Comparison of Water Quality Indices (Bani-Hassan River as a Case Study)

مقارنة مؤشرات جودة المياه(نهر بني حسن كحالة دراسية)

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Abstract

Water Quality Indices (WQI's) are tools to determine the conditions of water quality and provide overall summaries of water quality and potential trends of water quality on a simple and scientific basis.

The present research compares the results of the Canadian WQI method with two other water quality index methods (Mierels WQI and Weighted Arithmetic Index) for irrigation and drinking purposes. Six locations were being chosen on the Bani-Hassan River. Monthly parameters of raw water analysis during the period January to December 2015 were obtained to determine water quality indices. These parameters were: pH, EC, TDS, Turbidity, Total Hardness (TH), Ca^{+2}, Mg^{+2}, K^{+}, Na^{+}, Cl^{-}, SO_4^{-2}, $HCO_3^{-}$and Sodium Absorption Ratio (SAR).

The results of applying Canadian WQI and Weighted Arithmetic Index (WAI) for assessing the suitability of Bani-Hassan River for drinking purpose showed that; Canadian WQI method is classified water as (Fair) water quality while WAI method results is ranked it as (unsuitable) water for drinking usage.

In the case of the suitability of water for irrigation use, the results of applying Meireles WQI equations showed that the water quality of Bani-Hassan River is classified as a (Moderate Restriction) in water use, while the classification of the water using the Canadian equations was good for irrigation purpose.

When comparing (WQI) results of Canadian technic with two other technics (Weighted Arithmetic Index and Mieriles WQI) it is easy to say that Canadian method gives higher water quality value than the two other methods, in another word,Canadian Water Quality Index considered more elastic, however, the Weighted Arithmetic Index and Mieriles WQI methods utilized if there is need for restrictive control of water using.

Statistical analysis of the two methods (Canadian WQI and Mierels WQI) for irrigation use showed that there is a significant difference between the two technics results at significance level (0.05).

Keywords: Water Quality Index, Canadian Water Quality Index, Weighted Arithmetic Index, Mieriles Water Quality Index.

المستخلص

مؤشرات جودة المياه (WQI) هي أدوات لتحديد نوعية المياه وتوفر ملخصات عامة لجودة المياه والاتجاهات المحتملة لنوعية الماء على أساس بسيط و علمي.

يقارن هذا البحث طريقة الكندية لمؤشر نوعية المياه مع طرقتين اخرى لمؤشر نوعية المياه (Mierels WQI and Weighted Arithmetic Index) لأغراض الري والشرب. تم اختيار ستة مواقع على نهر بني حسن . تم الحصول على نتائج الشهرية لتحليل الماء الخام للفترة يناير إلى ديسمبر 2015 لتحديد مؤشرات نوعية المياه. تحليل المياه كانت من حيث: التوصيلية الكهربائية، الأملاح الذائبة الكلية، الرقم الهيدروجيني، العكارة، العسرة الكلية، الكالسيوم، المغنيسيوم، البوتاسيوم، الصوديوم، الكلورايدات، الكبريتات، الكاربونات، و نسبة امتصاص الصوديوم.

اظهرت نتائج تطبيق الطريقتين CWQI و WAI لتقييم مدى صلاحية مياه نهر بني حسن لغرض الشرب؛ ان الطريقة الكندية لمؤشر جودة المياه صنفت المياه بانها ذات جودة مقبوله في حين ان نتائج طريقة WAI قد صنفت المياه بانها ذات

جودة غير مقبولة لغرض الشرب.
اما في حالة مدى ملائمة المياه لغرض الري، اظهرت نتائج تطبيق معادلات (Meireles WQI) ان نوعية مياه نهر بني حسن تصنف على أنها ذات (تقييد معتدل) في استخدام المياه، في حين أن استخدام المعادلات الكندية تصنف مياه النهر بانها جيدة لغرض الري.
عند مقارنة التقنية الكندية مع التقنيتين الأخرى (Weighted Arithmetic Index and Mieriles WQI) فمن السهل القول أن الطريقة الكندية تعطي قيم اعلى لنوعية المياه من الطريقتين الأخرى، بعبارة أخرى، مؤشر نوعية المياه الكندي يعتبر أكثر مرونة، ومع ذلك، فإن مؤشرات طريقتين Weighted Arithmetic Index وMieriles WQI تستخدم إذا كانت هناك حاجة لمراقبة تقييدية على استخدام المياه.
وأظهر التحليل الإحصائي لنتائج الطريقتين Canadian WQI وMierels WQI لاستخدام المياه للري أن هناك فرقا ملحوظا بين نتائج التقنيتين عند مستوى الدلالة (0.05).

