Using The Canadian Method to Classify Irrigation Water Quality Index for Shatt Al- Kufa River Section (Al–Zerkh to Al–Qadisiya)

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Abstract

Shatt Al-Kufa (Kufa River) is the main supply of surface waters in Najaf, it is necessary to concern about the river water quality because of increasing demand for different using. This study aims to find the Water Quality Index (WQI) for irrigation use at many locations on Shatt Al-Kufa within the study section of the river. Nine water quality parameters: Sulfate (SO_4^{-2}), Chlorides (Cl^{-1}), Total Dissolved Solid (TDS), Electrical Conductivity (EC), Hydrogen Power (pH), Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Sodium (Na^{+}), and Potassium (K^{+}) were studied over ten months (January- October 2014) for nine locations along the study section. Sodium Adsorption Ratio (SAR) and Soluble Sodium Percentage (SSP) were also calculated. Firstly Food Agricultural Organization (FAO, 1985) was adopted to evaluate the suitability of water for irrigation use. Then Canadian Water Quality Index (CWQI) was applied to classify the water quality index of the river for irrigation. It is found that the mean values of parameters for all selected locations are within the highest allowable limits of FAO classification for irrigation, with respect to the values of (SAR) the results showed that the water samples were within the level (S1) which there was no harmful effects from sodium, while (SSP) values (except one value) fall within the water class of good according to Todd classification of irrigation water based on SSP. Results of the annual and seasonal average water quality indices according to the Canadian method were classified as Fair (65 – 79) in all selected locations. The effective reason which decrease the water quality index, was the presence of high values of (EC) and high concentrations of (TDS) in all locations, which it refers to high concentrations of salts. Approximately 100 % of EC and TDS water samples have concentrations that exceeded the permissible limits for irrigation water.

Keywords: Water Quality Index (WQI), Shatt Al – Kufa, Irrigation, Canadian Method.

الخلاصة

شط الكوفة (نهرالكوفة) هو المصدر الرئيسي للمياه السطحية في النجف. زيادة استعمال مياه النهر في الاحتياجات المختلفة ادى الى زيادة القلق على نوعية مياهه. تهدف الدراسة الى ايجاد مؤشر نوعية مياه الري(WQI) في عدة مواقع على النهر ضمن المقطع المدروس . تم دراسة تسعة مؤشرات لنوعية المياه : الكبريتات، الكلوريد، الاملاح الذائبة الكلية ،الموصلية الكهربائية، الرقم الهيدروجيني ،الكالسيوم، المغنسيوم ،الصوديوم والبوتاسيوم في تسعة مواقع مختلفة على طول المقطع المدروس ولمدة عشرة اشهر (كانون الثاني– تشرين الاول 2014). تم حساب نسبة امتزاز الصوديوم، ونسبة الصوديوم القابل للذوبان. اولا: اعتمدت المواصفة القياسية (FAO, 1985) لتقييم صلاحية هذه المياه للري، وتم تطبيق الطريقة الكندية (CWQI) لتصنيف مؤشر نوعية مياه النهر للري ثانيا . كانت معدلات قيم مؤشرات نوعية المياه لكل المواقع المختارة ضمن الحدود العليا المسموحة للري على وفق مواصفة (FAO, 1985). اما بالنسبة لقيم نسبة امتزاز الصوديوم (SAR) كانت ضمن المستوى (S1) ولا يوجد أي تأثير ضار للصوديوم. في حين كانت كل القيم السنوية (ما عدا قيمة واحدة) لنسبة الصوديوم القابل للذوبان (SSP) تقع ضمن صنف مياه جيده على وفق تصنيف (Tood, 2005) للري. صنفت نتائج المعدل السنوي والمعدلات الفصلية لمؤشر نوعية المياه حسب الطريقة الكندية ضمن صنف Fair (65 – 79) في جميع المواقع المختارة. السبب الفعال في نقصان مؤشر نوعية المياه يعود الى القيم العالية للموصلية الكهربائية والتركيز العالي للأملاح الذائبة الكلية في كل المواقع، تقريبا 100% من عينات المياه لها موصلية كهربائية وأملاح ذائبة كلية تتجاوز الحدود المسموحة لمياه الري.

الكلمات المفتاحية: مؤشر نوعية المياه، شط الكوفة، الري، الطريقة الكندية.

1. Introduction

Surface waters are facing an increasing trouble through the disposal of pollutants due to the quick growth of industrial and municipal actions because of the increasing of people growth as well as the increase in land drainage due to agricultural activities. Thus, there have been increasing concerns about the management of water quality all over the globe.

