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Water Quality Index for Assessment of Water Quality of Duhok Lake, Kurdistan Region of Iraq

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Abstract: Water quality of Duhok Lake was evaluated by Water Quality Index (WQI) technique. A water quality index provides a single number that expresses the overall water quality at a certain location and time based on several water quality parameters. The objective of an index is to turn complex water quality data into information that is understandable and usable by the public. Ten most important parameters such as pH, electrical conductivity (EC), total hardness, total alkalinity, dissolved oxygen (DO), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and sulfate (SO_4) were taken for the calculation of WQI. The result indicated that water quality of Duhok Lake poor in the years 1999, 2000 and is poor in 2009 too. The impact of various anthropogenic activities was evident on some parameters such as the EC, alkalinity and hardness. It is suggested that monitoring of the lake is necessary for proper management. Application of the WQI is also suggested as a very helpful tool that enables the public and decision-makers to evaluate water quality of lakes in Iraq.

Keywords: Water Quality Index, Duhok Lake.

1. Introduction

Water is an essential requirement of human and industrial developments and it is one the most delicate part of the environment (Das and Acharya, 2003). Tremendous increase in the demand for freshwater due to rapid growth of population and the accelerated pace of industrialization (Ramakrishnaiah *et al*., 2009). Human health is threatened by most of the agricultural development activities particularly in relation to excessive application of fertilizers and unsanitary conditions (Okeke and Igboanua, 2003). The availability of water in Iraq shows a great deal with spatial and temporal variability. The increase in population and expansion of economic activities undoubtedly leads to increasing demand for water use for various purposes. Water resources in Iraq, especially in the last two decades have also suffered from remarkable stress in terms of water quantity due to different reasons such as the dams built on Tigris and Euphrates in the riparian countries, the global climatic changes and the local severe decrease of the annual precipitation rates and improper planning of water uses inside Iraq (Rahi and T. Halihan, 2010 & Jones *et al.*, 2008). The quality of water is defined in terms of its physical, chemical and biological parameters and ascertaining its quality is crucial before use for various intended purposes such as potable water, agricultural, recreational and industrial water uses, etc. (Sargaonkar and Deshpande, 2003). Water quality index (WQI) is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policymakers. It, thus, becomes an important parameter for the assessment and management of surface water. WQI is defined as a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point of view of the suitability of surface water for human consumption (Atulegwu and Njoku, 2004). WQI is one of the most effective tools to monitor the surface as well as groundwater pollution and can be used efficiently in the implementation of water quality upgrading programmes. The objective of an index is to turn multifaceted water quality data into simple

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information that is comprehensible and usable by the (Mohammad and Pathak, 2010). WQI can also be used to aggregate data on water quality parameters at different times and in different places and to translate this information into a single value defining the period of time and spatial unit involved (Shultz, 2001). The objective of the present work is to apply the WQI tool to evaluate the historical changes in the water quality of Duhok Lake during the period from 1999 to 2009. It must be mentioned that the lake's water is one of the main water sources for Duhok Governorate.

1.1 Description of the Study Sites

Two sites were studied in Duhok reservoir which lies in the north part of Duhok, about 2 Km from the city center, of altitude 36º 50' 49 and longitudinal 43º 00' 33, to study physical and chemical variables, one which selected in the right side of the lake, while the second sites were selected on the left side the lake, were carried out seasonally variation over a period of one year (20-1-2009, 20-4-2009, 20-7-2009 and 20-10-2009) respectively (Fig. 1). Duhok dam was established in 1987 on Duhok river an impoundment of surface area around 256 hectares, coming in third in southern Kurdistan of Iraq after Dokan and Derbendikhan lake with a surface area of 27000 and 1200 hectares respectively. It is artificial lake water to the dam is mainly rain, snowmelt and the main tributaries Sundor and Gurmava that on their joining made up Duhok river. Geology of the area consists of clay marl, dolomite, poly clay-limestone and sandstone (Al-Ganabi, 1985). The climate of the studied area is a dry-summer approach Irano-Turanian type characterized by the occurrences of three seasons: a cold winter, mild growing period of spring and hot-dry summer (Al-Shalash, 1966 and Guest, 1966).

2. Sample Collection and Analysis

Historical water quality data related to Duhok Lake were collected in the years 1999-2000 (Raoof, 2002). Also, seasonally water samples were collected from the Lake during (20-1-2009, 20-4-2009, 20-7-2009 and 20-10-2009) respectively, sampling analyzed following methods outlined in the Standard Method for Examination of Water and Wastewater (APHA, 1998). Water samples were collected in stopper fitted polyethylene bottles and refrigerated at 4°C in order to be analyzed as soon as possible. The dissolved oxygen, electrical conductivity and pH were estimated on the spot at the time of sampling.