1. Introdution

In an endeavor to convey the water quality data in a simple manner, attempts have been made to formulate one or may a few numbers, which have been prepared to evaluate the water quality data. Such usually dimensionless numbers are called indices[1].

Water quality index (WQI) is a single term to describe the comprehensive water quality condition. It is a very useful method to select proper treatment technique to meet the concerned issues, compare the water quality of different resources and determine the health of a watershed in the different parts of it [2]. Meanwhile, the water quality index is used to understand the changes in water quality of ecosystems for a certain time period.

Using of the index in evaluating water quality has been recently innovated. Horton [3] was the first who proposed an index to describe water quality. His method includes computing (WQI) using the arithmetic weighted mean technic. Brown et al [4], improved Horton index. His work was supported by the National Sanitation Foundation (NSF) and so referred as (NSFWQI). Bahargava [5] proposed a WQI model to assess the Ganga River in India using sensitivity function technique. Canadian (WQI) was proposed by the Canadian Council of Ministers of the Environment (CCME) [6]. The CCME WQI or Canadian Water Quality Index (CWQI) water quality is based on Harmonic Square Sum. Meireles, et al[7] developed the irrigation water quality index in the Acarau Basin, Brazil. Several water quality indices have been formulated by several researchers and organizations to compare various water quality parameters such as Oregon Water Quality Index (OWQ) [8] , Florida Stream Water Quality Index (FWQI) [9], Nagles et al.[10], Pandey and Sundaram[11], Hèbert method [12] and etc.

The present study aimed to evaluate the application of the Canadian WQI to monitor the suitability of surface water quality in Bani-Hassan River for irrigation and drinking purposes and comparing the results of this index with other two methods (Arithmetic Mean Index method and Meireles WQI method).

2. Methodology

2.1. Case Study

The Bani-Hasan River branched from the right side of the Euphrates River. It flows from the Al-Hindiya Barrage on Euphrates river and then heading towards the south in parallel to the right bank of the Shatt Al-Hindiya for a distance about 65 km passing through an agricultural area characterized by groves dense of fruit trees and date palm. The length of the stream in Karbala province is about 44.5 km and 20.5km distributed between Najaf and Babylon provinces. The total area which is irrigated by the river is about 114000 acres. The design discharge of the river is about 45m^3/Sec. A few researchers were focused on this river. The present study attempt to give further basic information about physicochemical properties of this river.

2.2. Sampling and Analysis

Six stations distributed along Bani-Hasan River has been selected to determine the water quality index. These stations are located between latitudes 32° 36′ 54" N to 32° 32′ 37.7" N and longitudes 44°14′ 7" E to 44°14′ 3.5". Figure (1) illustrates the locations of these stations.

To determine the suitability of water quality of Bani-Hassan River for irrigation and drinking usages, monthly parameters for raw water during the period January to December 2015 were obtained from the Directorate of Karbala water and then organized. These physicochemical parameters were: Turbidity, Total Hardness (TH), pH, EC, TDS, HCO_3^-, Cl^-, SO_4^{2-}, Ca^{2+}, $Mg^{2+}$and Na^+.

