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EVALUATION OF WATER QUALITY OF HEMREN LAKE

Saad Sh. Sammen
Engineering College, Diyala University
E-mail : Saad123engineer@yahoo.com
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ABSTRACT:- In this study Water Quality Index (WQI) was applied in Hemren Lake, Diyala province, Iraq using ten water quality parameters (pH, Electrical Conductivity, Hardness, Total Dissolve Soluble, Sodium, Calcium, Magnesium, Potassium, Chloride, Phosphate) from 2008 to 2010 to evaluate the suitability of Hemren Lake ecosystem for drinking and irrigation uses. The Weighted Arithmetic Index method (WAM) and the Canadian Council of Ministers of the Environment Water Quality Index methodology (The CWQI 1.0 model) were used to calculate the water quality index (W.Q.I). The results indicated that drinking water quality of Hemren Lake is good and marginal for the study period according to (WAM) and (CCME) respectively, while the irrigation water quality is good and according to (WAM) and (CCME). 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, Water Quality Assessment, Hemren Lake.

1. INTRODUCTION

The availability of water both in terms of quality and quantity is essential for the very existence of mankind. Water, though indispensable and plays a pivotal role in our lives, yet is one of the most badly abused resources. Lack of awareness and civic sense, use of inefficient methods and technology lead to more than 50% of water wastage in the domestic, agriculture & industrial sectors. Water pollution is rendering much of the available water unsafe for consumption. There is heavy extraction of water for domestic, industrial and agricultural purpose. Age-old customs and habits of community, cattle bathing and washing in rivers are responsible for rampant pollution of river water. The release of domestic waste water, agricultural runoff water & industrial effluents promote excessive growth of algae in water bodies, which results in their eutrophication.

In Iraq Water resources, especially in the last two decades have also suffered of 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,2010 and Jones,2008). It is not surprising that, due to the above factors, studying water quality is so much important to be carried out in order to keep our awareness and understanding of our environment. Also, accurate information on the condition and trends of water resources quantity and quality is required as a basis for economic and social development, and for the development and maintenance of environmental quality.

Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of surface water, and is widely used in multiple scientific publications related to the necessities of sustainable management (Parparov, 2006). Water quality in an aquatic ecosystem is determined by many physical, chemical and biological factors (Sargaonkar, 2003). Therefore, particular problem in the case of water Quality monitoring is the complexity associated with analyzing the large number of measured variables (Boyacioglu, 2006) and High variability due to anthropogenic and natural influences (Simeonov, 2002).

There are a number of methods to analyze water quality data that vary depending on informational goals, the type of samples, and the size of the sampling area. Research in this area has been extensive, as indicated by the number of methods proposed or developed for classification, modeling and interpretations of monitoring data (Simeonov, 2002 and Boyacioglu, 2006). One of the most effective ways to communicate information on water quality trends is by use of the suitable indices (Dwivedi, 2007). Indices are based on the values of various physico-chemical and biological parameters in a water sample. The use of indices in monitoring programs to assess ecosystem health has the potential to inform the general public and decision-makers about the state of the ecosystem (Nasirian, 2007 and Simoes, 2008).

2. WATER QUALITY INDEX (WQI)

A Water Quality Index (WQI) is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water (Deininger, 1971; Harkins, 1974 and Tiwari, 1988). The objective of water quality index is to turn complex water quality data into information that is understandable and usable by the public. A single number cannot tell the whole story of water quality; there are other water quality parameters that are not included in the index. However, a water quality index based on some very important can provide a simple indicator of water quality. In general, water quality indices indicator data from multiple water quality parameters into a mathematical equation that rates the health of a water body with number.

The concept of indices to represent gradation in water quality was first proposed by Horton (Horton, 1965). It indicates the quality by an index number, which represents the overall quality of water for any intended use. Water Quality Index (WQI) method has been applied in many countries to assess the overall status of their water bodies, such as United Status (Canter, 1996); UK (House, 1989), Canada (Khan, 2003 and Lumb, 2006), (Sisodia, 2006); India (Dwivedi, 2007 and Chaturvedi, 2010); Brazil (Stambuk, 1999); Bangladesh (Alam, 2006); Kenya (Otieno, 2008). In Iraq, there are three studies about application of WQI method to assess the health state of Euphrates river (Al-Othman, 2010) and Tigris river (Alobaidi, 2010) and Dokan Lake ecosystem (Alobaidi, 2010). The present study is aimed to calculate the Water Quality Index (WQI) of the Hemren lake in order to assess the suitability of its water for drinking and irrigation uses.