The study of water quality index is an attempt to evaluate the historical changes in water quality of Duhok Lake. WQI was calculated by weighted index method to determine the suitability of surface water for drinking purposes. WQI was calculated for assessing the suitability of water for biotic communities and also drinking purposes (Table 1 and 2). In the formulation of WQI, the importance of various parameters depends on the intended use of water; here, water quality parameters are studied from the point of view of suitability for human consumption It was done by considering twelve important physicochemical properties using the 'standards' (Permissible values of various parameters) for the drinking water used in this study are those recommended by the WHO (WHO, 2004). In order to calculate WQI ten important parameters, pH, electrical conductivity (EC), total hardness, total alkalinity, dissolved oxygen (DO), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and sulfate (SO_4) have been selected. These parameters maximums contribute to the quality of the lake.

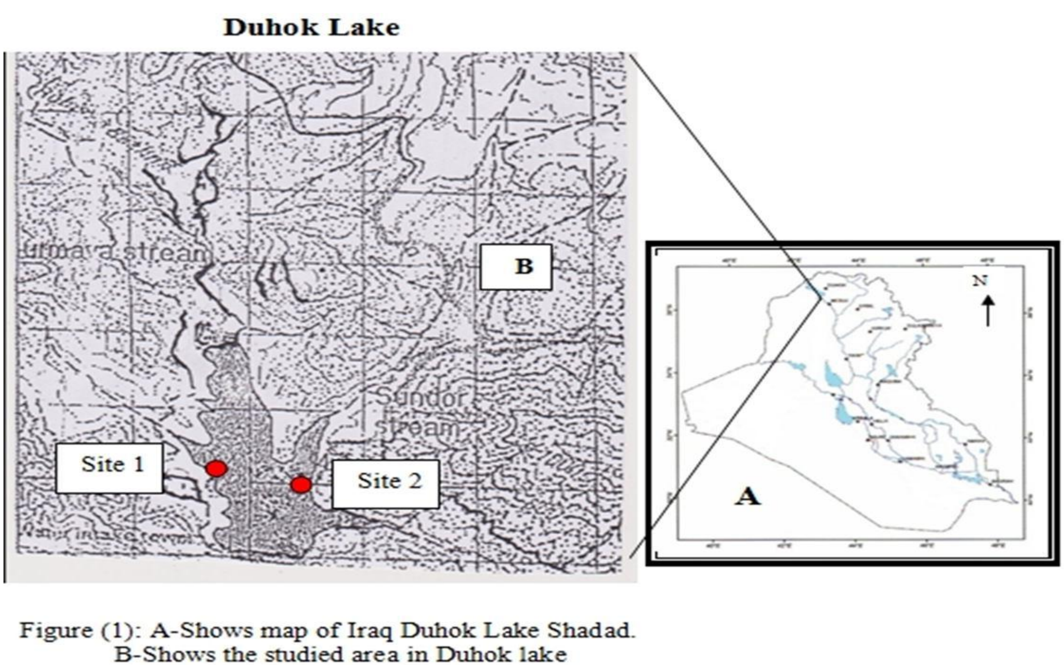

Figure (1): A-Shows map of Iraq Duhok Lake Shadad.
B-Shows the studied area in Duhok lake

The steps for Water quality index (WQI) are:

The quality rating scale for each parameter qi was calculated by using this expression:

$$qi = (Ci / Si) \times 100$$

A quality rating scale (qi) for each parameter is assigned by dividing its concentration (Ci) in each water sample by its respective standard (Si) and the result multiplied by 100.

Unit weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) of the corresponding parameter:

$$Wi = 1 / Si$$

The overall WQI was calculated by aggregating the quality rating (Qi) with unit weight (Wi) linearly:

$$WQI = \left(\sum_{I=1}^{i=n} wi\ qi \right)$$

$$\text{Overall WQI} = \Sigma\ qi\ wi / \Sigma\ wi$$

Table 1. Water quality classification based on WQI value (Ramakrishnaiah *et al.*, 2009).

Water Quality Index Level	Water Quality Status
< 50	Excellent
50-100	Good
100-200	Poor
200-300	Very poor
> 300	Unsuitable

3. Results and Discussion

Water quality index in the historical and the present study is established from important various physicochemical parameters in different seasons. The values of various physicochemical parameters for calculation of water quality index present in Table 3. Season water quality index calculations are depicted in Table 4, 5, 6 and 7.

Table 2. Drinking water standard and unit weight of the water quality parameters.