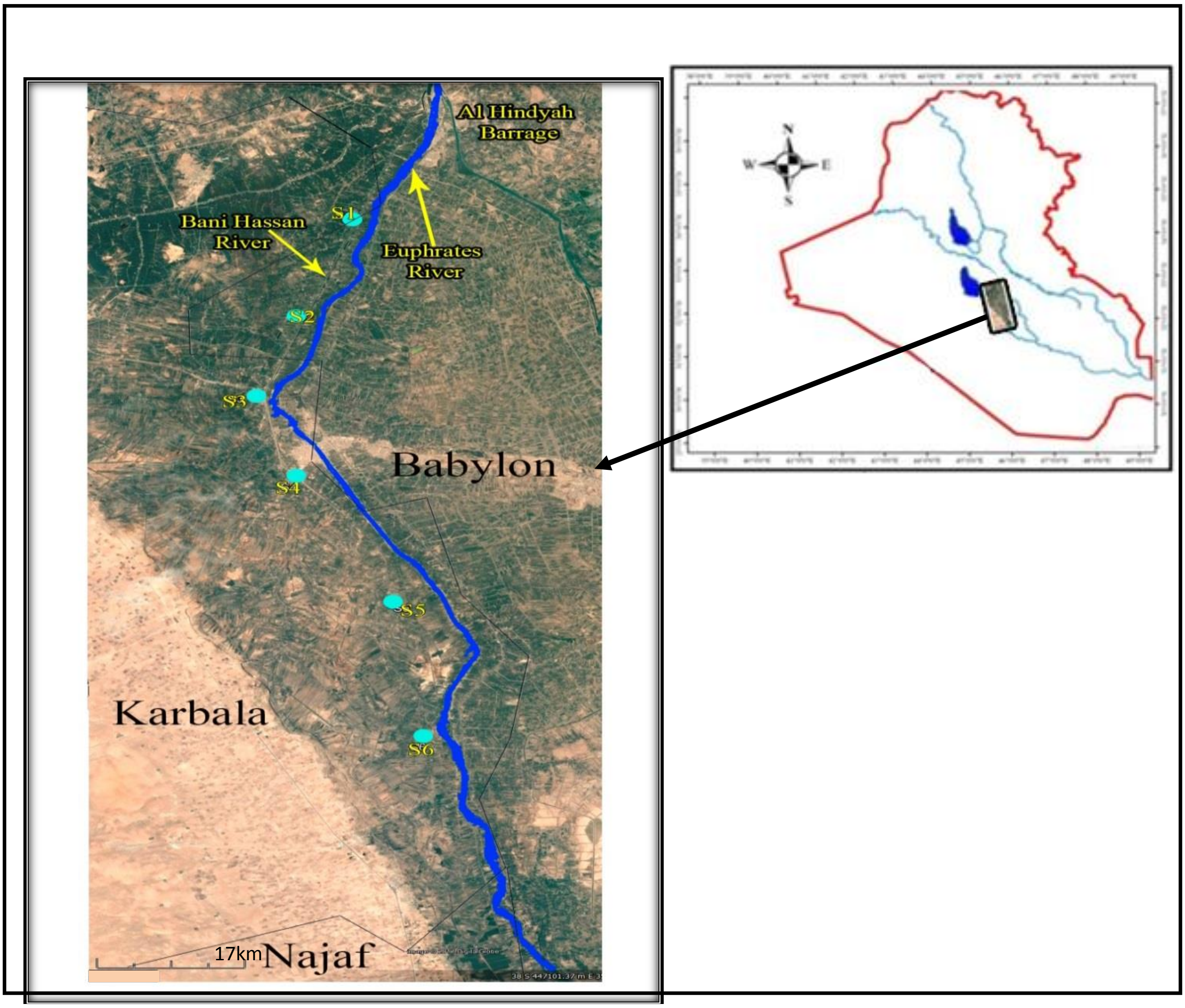

Figure (1): Lcation of sampling stations on Bani-Hassan Rivers.

2.3 Water Quality Index (WQI)

WQI is a mechanism for presenting a cumulatively derive numerical expression defining a certain level of water quality.

The concept of the Water Quality Index (WQI) is to simplify understanding of water quality issues by merging a large amount of data and generating a score, which describes water quality conditions in simple terms such as excellent, fair, poor etc. Although integrating multiple water quality parameters may cause to losing some information; this loss is outbalanced by the gaining a term which is understandable and interpreted by non-scientists and also allowing to made temporal and spatial comparisons of water quality[13,14 and 15].

Several WQI's have been developed which differ from each other based on the way of statistical integration parameter values and interpretation of the results.

A totally different approach was adopted in the Canadian Water Quality Index. Canadian WQI is being used by many countries all over the world and also has been endorsed by the United

Nations Environmental Program (UNEP) in 2007 as a model for Global Drinking Water Quality Index (GDWQI) [16].

All the indices method are based on one or more limited and the search for a perfect one is still a challenge.

In this study, Canadian Water Quality Index (CWQI) was applied and tested for drinking and irrigation intents. The results of CWQI were compared with Weighted Arithmetic Index and Mieriel WQI for drinking and irrigation purpose respectively. The drinking water quality standard recommended by the World Health Organization (WHO) [17] and irrigation water quality standard recommended by the Food and Agriculture Organization (FAO) of United Nations and adapted from University of California Committee of Consultants 1974 [18] were used as objective values in determining the WQI's. Laboratory determinations needed to evaluate common irrigation water quality problems according to FAO standards[17] and Allowable limits of water quality parameters in a surface water body used as a drinking water source according to WHO standards [18] are illustrated in Table (1). Index scores were determined for the following parameters: pH, EC, TDS, Turbidity, Total Hardness (TH), Ca^{+2}, Mg^{+2}, K^{+}, Na^{+}, Cl^{-}, SO_4^{-2}, $HCO_3^{-}$and Sodium Absorption Ratio (SAR).