3. MATERIALS AND METHODS

3-1. Description of the Study Area

The area study (Hemren Lake) lies in the northwestern part of Iraq, about 150 Km from the Baghdad city within Diyala governorate (Figure1). The lake has a full–pool operating altitude of 92m above mean sea level and its boundaries extend between a latitude of 25º61' 34º14' N and a longitude of 30º12'- 44º09'E. It was formed during 1976-1981 by Hemren dam on the Diyala River. Morphometric features of Hemren lake are as follow: the volume of the lake is 2.06 billion cubic meters with a surface area of about 327 km^2 at high level period. The area faced two successive drought years (2008 and 2009). Besides that, the population increased and quite different industrial activities took place.

3.2. Sample Collection and Analysis

Water quality data for Hemren Lake were collected in the years 2008 – 2010 (Water Resources Ministry). The water samples were then analyzed for 10 parameters: pH, Electrical Conductivity, , Hardness, Total Dissolve Soluble , Sodium, Calcium, Magnesium, Potassium, Chloride, phosphate.

3.3. Calculation of the WQI

The Water Quality Index (WQI) was calculated using two methods the Weighted Arithmetic Index method and the Canadian council of Ministers of the Environment Water Quality Index methodology (CCME WQI) b using the CWQI 1.0 model.

3.3.1. The Weighted Arithmetic Index Method (WAMWQI)

The calculation and formulation of the WQI involved the following steps:

1- In the first step, Relative weight (Wi) for each parameter was calculated by a value inversely proportional to the recommended standard (Si) of the corresponding parameter:

$$Wi = 1 / Vs \qquad \ldots\ldots\ldots\ldots\ldots\ldots\text{(1)}$$

Where:

Wi : Relative weight

Vs : recommended standard value for each parameter.

2- In the second step, the In the third step, a quality rating scale (Qi) for all the parameter was calculated by using this expression:

$$\text{Quality rating, } Qi = 100\,[(Vn - V_i) / (Vs - V_i)] \quad \ldots\ldots\ldots\ldots\text{(2)}$$

Where:

Vn: actual amount of nth parameter

Vi: the ideal value of this parameter (Vi = 0, except for pH = 7.0)

Vs: recommended WHO standard of corresponding parameter

Finally, the water quality index was calculated by using this expression:

$$\text{Water Quality Index (WQI)} = \sum Qi\,Wi / \sum Wi \quad \ldots\ldots\ldots\ldots\text{(3)}$$

Generally, WQI are discussed for a specific and intended use of water. In this study the WQI for human consumption is considered and permissible WQI for the drinking water is taken as 100.

The computed WQI values could be classified according to the table (1) (Ramakrishuaiah, 2009)

3.2.2. The Canadian council of Ministers of the Environment method (CCME WQI)

For the calculation of Water Quality Index (WQI) by using the Canadian Council of Minister of the Environment Water Quality Index (CWQI 1.0 model), The index is based on three attributes of water quality that relate to water quality objectives:- (CCME, 2001)

1- Scope (How many?) The number of water quality variables that do not meet objectives in at least one sample during the time period under consideration, relative to the total number of variables measured.
2- Frequency (How often?) The number of individual measurements that do not meet objectives, relative to the total number of measurements made in all samples for the time period of interest.
3- Amplitude (How much?) The amount by which measurements which do not meet the objectives depart from those objectives.

The body of water, the period of time and the variables and objectives should be defined first. Then the three factors that make up the index must be calculated. The calculation of F1 and F2 is relatively straightforward and F3 requires some additional steps (CCME, 2001).

F_1 (Scope) represents the percentage of variables that do not meet their objectives at least once during the time period under consideration (failed variables), relative to the total number of variables measured.

$$F_1 = \left[\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right] \times 100 \qquad \text{............................(4)}$$

F_2 (Frequency) represents the percentage of individual tests that do not meet objectives (failed test).

$$F_2 = \left[\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right] \times 100 \qquad \text{.............................(5)}$$

F_3 (Amplitude) represents the amount by which failed test values do not meet their objectives. F_3 is calculated in three steps.