Parameters	Unit	Water quality standard	Unit weights (Wi)
EC	µs/cm	1000	0.001
pH		6.5-8.5	0.130
Alkalinity	$mgCaCO_3/L$	200	0.01
Hardness	$mgCaCO_3/L$	200	0.01
Dissolved Oxygen	mg /L	5	0.2
Calcium	mg /L	100	0.01
Magnesium	mg /L	30	0.03
Sodium	mg /L	20	0.05
Potassium	mg /L	10	0.1
Sulfate	mg /L	500	0.002

Table 3. Seasonal variation of physicochemical parameters in Duhok Lake during 2009.

Parameters	Winter	Spring	Summer	Autumn
EC	1040	1115	1415	1345
pH	7.6	7.8	8.1	7.8
Alkalinity	204	214	228	219
Hardness	383	391	416	410
Dissolved Oxygen	8.4	8.2	7.8	8.3
Calcium	87	86	103	96
Magnesium	35	32	38	36
Sodium	17	18	20	18
Potassium	4.1	4.7	5.0	4.9
Sulfate	403	405	419	437

Table 4. Calculation of Water Quality Index in winter season.

Parameters	Observed Value	Standard Values	Unit weights (Wi)	Quality rating scale (qi)	Water Quality Index (WQI)
EC	1040	1000	0.001	104.0	0.104
pH	7.6	6.5-8.5	0.133	101.3	13.47
Alkalinity	204	200	0.01	102.0	1.02
Hardness	383	200	0.01	191.5	1.915
Dissolved Oxygen	8.4	5	0.2	168.0	33.6
Calcium	87	100	0.01	87.0	0.87
Magnesium	35	30	0.03	116.6	3.498
Sodium	17	20	0.05	85.0	4.25
Potassium	4.1	10	0.1	41	4.1
Sulfate	403	500	0.002	80.6	0.161
			Σ wi=0.546	**Σqi=1077**	**Σ qi wi=62.988**

Overall WQI = Σ qi wi / Σ wi (115.36)

Table 5. Calculation of Water Quality Index in spring season.

Parameters	Observed Value	Standard Values	Unit weights (Wi)	quality rating scale (qi)	Water Quality Index (WQI)
EC	1115	1000	0.001	111.5	0.115
pH	7.8	6.5-8.5	0.133	104	13.832
Alkalinity	214	200	0.01	107	1.07
Hardness	391	200	0.01	195.5	1.955
Dissolved Oxygen	8.2	5	0.2	164	32.8
Calcium	86	100	0.01	86	0.86
Magnesium	32	30	0.03	106.6	3.198
Sodium	18	20	0.05	100	5.0
Potassium	4.7	10	0.1	47	4.7
Sulfate	405	500	0.002	81	0.162
			Σ wi=0.546	**Σqi=1102.6**	**Σ qi wi=63.692**

Overall WQI = Σ qi wi / Σ wi (115.65)

Table 6. Calculation of Water Quality Index in summer season.

Parameters	Observed Value	Standard Values	Unit weights (Wi)	quality rating scale (qi)	Water Quality Index (WQI)
EC	1415	1000	0.001	141.5	0.141
pH	8.1	6.5-8.5	0.133	108.0	14.36
Alkalinity	228	200	0.01	114	1.14
Hardness	416	200	0.01	208	2.08
Dissolved Oxygen	7.8	5	0.2	156	31.2
Calcium	103	100	0.01	103	1.03
Magnesium	38	30	0.03	126.6	3.798
Sodium	20	20	0.05	100	5.0
Potassium	5.0	10	0.1	50	5.0
Sulfate	419	500	0.002	83.8	0.1676
			Σ wi=0.546	**Σqi=1190.9**	**Σ qi wi=64.316**

Overall WQI = Σ qi wi / Σ wi (117.79)

Table 7. Calculation of Water Quality Index in autumn season.

Parameters	Observed Value	Standard Values	Unit weights (Wi)	quality rating scale (qi)	Water Quality Index (WQI)
EC	1345	1000	0.001	134.5	0.1345
pH	7.8	6.5-8.5	0.133	104	13.832
Alkalinity	219	200	0.01	109.5	1.095
Hardness	410	200	0.01	205	2.05
Dissolved Oxygen	8.3	5	0.2	166	33.2
Calcium	96	100	0.01	96	0.96
Magnesium	36	30	0.03	120	3.6
Sodium	18	20	0.05	90	4.5
Potassium	4.9	10	0.1	49	4.9
Sulfate	437	500	0.002	87.4	0.1748
			Σ wi=0.546	**Σqi=1161.4**	**Σ qi wi=64.446**

Overall WQI = Σ qi wi / Σ wi (118.03)

Table 8. Historical changes in the computed water quality index in Duhok Lake.