Table (1): The drinking water quality standard recommended by (WHO) [17] and irrigation water quality standard recommended by (FAO) [18]

Water parameter	Symbol	Usual Range in Irrigation Water		Usual Range in Drinking Water	
Electrical Conductivity	EC	0 – 3000	μs/cm	0 - 2500	μs/cm
Total Dissolved Solids	TDS	0 – 2000	ppm	0 - 1000	ppm
Calcium	Ca^{++}	0 – 20	me/l	0 - 200	ppm
Magnesium	Mg^{++}	0 – 5	me/l	0 - 150	ppm
Sodium	Na^{+}	0 – 40	me/l	0 - 200	ppm
Bicarbonate	HCO_3^{-}	0 – 10	me/l	-	-
Chloride	Cl^{-}	0 – 30	me/l	0 - 250	ppm
Sulphate	SO_4^{--}	0 – 20	me/l	0 - 250	ppm
Potassium	K^{+}	0 – 2	ppm	-	-
Acid/Basicity	pH	6.0 – 8.5	1–14	6.5 – 8.5	1–14
Sodium Adsorption Ratio	SAR	0 – 15	$(me/l)^{1/2}$	-	-
Total hardness	T.H	-	-	0 - 500	ppm
Turbidity	Tur.	-	-	5	NTU

2.3.1.Canadian Water Quality Index (CWQI)

CWQI was applied to determine the quality of Bani-Hassan River for drinking and irrigation purposes. The detailed formulation of the index, as described in the Canadian Water Quality Index 1.0 – Technical Report [19], is as follows:

The index is based on calculation three factors (F1, F2, and F3).

1) F1 (Scope) illustrates the percentage of the variables which deviate from the limits of standard values (failed variables). The F1 (Scope) was calculated as shown in Equation (1):

$$F_1 = \left[\frac{\text{Number of failed variables}}{Total\ number\ of\ variables} \right] \times 100 \quad (1)$$

2) F_2 (Frequency) as was calculated in Equation (2) signifies the percentage of the failed tests that deviate from the guideline values relative to the total number of the tests.

$$F2 = \left[\frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests}\right] \times 100 \quad (2)$$

3) F_3 (Amplitude) represents the amount by which the values of failed test do not match their objectives. F3 is calculated in three steps:

When any individual test concentration value must not exceed the guideline limit so this value is termed an "Excursion" and is expressed as follows.:

$$\text{Excursion} = \left[\frac{\textit{Failed test value}}{\textit{Guideline value}}\right] - 1 \qquad (3)$$

If the test results are less than the objective value (in case of minimum objective), "Excursion" was calculated as follows:

$$\text{Excursion} = = \left[\frac{\textit{Guideline value}}{\textit{Failed test value}}\right] - 1 \qquad (4)$$

The collective amount of non-compliant individual test results is calculated by summation of the excursions of the tests and dividing by the total number of tests.

This value is assigned as the normalized sum of excursions, (nse), and is expressed as:

$$\text{nse} = \frac{\sum_{i=1}^{n} \text{Excursion}}{\text{Number of tests}} \qquad (5)$$

The normalized sum of the excursions from objective value (nse) then scaled by an asymptotic function as shown in equation (6) to yield a value which ranged between 0 and 100.

$$F3 = \left[\frac{\text{nse}}{0.01\text{nse} + 0.01}\right] \qquad (6)$$

Once the three factors have been calculated, the CWQI is finally calculated as follows:

$$\text{CWQI} = 100 - \left[\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right] \qquad (7)$$

The divisor 1.732 has been introduced to normalize the index value and to scale it from 0 to 100 in order to state the quality of water, where the 0 value represents the "very poor" water quality and 100 represents the "excellent" water quality. The assignment of CWQI values to different categories is a somewhat subjective process and also demands expert judgment and public's expectations of water quality. According to the CWQI water quality was ranked in 5 categories as illustrated in Table (2):

Table (2): Water quality classification according to CWQI [19]

Class	Water Quality Index Value	Water Quality
I	100 - 95	Excellent
II	94 - 80	Good
III	79 - 60	Fair
IV	59 - 45	Marginal
V	44 - 0	Poor

2.3.2 Weighted Arithmetic Index (WAI)

The Weighted Arithmetic Index of Bani-Hassan River has been calculated using the drinking water quality standard recommended by the (WHO) [17]. To calculate WQI based on the (WAI) method the following steps have been applied [4]:

2.3.2.1 Calculation of Sub Index of Quality Rating (q_n)

If there are ***n*** parameters of water quality; the quality rating or sub index (q_n) belongs to the n^{th} parameters is a number which reflects the proportion of these parameter concentrations in polluted water to its standard value. The value of q_n is calculated using the following expression:

$$q_n = \frac{100\,(Vn - Vio)}{(Sn - Vio)} \qquad (8)$$

Where

q_n is the quality rating of the n^{th} parameters of water quality

V_n is estimated concentration of the n^{th} parameters at a particular sampling station

S_n is the standard allowable value of the n^{th} parameters

V_{io} is the typical value of n^{th} parameter in pure water and are taken zero for all parameters of drinking water except pH, which is taken 7.0

2.3.2.2. Calculation of Unit Weight (W_n)

To calculate the unit weight (W_n) of several water quality parameters as shown in Equation (9) there is an inverse ratio to the recommended standard values (S_n) of the corresponding parameters.

$$W_n = \frac{K}{S_n} \qquad (9)$$

Where;

W_n is the unit weight of n^{th} parameters.