1. The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an excursion and is expressed as follows:

When the test value must not exceed the objective:

$$excursion_{(i)} = \left[\frac{\text{Failed Test Value}}{\text{Objective}_{(j)}}\right] - 1 \qquad \text{......................(6)}$$

For the cases in which the test value must not fall below the objective:

$$\text{excursion}_{(i)} = \left[\frac{\text{Objective}_{(j)}}{\text{Failed Test Value}_{(i)}}\right] - 1 \qquad \text{......................(7)}$$

If the objective equals zero:

$\text{excursion}_{(i)}$ = Failed Test ....(8)

2. The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as normalized sum of excursions, or NSE, is calculated as:

$$NSE = \frac{\sum_{i=1}^{n} \text{excursion}_{(i)}}{\text{number of tests}} \qquad \text{......................(9)}$$

$$F_3 = \left[\frac{NSE}{0.01NSE + 0.01}\right] \qquad \text{......................(10)}$$

Once the factors have been obtained, the index itself can be calculated by summing the three factors as if they were vectors. The sum of the squares of each factor is therefore equal to the square of the index. This approach treats the index as a three-dimensional space defined by each factor along one axis. With this model, the index changes in direct proportion to changes in all three factors.

$$WQI = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right] \qquad \text{......................(11)}$$

The divisor (1.732) normalizes the resultant values to a range between (0) and (100), where (0) represents the worst water quality and (100) represents best water quality. The computed WQI values could be classified according to the table (2)

4. RESULTS AND DISCUSSION

In this study, The WQI was used to aggregate diverse parameters and their dimensions into a single score, displaying a picture of the changing (seasonal and yearly) for water quality of Hemren lake. CCMEWQI was calculated by using CCME 1.0 software.

It was observed From the computed annual WQI for the drinking use ranged from 71.47 during 2008 and 79.2 during 2009 to 61.67 during 2010 according to (WAM) and therefore can be categorized into Good water as shown in (figure 2 and table 3) while ranged from 48 during 2008, 47.25 during 2009 to 53.5 during 2010 according to (CCME) and therefore can be categorized into marginal water as shown in (figure 3 and table 3).

Also, it was observed that annual WQI for the irrigation use ranged from 81.47 during 2008 and 85.17 during 2009 to 84.1 during 2010 according to (WAM) and therefore can be categorized into good water as shown in (figure 4 and table 4), while ranged from 89.5 during 2008, 100 during 2009 to 100 during 2010 according to (CCME) and therefore can be categorized into good and excellent water as shown in (figure 5 and table 4).

However, it was generally observed that 100% of monthly computed drinking WAM WQI values for the study period have fallen under good water quality as shown in (figure 6) and 45.45%, 45.45% and 9.1% of monthly computed drinking CCME WQI values for the study period fallen under poor, marginal and fair water quality respectively as shown in (figure 7) . While for irrigation WQI 100% of all monthly computed WAM WQI values from 2008 to 2010 have fallen under good water quality and 81.8% ,9.1% and 9.1% of computed CCME WQI have fallen under excellent, good and fair water quality.

Descriptive statistics for all water quality parameters examined are shown in (Table5).While the correction factore were shown in tables (6 - 9). In order to reach a better view on the causes of deteriorated water quality in the Hemren lake water, selected results from the determination of water quality parameters are discussed below.

The results of pH varied from 7.19 to 8.18, indicating that the water samples are almost neutral to sub-alkaline in nature. pH is an important factor that determines the suitability of water for various purposes (Ahipathy, 2006). The observed values show a relative agreement with pH values of surface water which lie within the range of 6.5 to 8.5 (World Health

Organization, 2004).However, the values come also in accordance with the known values of Iraqi inland waters (Rozoska, 1980).

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 (World Health Organization, 2004 and 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 (World Health Organization, 2004). The results showed that EC values were slightly higher than the permissible level recommended by the WHO for drinking water.

The observed values of (total dissolved solids (T.D.S)) and (calcium, magnesium) were slightly lower than and higher than the permissible level recommended by the WHO for drinking water.

Chloride, sodium and potassium values are lower than the permissible level recommended by the WHO for drinking water.

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. Still, no significant correlation with WQI was observed.

Finally the observed values showed that the sulphate is (31.11)% higher than than the permissible level recommended by the WHO for drinking water.

CONCLUSIONS

There are some limitations of WQI. For instance, WQI may not carry enough information about the real quality situation of the water. Also many uses of water quality data cannot be met with an index. But there are more advantages of WQI than disadvantages. An index is a useful tool for "communicating water quality information to the public and to legislative decision makers;" it is not "a complex predictive model for technical and scientific application" (McClelland, 1974). The Water Quality of the Hemren reservoir was found that the water was almost clear throughout the sampling time. This quality is impacted by ten Physico- Chemical and bacteriological parameters: pH, Electrical Conductivity, , Hardness, Total Dissolve Soluble , Sodium, Calcium, Magnesium, Potassium, Chloride, phosphate.

Therefore, the preventative measures in Hemren Lake must be implementing for good water quality in multiuse.

