.951	5.153	1	1.676
S. 12	0.341	1.08	1.248	3.106	3.200	2.030	5.762	1	2.221
S. 13	0.432	1.16	1.322	2.020	2.933	2.130	6.091	1	2.136
S. 14	0.389	1.32	1.386	4.255	4.667	2.154	6.248	1	2.677
S. 15	0.342	1.07	1.294	3.616	3.400	2.048	5.976	1	2.343
S. 16	0.324	1.14	1.349	4.511	4.533	2.013	5.935	1	2.601

All parameters are in mg l^{-1} except turbidity is by NTU, DO by %, and pH unitless

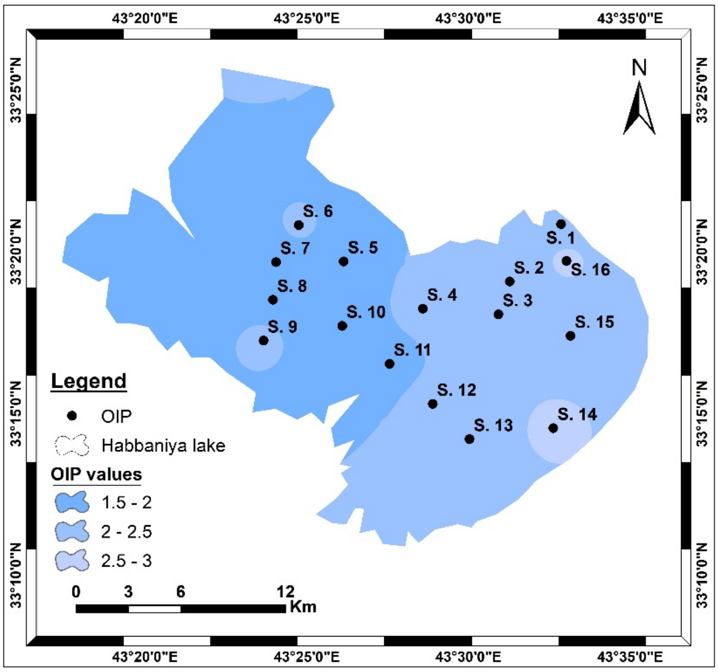

Fig.7. OIP of Habbaniya lake

5. Conclusions

Habbaniya lake waters fall within permissible limits of ECE standard and it supports aquatic life in it, based on values obtained it is also used for drinking with only disinfection and filtration. Lake water is called fresh water and it is low-enriched water with salts. The DO content of its water is excellent and not polluted based on COD and BOD values. The situation of the lake in this paper is better than before the year 2014, based on the results obtained. OIP values display samples of the Habbaniya lake changed from acceptable water to slightly polluted for the pollution level. It is in the northwestern part of the lake appears in the distribution map to be lower than in the southeastern part. This paper demonstrated the usefulness of the OIP because it is characterized by the integrating of the results used in the evaluation. It also helps diagnose and solve problems related to pollution, whether for Habbaniya lake or other lakes and rivers that can be applied to them. In other words, there is a need to apply this tool to different types of lakes and rivers (water bodies in general) to prove its usefulness. In general, Habbaniya lake is fairly clean (non-polluting). In other words, its water is not dangerous to the environment now, but it may face the risk of pollution, based on OIP.

Acknowledgements

First and foremost, the authors want to sincerely thank staff members of the Department of Applied Geology, College of Science, University of Anbar, Ramadi, Iraq, for their help during the whole process of this work. The authors also like grateful to the team of the Anbar Water Directorate, they assisted with the analysis of the samples in the laboratory. The authors are very grateful to the Editor in Chief Prof. Dr. Salih M. Awadh, the Secretary of Journal Mr. Samir R. Hijab, and the Technical Editors for their great efforts and valuable comments.

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