S_n is the standard value of n^{th} parameters.

K is proportional constant; It can be calculated by using the following equation:

$$K = \frac{1}{\sum \frac{1}{S_n}} \qquad (10)$$

To determine the overall water quality index, the quality rating with the linearly unit weight was aggregated, and then the index can be calculated using the following equation:

$$WAI = \frac{\sum_{n=1}^{n} W_n}{\sum_{n-1}^{n} W_n} \qquad (11)$$

The standard values of different parameters in drinking water, recommended by the World Health Organization, [17], and unit weight calculation of sample analysis results are given in Table (3). The classification of water quality based on the weighted arithmetic index method is tabulated in Table (4) [16].

Table (3): Drinkable water standards [17] and unit weight values.

Chemical Parameters	Highest Permitted Value of water (S_n)	$1/S_n$	K	W_n
pH	8.5	0.1176	2.8926	0.3403
EC	2500	0.0004		0.0011
TDS	1000	0.001		0.0028
Total Hardness	500	0.0020		0.0057
Chloride	250	0.004		0.0115
Calcium	200	0.005		0.0144
Magnesium	150	0.0067		0.0192
Sodium	200	0.005		0.0144
Sulphate	250	0.004		0.0115
Turbidity	5	0.2		0.5785

Table (4): Status of water quality based on Weighted Arithmetic Index method [4]

Index Value	Notes	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
>100	Unsuitable for drinking	E

2.3.3 Meireles Water Quality Index (MWQI)

Meireles proposed a new classification for irrigation water and determined Water Quality Index for irrigation purpose [7].The Meireles Water Quality Index (MWQI) method was developed for Bani-Hassan River in two steps:

In the first step, the parameters which cause more variability in irrigation water quality were specified. To develop the proposed WQI; five parameters; EC, Na^+, Cl^-, HCO_3^-, and SAR parameters were selected. These take the major factorial weight, which means defining best water quality.

In the second step, a definition of water quality measurement limits (q_i) and accumulated weights (w_i) was established. The values of (q_i) were found based on each parameter value, considering the criteria which established by Ayers and Westcot [21] and irrigation water quality parameters proposed by the University of California Committee of Consultants - UCCC and as listed in Table (5).

Table (5): Values of parameter limiting for calculation of quality measurement (q_i). [7,21]

Q_i	EC (μs/cm)	SAR $(meq/l)^{1/2}$	Na^+	Cl^-	HCO_3^-
			meq/l		
85-100	200≤EC<750	2≤SAR<3	2≤Na<3	1≤Cl<4	1≤HCO3<1.5
60-85	750≤EC<1500	3≤SAR<6	3≤Na<6	4≤Cl<7	1.5≤HCO3<4.5
35-60	1500≤EC<3000	6≤SAR<12	6≤Na<9	7≤Cl<10	4.5≤HCO3<8.5
0-35	EC<200 or EC≥3000	SAR≥12 Or SAR<2	Na<2 or Na≥9	Cl≥10 Or Cl<1	HCO3<1 or HCO3≥8.5

The values of q_i were obtained by applying Equation (12):

$$Q_i = Q_{imax} - \{(x_{ij} - x_{inf})*Q_{iamp})/x_{amp}\} \quad (12)$$

Where

Q_{imax} is the greatest value of Q_i for the corresponding class;
X_{ij} is the measured value of the parameter in the laboratory;
x_{inf} is the lower value of the parameter to which the class belongs;
Q_{iamp} is class capacity;
x_{amp} is the class capacity to that the parameter belongs.

To determine x_{amp} in case of the last class of each parameter, the highest value obtained from the physico-chemical analysis of the water samples was considered to be the upper limit. The weight of each parameter applied in calculating MWQI was normalized such that the sum of them equals one. Table (6) illustrates the weights of the WQI parameters.

Finally Water Quality Index was calculated using Equation (13) as follows:

$$WQI = \sum_{i=1}^{n} q_i \, w_i \quad (13)$$

Where

q_i represents the quality of the i^{th} parameter which is a function of its measurement or concentration and range between 0 to 100,; and

w_i represents the normalized weight of i^{th} parameter which is in relation to its importance in the variability of water quality.

Proposed classification of the water quality index was based on classes and existent WQI, and was founded by considering some factors such as a reduction in the infiltration of water, toxicity to plants, and the hazard of salinity problems as noticed in the class division that presented by Bernardo, Holanda and Amorim [22,23]. Water use restrictions of the WQI classes were illustrated in Table (7).

Table (6): Weights of parameters in calculation MWQI [7].