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Table (1):- Water Quality Classification Based On WQI Value According To (WAM).

W.Q.I Value	Water Quality
< 50	Excellent
50 – 100	Good
100 – 200	Poor
200 – 300	Very Poor
> 300	Unsuitable for Drinking

Table (2):- Water Quality Classification Based on WQI Value According to (CCME, 2001).

CCME WQI Categories	CCME WQI Value	Water quality status
Excellent	(95 – 100)	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within objectives virtually all of the time.
Good	(80 – 94)	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
Fair	(65 – 79)	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
Marginal	(45 – 64)	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Poor	(0 – 44)	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

Table (3):- Annual Water Quality Index for Drinking use in Hemren Lake.

Year	WAM W.Q.I	CCME W.QI
2008	71.47	48
2009	79.2	47.25
2010	61.67	53.5

Table (4):- Annual Water Quality Index for irrigation use in Hemren Lake.

Year	WAM W.Q.I	CCME W.QI
2008	81.47	89.5
2009	85.17	100
2010	84.1	100

Table (5):- Statistical summary of Hemren Lake water quality data.

parameters	Minimum Value	Maximum Value	Mean	Standard Deviation
PH (pH unit)	7.19	8.18	7.78	0.30
EC (µS/cm)	477	921	678.63	142.77
T.D.S (mg/L)	120	716	452.67	147.95
Ca (mg/L)	34.852	212.97	82.38	34.85
Mg (mg/L)	18.3	74.4	36.16	13.31
Na (mg/L)	12	95	34.79	22.47
K (mg/L)	2.9	5.6	4.50	0.88
Cl (mg/L)	16	110	39.85	22.39
SO4 (mg/L)	20	500	196.67	115.56
T.H (mg/L)	162.16	536.53	340.28	91.08

Table (6):- Correction Factors for Drinking Water According to CCME.

	WQI	PH	EC	T.D.S	Ca	Mg	Na	K	Cl	SO4	T.H
WQI	1										
PH	0.078	1									
EC	-0.645	0.072	1								
T.D.S	0.307	0.074	-0.259	1							
Ca	-0.527	-0.111	0.298	0.094	1						
MG	-0.735	0.043	0.646	-0.091	0.351	1					
Na	-0.192	0.145	0.221	-0.015	-0.445	0.509	1				
K	0.305	0.067	0.078	0.215	-0.286	0.128	0.37	1			
Cl	-0.386	0.148	0.789	-0.152	0.159	0.597	0.277	0.431	1		
SO4	-0.322	-0.279	0.186	-0.122	0.071	0.22	0.079	0.054	0.252	1	
T.H	-0.2	-0.018	-0.184	0.017	0.268	0.218	0.127	-0.222	-0.354	-0.520	1

Table (7):- Correction Factors for Drinking Water According to WAM.

	WQI	PH	EC	T.D.S	Ca	Mg			Cl	Na	K
WQI	1										
PH	0.548	1									
EC	0.259	0.072	1								
T.D.S	0.047	0.074	-0.259	1							
Ca	-0.160	-0.111	0.298	0.094	1						
MG	0.349	0.043	0.646	-0.091	0.351	1					
Na	0.455	0.145	0.221	-0.015	-0.445	0.509	1				
K	0.233	0.067	0.078	0.215	-0.286	0.128	0.37	1			
Cl	0.532	0.148	0.789	-0.152	0.159	0.597	0.277	0.431	1		
SO4	-0.089	-0.279	0.186	-0.122	0.071	0.22	0.079	0.054	0.252	1	
T.H	-0.053	-0.018	-0.184	0.017	0.268	0.218	0.127	-0.222	-0.354	-0.520	1

Table (8):- Correction Factors for Irrigation Water According to WAM.

	WQI	PH	EC	T.D.S	Ca	Mg	Na	K	Cl	SO4	T.H
WQI	1										
PH	0.078	1									
EC	-0.645	0.072	1								
T.D.S	0.307	0.074	-0.259	1							
Ca	-0.527	-0.111	0.298	0.094	1						
MG	-0.735	0.043	0.646	-0.091	0.351	1					
Na	-0.192	0.145	0.221	-0.015	-0.445	0.509	1				
K	0.305	0.067	0.078	0.215	-0.286	0.128	0.37	1			
Cl	-0.386	0.148	0.789	-0.152	0.159	0.597	0.277	0.431	1		
SO4	-0.322	-0.279	0.186	-0.122	0.071	0.22	0.079	0.054	0.252	1	
T.H	-0.2	-0.018	-0.184	0.017	0.268	0.218	0.127	-0.222	-0.354	-0.520	1

Table (9):- Correction Factors for Irrigation Water According to WAM.