Time (Year)	Overall Water Quality Index
1999	143.64
2000	136.27
Winter-2009	115.36
Spring-2009	115.65
Summer-2009	117.79
Autumn-2009	118.03

Among all the physicochemical parameters selected for the water quality index calculation, the importance of Electrical Conductivity (EC) is due to its measure of cations which greatly affects the taste and thus has significant impact on the user acceptance of the water as potable (WHO, 2004 & Pradeep, 1998). It is an indirect measure of total dissolved salts. High conductivity may arise through natural weathering of certain sedimentary rocks or may have an anthropogenic source, e.g. industrial and sewage effluent (WHO, 2004). The results showed that EC values were slightly higher than the permissible level recommended by the WHO for drinking water. The pH of the aquatic systems is an important indicator of the water quality and the extent pollution in the watershed areas. Results obtained for pH varied between 7.60 and 8.10. However, the pH concentration in the study area is within allowable limits for surface water (WHO, 2004). However, the values come also in accordance with the known values of Iraqi inland waters (Rozoska, 1980). The observed values of alkalinity were slightly higher than the permissible level recommended by the WHO for drinking water (WHO, 2004), was ranged from 204-228mg $CaCO_3$/L (Abdo, 2005) reported that pollution by sewage and its decomposition seem to be a possible cause for higher values of alkalinity in the water. This variation of lakes due to the increase in bicarbonate concentrations during hot seasons may be attributed to the fact that the increase in temperature accelerates the organic matter accessible to bacterial decomposition, where the HCO^{3-} is the final product of this decomposition (Abdo, 2005). The Total Hardness (TH) is also an important parameter of water quality whether to be used for domestic, industrial or agricultural purposes. The results obtained by water surveys conducted in this investigation showed that TH values were often higher than the minimal permissible level recommended by the WHO for drinking water (WHO, 2004). The maximum calcium and magnesium concentrations were 103 and 38mg/L respectively. Lake's hardness is affected by the type of minerals in the soil and watershed bedrock and by the amount of lake water coming into contact with these minerals. If a lake gets groundwater from aquifers containing limestone minerals such as calcite ($CaCO_3$) and dolomite ($CaMgCO_3$), hardness and alkalinity shall be high and, higher degree of hardness in the study area may be attributed to the disposal of untreated or improperly treated sewage and industrial waste (Yalçın, 2005). The mean values of DO have never reached critical values in the most times of the study period, indicating good water quality conditions. The minimum value of dissolved oxygen was 7.8mg/L complies with WHO standards and is considered good to sufficient for human consumption and most aquatic biota (Wilcock, 1995). The results of DO in Duhok Lake are consistent with those of unpolluted water bodies in other parts of Iraq (Rozoska, 1980). Unpolluted waters are likely to have dissolved oxygen above 5.0mg/L (WHO, 2004). The present results show a slight variation in the sodium distribution patterns during winter, spring and summer. This is mainly attributed to the high solubility of the salts that keep a homogenous distribution and mass balance for sodium (Wetzel, 1983). However, the high values of the sodium contents was 20mg/L during summer, may be due to the release and the dissolution of the sodium ions from sediment and rocks into the overlying water. The slight seasonal variations in the potassium of the ponds indicate that the conservative nature of K. The ranges of K^+ were found to be from 4.1-5.0mg/L in the studied area. Sodium and potassium concentrations of the water ponds followed the same seasonal trend. Sulphate is naturally present in surface water as SO_4^{2-}. Industrial discharges and atmospheric precipitation can also add significant amounts of sulphate to surface waters. The concentration of the sulphate value ranged from 403 to 437mg/L which is within the tolerable limits of 500mgL^{-1} (WHO, 2004). The computed overall WQI was ranged from 143.64 during 1999 to 136.27 during 2000 and therefore can be categorized as “poor water” during 1999 and 2000 to “Poor water”, and during this study were sampled collected seasonally during 2009, computed water quality index values ranged from 115.36 during winter, 115.65 during spring, 117.79 during summer and 118.03 during. The high value of WQI has been found mainly from higher value of EC, Alkalinity and Hardness. This could be attributed to improper disposal of wastes, cottage activities, and large quantity of agricultural and urban run-off, sewage, over application of inorganic fertilizer, improper operation and maintenance of septic system (WHO, 2004). During the last decade, Duhok Lake has been subjected to a rapid decline in water quality status which is possibly due to the increase in the population and human activities. It is clear that the domestic discharge and agricultural activities in addition to the last ten years of drought are the major threats to Duhok Lake’s water quality.

4. Conclusion

The results obtained from the study reveals that Duhok Lake is polluted and this could be attributed to anthropogenic activities such as agricultural activities, cottage industries. The WQI of the samples was exceeded 100, the upper limit for drinking water. Application of Water Quality Index (WQI) in this study has been found useful in assessing the overall quality of water and to get rid of judgment on the quality of the water. This method appears to be more systematic and gives a comparative evaluation of the water quality of sampling stations. It is also helpful for the public to understand the quality of water as well as being a useful tool in many ways in the field of water quality management.

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