Parameters	w_i
Electrical Condutivity (EC)	0.211
Sodium (Na^+)	0.204
Bicarbonate (HCO_3^-)	0.202
Chloride (Cl^-)	0.194
Sodium Adsorption Ration (SAR)	0.189
Total	1.000

Table (7): Characteristics of water quality index classes [7].

IWQI	Restrictions on Water Usage	Recommendation	
		Soil	Plant
85-100	No Restriction (NR)	May be utilized for the most soils of low probability of causing sodality and salinity problems, being d leaching within irrigation practices is recommended, exclude very low permeability soils.	For most plants there are no toxicity risk
70-85	Low Restriction (LR)	Recommended to utilize in irrigated soils with moderate permeability or light texture salt leaching is recommended. Soil sodality in soils with heavy texture may occur, in high clay soils being recommended to avoid its utilize.	No toxicity risk for most plants
55-70	Moderate Restriction (MR)	May be utilized in moderate to high permeability soils, and moderate salts leaching is suggested.	Plants with moderate tolerance to salts may be grown
40-55	High Restriction (HR)	May be utilized in high permeability soils with no compacted layers. Irrigation schedule must be with a high frequency of water with SAR above 7.0 and EC more than 2000 µS cm-1.	Should be used for irrigation of plants with moderate to high tolerance to salts with special salinity control practices, except water with low Na, Cl and HCO3 values
0-40	Severe Restriction (SR)	In irrigation with less than normal condition its usage must be avoided. In special cases, may be used occasionally. Water with high SAR and low salt content gypsum application is required. In water with high salinity level, high permeability soils are required, and to avoid salt collection, excess water must be used.	Only plants with high salt tolerance, except for waters with extremely low values of Na, Cl and HCO3.

3. Results and Discussion

Water Quality Index was developed based on various physiochemical parameters for six sites on Bani-Hassan River. To characterize the quality of water Maximum (Max.), Minimum(Min.) and Median as well as Standard Deviation (Std. Dev.) and Average values were calculated from the results of sample analyzing data. Descriptive statistics for the results of water quality analyzing data of Bani-Hassan River in Karbala province are given in Table (8).

Table (8): Statistical Summary of water quality analysis for Bani-Hassan River.

Parameter		pH	EC	TDS	T.H	Turb.	Ca^{+2}	Mg^{+2}	Cl^{-}	Na^{+}	SO_4^{-2}
1	Max.	8.1	1456	936	548	17	159	44	185	127	452
	Min.	7.7	1250	764	407	9	99	36	132	100	277
	Median	7.8	1358	876	495	12	139	40	154	107	413
	Std. Dev.	0.12	56.76	52.1	59.88	2.95	26.37	3.09	15.48	8.99	72.13
	Average	7.9	1355	864	484.2	12.8	128.9	39.6	153.6	110.0	373.8
2	Max.	8.1	1469	932	548	15	158	47	176	125	448
	Min.	7.6	1233	780	395	5	93	25	138	104	268
	Median	7.95	1369	870	485.5	12	135.5	39.5	153	110.5	392.5
	Std. Dev.	0.13	66.12	44.88	49.68	3.47	24.58	6.13	12.65	7.60	54.52
	Average	7.93	1365.1	871.5	480.2	10.3	128.5	38.7	153.4	111.2	375.9
3	Max.	8.1	1449	996	564	16	148	50	196	129	452
	Min.	7.8	1120	732	387	4	95	28	122	100	265
	Median	8	1349	872	488	7	129	39	148	109	407
	Std. Dev.	0.11	85.14	67.13	60.10	3.81	22.55	6.04	18.19	8.65	66.01
	Average	7.9	1324.5	864.5	473.5	9.0	121.8	41.2	154.2	110.3	361.1
4	Max.	8	1449	930	572	11	150	49	186	130	452
	Min.	7.8	1244	792	396	5	92	33	144	101	276
	Median	8	1349	872	488	7	129	39	148	109	407
	Std. Dev.	0.1	75.7	49.6	61.3	2.0	23.4	4.4	14.0	12.6	66.1
	Average	7.9	1339.1	862.9	473.0	7.4	124.8	39.2	155.2	113.0	368.2
5	Max.	8	1414	996	558	16	154	51	197	142	452
	Min.	7.8	1179	732	395	5	92	34	134	99	270
	Median	7.8	1351	884	502	9.5	139	39	150	111.5	401
	Std. Dev.	0.1	65.0	67.0	49.1	3.4	22.2	5.8	21.7	13.2	56.8
	Average	7.9	1339.1	879.6	495.9	9.4	131.9	40.6	157.3	114.5	391.2
6	Max.	8.1	1437	924	560	8	152	49	178	130	456
	Min.	7.8	1201	754	388	5	91	36	138	100	270
	Median	8	1343.5	859	462	6	109.5	40	154	110.5	347
	Std. Dev.	0.1	75.6	50.4	63.5	1.4	25.4	4.9	12.8	11.2	69.5
	Average	8.0	1347.1	849.0	466.1	6.4	118.6	41.5	154.6	112.5	356.4