	WQI	PH	EC	T.D.S	Ca	Mg	Na	K	Cl	SO4	T.H
WQI	1										
PH	0.539	1									
EC	0.406	0.072	1								
T.D.S	0.011	0.074	-0.259	1							
Ca	-0.050	-0.111	0.298	0.094	1						
MG	0.465	0.043	0.646	-0.091	0.351	1					
Na	0.498	0.145	0.221	-0.015	-0.445	0.509	1				
K	0.440	0.067	0.078	0.215	-0.286	0.128	0.37	1			
Cl	0.602	0.148	0.789	-0.152	0.159	0.597	0.277	0.431	1		
SO4	-0.072	-0.279	0.186	-0.122	0.071	0.22	0.079	0.054	0.252	1	
T.H	0.008	-0.018	-0.184	0.017	0.268	0.218	0.127	-0.222	-0.354	-0.520	1

Fig. (1):- Hemren Lake Basin.

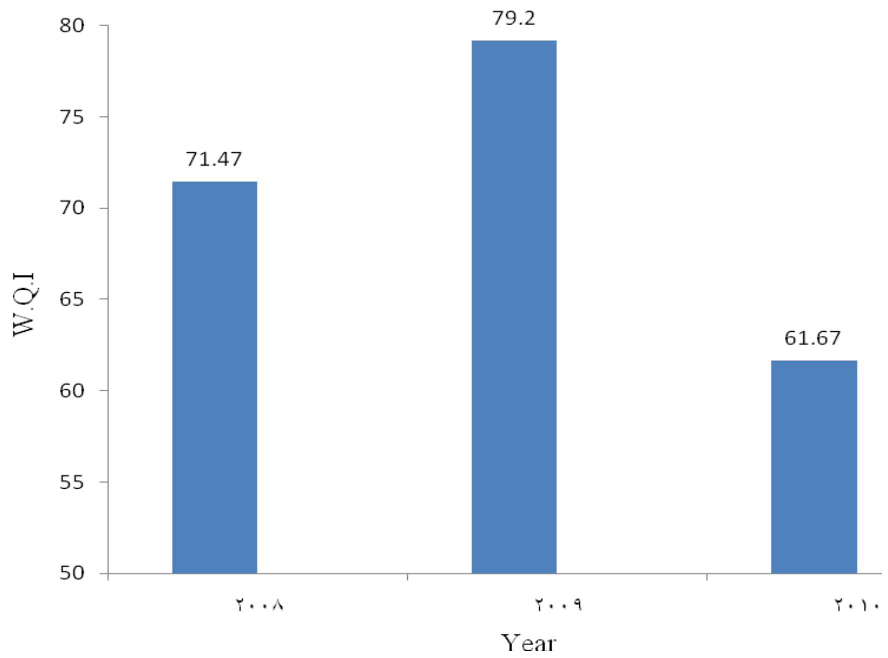

Fig. (2):- Annual Water Quality Index for drinking use According to WAM.