The results of applying Canadian WQI and Weighted Arithmetic Index for drinking purpose are shown in Table (9) and Table (10) respectively. It can be clearly seen that the results of CWQI method are ranked as class (III) with Fair water quality while WAI method results were fallen at class (E) with unsuitable condition for drinking purposes. Figure (2) shows the results of the two methods (CWQI and WAI).

Table(9):Annual mean results of applying the Canadian WQI method (Drinking purposes)

No. Location	1	2	3	4	5	6
Canadian WQI	75	77	78	79	78	79
Categorization	Fair	Fair	Fair	Fair	Fair	Fair
Class	III	III	III	III	III	III
F1(Scope)	30	30	30	30	30	30
F2(Frequency)	24.4	23	20.8	20	19	20
F3(Amplitude)	17.3	14.4	11.2	1.9	13	6.8

Table(10):Annual mean using Weighted Arithmetic Index method (Drinking purpose)

Location No.	1	2	3	4	5	6
Arithmetic WQI	168	146	131	113	134	101
Categorization	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable
Class	E	E	E	E	E	E

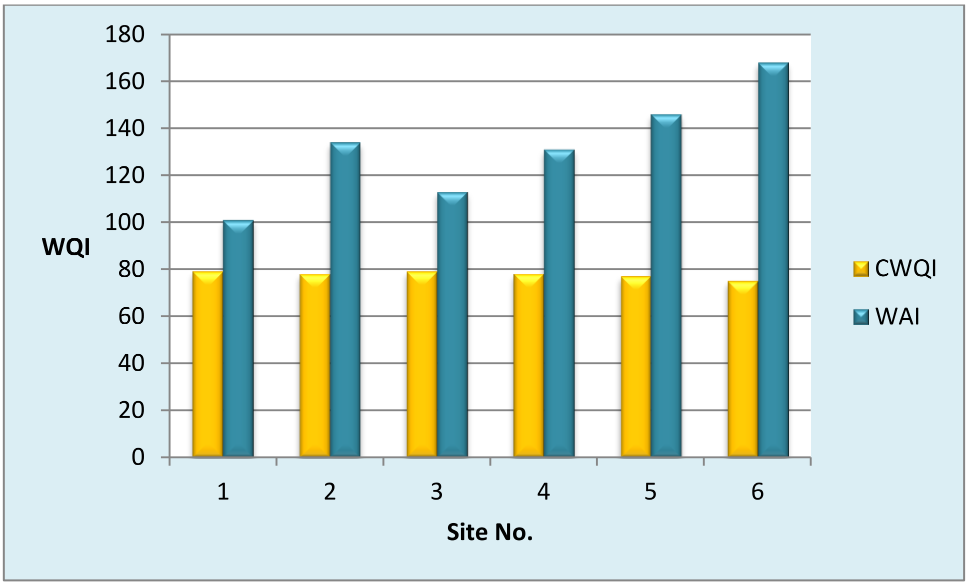

Figure (2): The results of Weighted Arithmetic Index and the Canadian WQI for multi locations at Bani-Hassan River.

In the case of the suitability of water for irrigation use the results of applying Meireles WQI equations showed that the water quality of Bani-Hassan River is classified as a moderate restriction in water use while by using the Canadian equations the water is classified as a class (II) with good water quality for irrigation purpose. The results of applying CWQI and MWQI are shown in Table (11) and Table (12) respectively. Figure (3) shows the results of the two methods (MWQI and CWQI).

Table (11): Annual mean using CWQI method (Irrigation purpose)

Location No.	1	2	3	4	5	6
CWQI	85	85	86	86	85	86
Categorization	Good	Good	Good	Good	Good	Good
Class	II	II	II	II	II	II
F1(Scope)	18.2	18.2	18.2	18.2	18.2	18.2
F2(Frequency)	14.1	15.5	14	14.1	16.4	13.6
F3(Amplitude)	10.1	10	10	10	10	11

Table(12): Annual mean using Weighted Arithmetic WQI method (Irrigation purpose)

Location No.	**1**	**2**	**3**	**4**	**5**	**6**
MWQI	64	67	67	66	66	67
Categorization	(MR)	(MR)	(MR)	(MR)	(MR)	(MR)
Class	III	III	III	III	III	III

As the results of WQI's values show; Canadian WQI method values are higher than Meireles WQI and Weighted Arithmetic Index methods values.

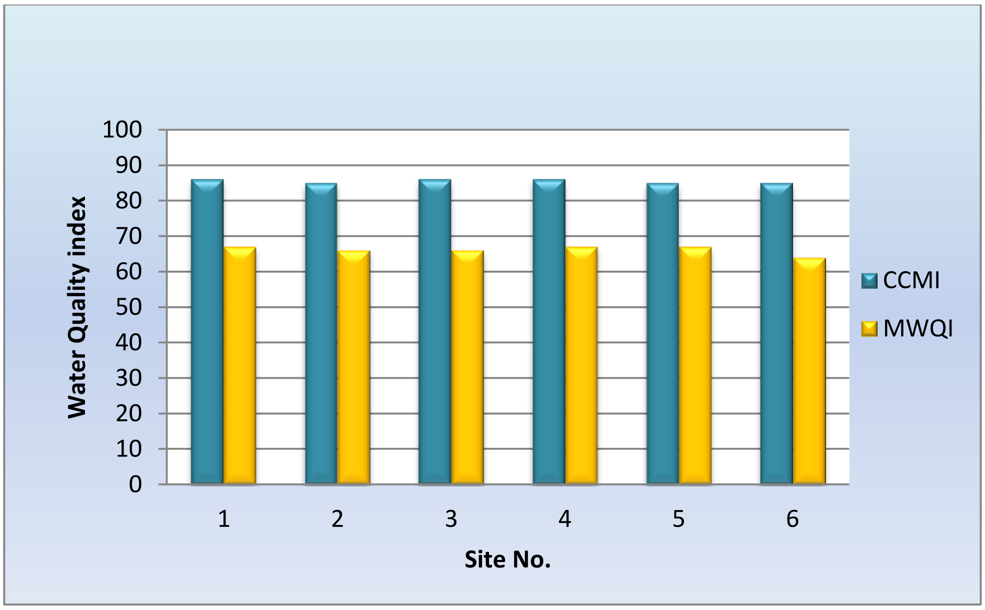

Figure (3): Results of Mierels WQI and the Canadian WQI for multi locations at Bani-Hassan River for irrigation purpose.

3.1 Statistical Analysis

Due to the importance of the irrigation in this region, data of WQI's for irrigation purpose in the two methods had been tested by (IBM SPSS 23 program). To realize if there is a significant difference between the results of the two methods at the certain significant limit the paired t-test has been adopted which is a statistical procedure to determine whether the mean difference between the two sets of observations is zero.

The results of running paired t-test by SPSS program are tabulated in Table (13) to Table (15).

Table(13): Paired Samples Statistics

	N	Mean	Std. Deviation	Std. Error Mean
CWQI	6	85.5	0.548	0.05
MWQI	6	66.17	1.169	0.228

Table (14):Paired Samples Correlations

	N	Correlation	Sig.
Pair CWQI & MWQI	6	.469	.349

Table (15): Paired Samples Test.

	Paired Differences					T	df	Significant. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair CWQI MWQI	19.333	1.033	0.422	18.249	20.417	45.853	5	0.000

As shown in Table (13) CWQI has a higher mean score than Mieriles WQI.

Table (15) illustrates that there is moderate and positive correlation (r =0.469) [$0.3 < | r | < 0.5$], and the population correlation coefficient is not zero ($p \neq 0$) so a nonzero correlation could exist [significant(sig.) = 0.349]

As noticed in Table (15) the mean difference is equal to 19.333 and standard deviation and standard error mean of difference were 1.033 and 0.422 respectively. Furthermore, 95% confidence interval for the mean difference was (18.249 to 20.417). Calculated *t*-value (**T**) is 45.8530, the degrees of freedom (**df**) is 5, and the p-value denoted by “Sig. (2-tailed)” is 0.

4. Conclusion

The results of applying Canadian WQI and Weighted Arithmetic Index (WAI) for drinking purpose showed that the water of River is ranked as a class (III) with Fair water quality according to Canadian WQI method. While WAI method results classify the water as class (E) with the unsuitable conditions for drinking purposes.

In the case of water suitability for irrigation, the results of applying Meireles WQI equations showed that the water quality of Bani-Hassan River is classified as a (Moderate Restriction) in water use, while by applying the Canadian equations the water is classified as a class (II) with good water quality.

In comparing WQI's results of Canadian technic with two other technics (Weighted Arithmetic Index and Mieriles WQI) it is easy to say that Canadian method gives higher water quality value than the two other methods, in another word, (CWQI) considered more elastic, however, the (WAI and MWQI) methods utilized if there are need for restrictive control of water using.

Stastical analysis of the two methods results (Canadian WQI & Meireles WQI) for irrigaton water showed that there is a statistically significant difference between their results. In other words, the difference between the two technics is not equal to zero.

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