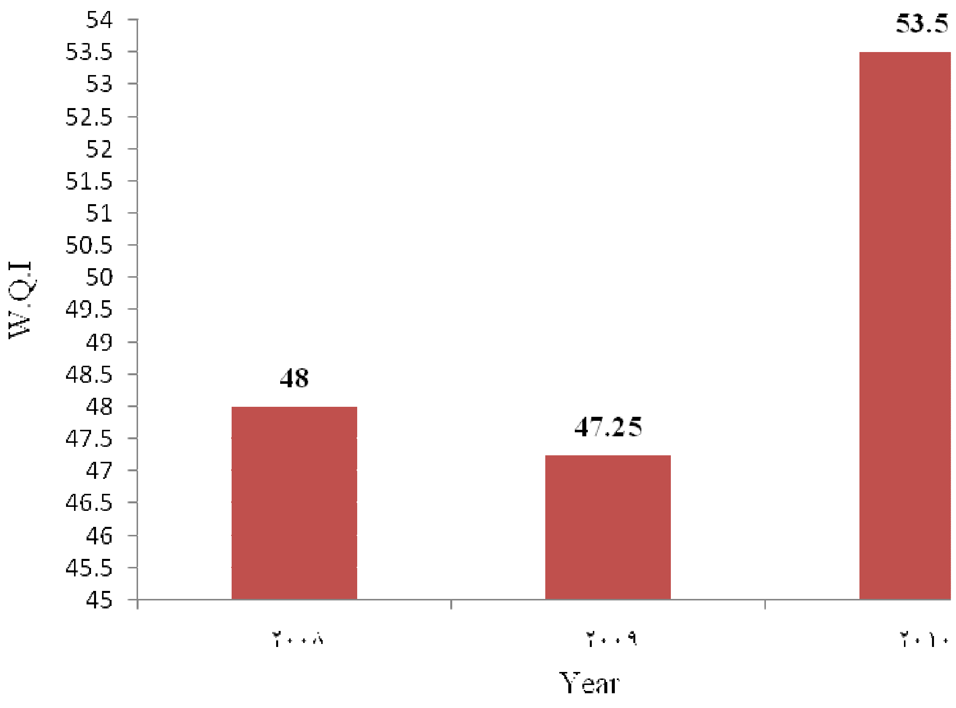

Fig. (3):- Annual Water Quality Index for drinking use According to CCME.

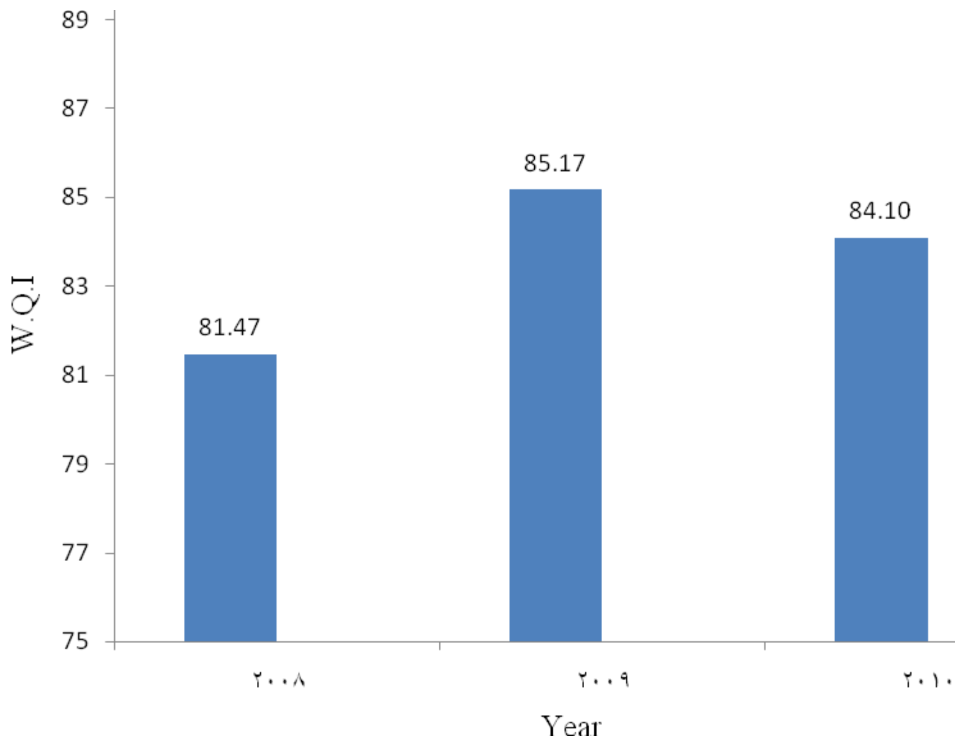

Fig. (4):- Annual Water Quality Index for irrigation use According to WAM.

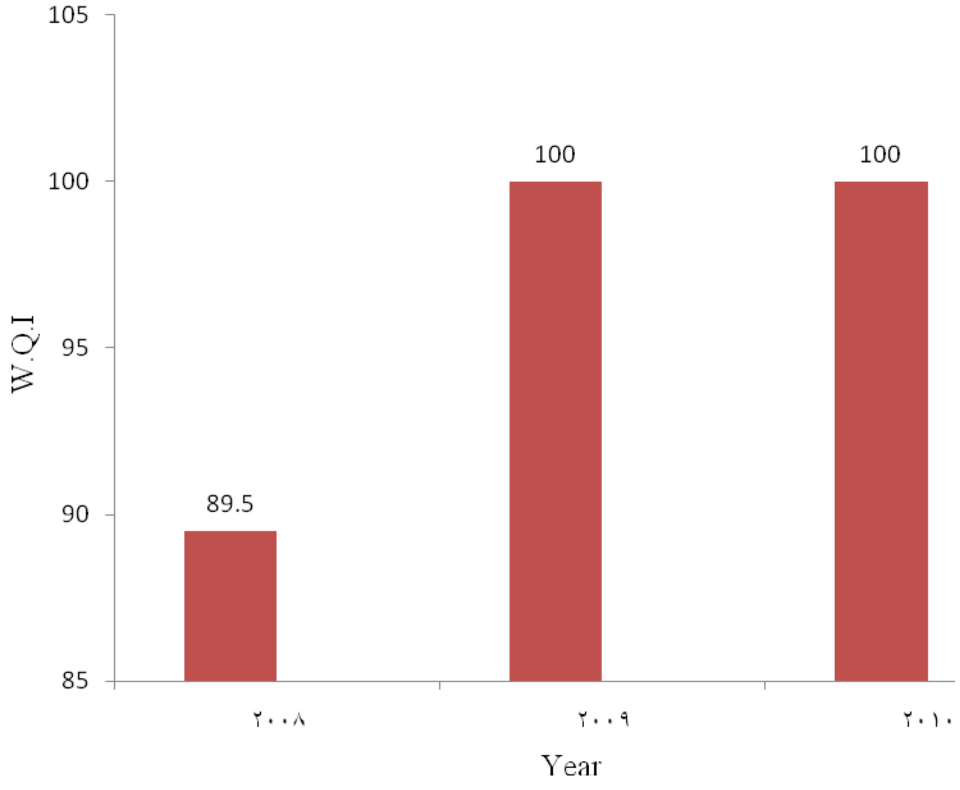

Fig. (5):- Annual Water Quality Index for irrigation use According to CCME.

Fig. (6):- Monthly Water Quality Index for drinking use According to WAM.

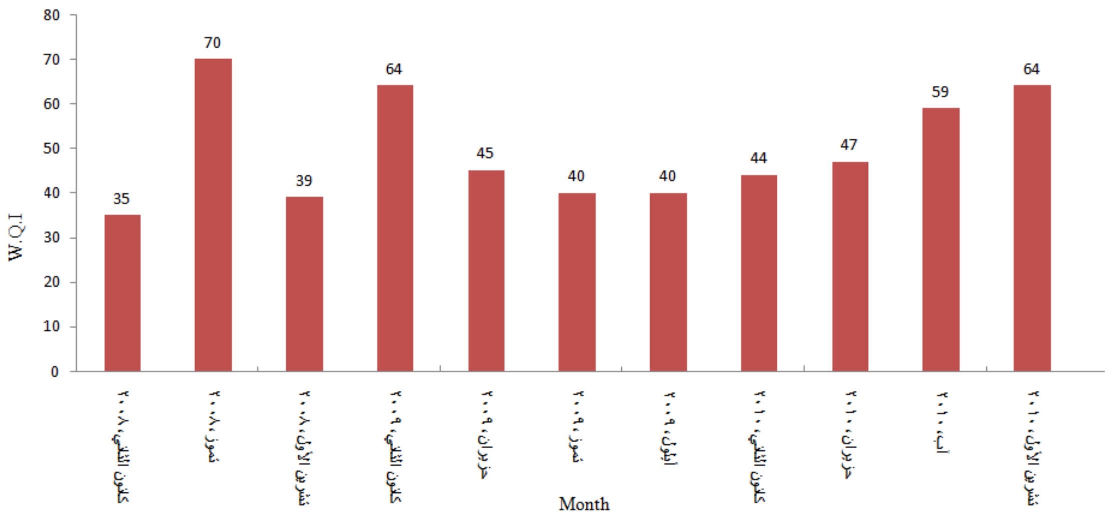

Fig.(7):- Monthly Water Quality Index for drinking use According to CCME.

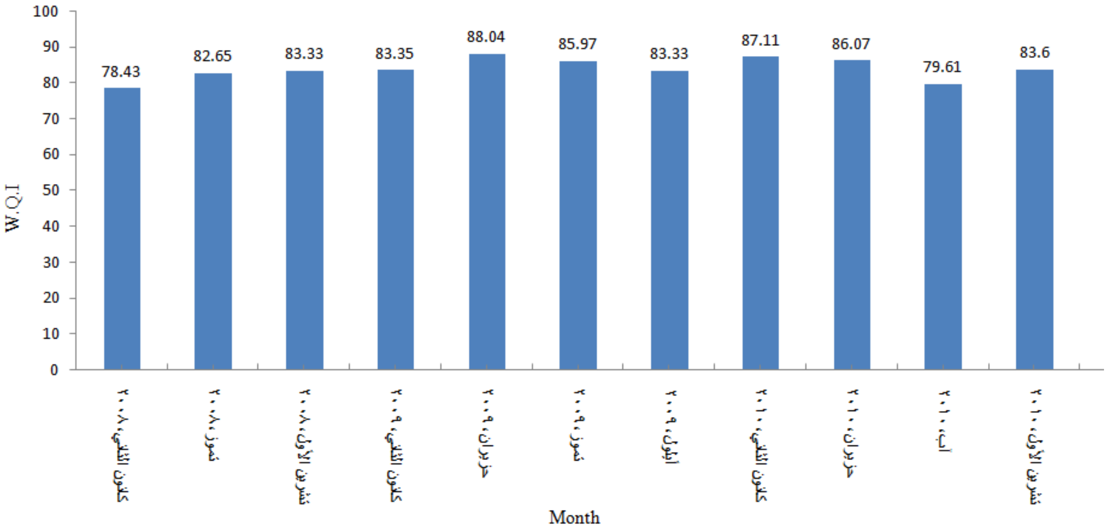

Fig.(8):- Monthly Water Quality Index for irrigation use According to WAM .

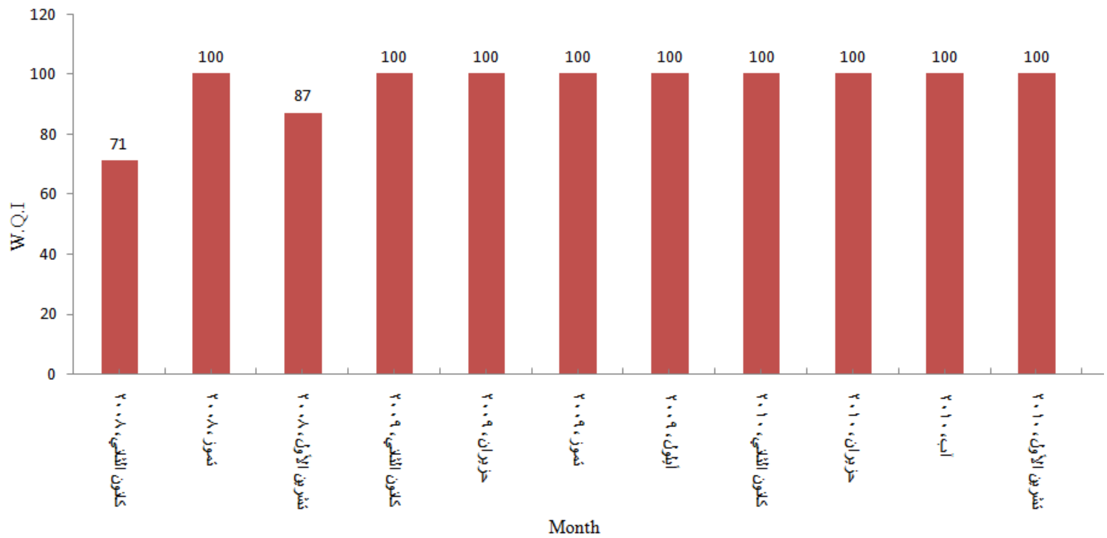

Fig.(9):- Monthly Water Quality Index for irrigation use According to CCME.

تقييم نوعية المياه لبحيرة حمرين

سعد شوكت سمين

مدرس مساعد

كلية الهندسة _جامعة ديالى

الخلاصة

في هذه الدراسة تم تطبيق دليل نوعية المياه لبحيرة حمرين في محافظة ديالى – العراق ، باستعمال عشرة عناصر هيدروكيمائية وهي (مقياس PH ، التوصيلة الكهربائية، العسرة، الاملاح القابلة للذوبان، الصوديوم، الكالسيوم، المغنيسيوم، البوتاسيوم، الكلور، والفوسفات) لتقييم مدى ملائمة النظام المائي في بحيرة حمرين مياه شرب او ري. طريقة الدليل الحسابي الموزون وطريقة دليل نوعية المياه لمجلس وزراء البيئة والذي تم تطبيقه من خلال برنامج رياضي وهو (CCME WQI 1.0) استعملتا لحساب دليل نوعية المياه. النتائج اظهرت ان نوعية مياه الشرب في بحيرة حمرين جيدة وهامشية طبقاً لطريقة الدليل الحسابي الموزون وطريقة دليل مجلس وزراء البيئة على التوالي. اما نوعية مياه الري فكانت جيدة و جيدة – ممتازة طبقاً لطريقة الدليل الحسابي الموزون وطريقة دليل مجلس وزراء البيئة على التوالي. عملية ايجاد دليل نوعية المياه تعتبر اداة مهمة بالنسبة لتقييم نوعية المياه لبحيرات العراق.