Surface water characteristics, also, vary with time and space. Concentrations of impurities increase because of mineral pick up from surface runoff, silt and debris are carried by surface water, often resulting in muddy or turbid streams. Wastes have a major impact on water quality and add greatly to the spectrum of impurities present **(Al-Obaidi, 2009).**

One of the main objective of any water contamination study is to determine or evaluate general status of the water body concerned. Water quality can be judged either by individual parameter for any specific interest or by a few selected significant parameters to judge the overall quality of the water. Many countries use water quality indexing (WQI) method to assess the overall status of their rivers. These indices vary from country to country but the idea is similar, where a few significant parameters are chosen and compounded to numerical rating for the assessment of the river water quality **(Al- Mamun and Idris, 2008)**.

The Water Quality Index aims at assessing the quality of water from a supply through a single numerical value, calculated on the basis of one system which translates every the elements and their concentrations present in a simple into a single value. This is a very efficient method that allows to evaluate the quality of different water samples based on the indicator values of each sample **(Mohammed, 2013)**.

Water quality is defined in terms of its biological, chemical and physical parameters. Water quality achieving is important before using for different intended uses such as drinking water , agricultural, and industrial water usages. Determining of water quality parameters is significant to identify the quality, conditions and pollution level of surface water. Related data must be processed and the results should be presented to specialists. One of the simplest methods to evaluate water quality conditions is by using water quality indices **(Abd- Alwahed, 2015)**.

WQI is an aggregation parameter calculated on many WQ parameters according to a defined method. WQI is scaled from 0 (the bad water quality) to 100 (the best water quality) **(Ott. 1978)**.

WQI provides a single number that expresses overall water quality evaluation at certain position and time based on a number of water quality parameters. The aim of an index is to turn difficult water quality data into information that is clear and useable by the public, a single number cannot tell the total story of water quality ; there are many other water quality parameters that are not included in the index. However, a water quality index based on some very significant parameters can give a simple indicator of water quality **(Hussain *et.al.*, 2014)**.

In general, the water quality parameters that affect adversely on the water quality for irrigation use are: Sulfate (SO_4^{-2}), Chlorides (Cl^{-1}), Total Dissolved Solid (TDS), Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR),and Hydrogen Power (pH) **(Khan *et.al.*, 2003)**.

In Najaf _ Iraq, Shatt Al- Kufa (Kufa River) is the main source of water needed for drinking, irrigation, industry and other applications. This river shows decreasing quantity and quality of water because of the rapid growth of industrial, agricultural and municipal activities**.** After war and due to the bad conditions into most services in the country (including water supply). It is decided to study some of important characteristics of Shatt Al- Kufa especially when wastes began to through to the river directly without treatment.

The objectives of this study can be summarized by:

1. Study the variation of the water quality parameters of Shatt Al-Kufa River for irrigation use and determine the main parameters that is Consider the main contaminant to the river.
2. Assess the suitability of Shatt Al-Kufa River for irrigation by using (FAO,1985) and **(Tood and Mays, 2005)** classifications.
3. Find and classify water quality index for irrigation use of Shatt Al-Kufa by using the Canadian method.

2. Study Area

Shatt Al-Kufa is one of the two major branches of Euphrates River which is divided into its two rivers (Shatt Al- Kufa and Shatt Al Abbasiyya) at (2 km) to the south of the Kifl city and 60% of its water is discharged to Shatt Al - Kufa. It is located at an elevation of (30 m) above sea level. Its coordinates are 31^o 54 $'$ N and 44^o 28 $'$ 60 $''$ E in DMS (Degrees Minutes Seconds) or 31.9 and 44.4833 (in decimal degrees) **(Shatt Al -Kufa Map, 2014).**

Shatt Al- Kufa doesn't have any branching tables along the distance of 40 km from its beginning until it arrives Abu-Skir city to the south of Kufa city , so it is the main source of surface water for different activities (human, industrial, agricultural , and etc) in Najaf city.

The average annual discharge of this river is about (118.7 m^3/s) and varies from season to season . The highest monthly rate (196.5 m^3/s) was in July and the lowest annual rate (77.3 m^3/s) was in January.The annual amounts incoming of Shatt Al-Kufa is (3.745 billion m^3) and the total area of benefiting agricultural lands from its water is ($375*10^6$ m^2) **(Biladnews, 2015)**.

This study includes selecting nine locations on the study section from Shatt Al-Kufa from its beginning at Al- Zerkh moving towards Al- Qadisiya as shown in Fig. 1. The nine selected locations are also illustrated in Table 1.

3. Data Collection

Nine water quality parameters for irrigation were collected in this study: Sulfate (SO_4^{-2}), Chlorides (Cl^{-1}), Total Dissolved Solid (TDS), Electrical Conductivity (EC), Hydrogen Power (PH), Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Sodium (Na^+), and Potassium (K^+). These parameters were collected from laboratories of the Water Resources Management / Ministry of Water Resources in Iraq. These data are shown in Table 2. Sodium Adsorption Ratio (SAR) and Soluble Sodium Percentage (SSP) were also illustrated in Table 3.

The observations were measured at nine locations along the study section of Shatt Al –Kufa, and during the period (January- October 2014) which represented ten months.

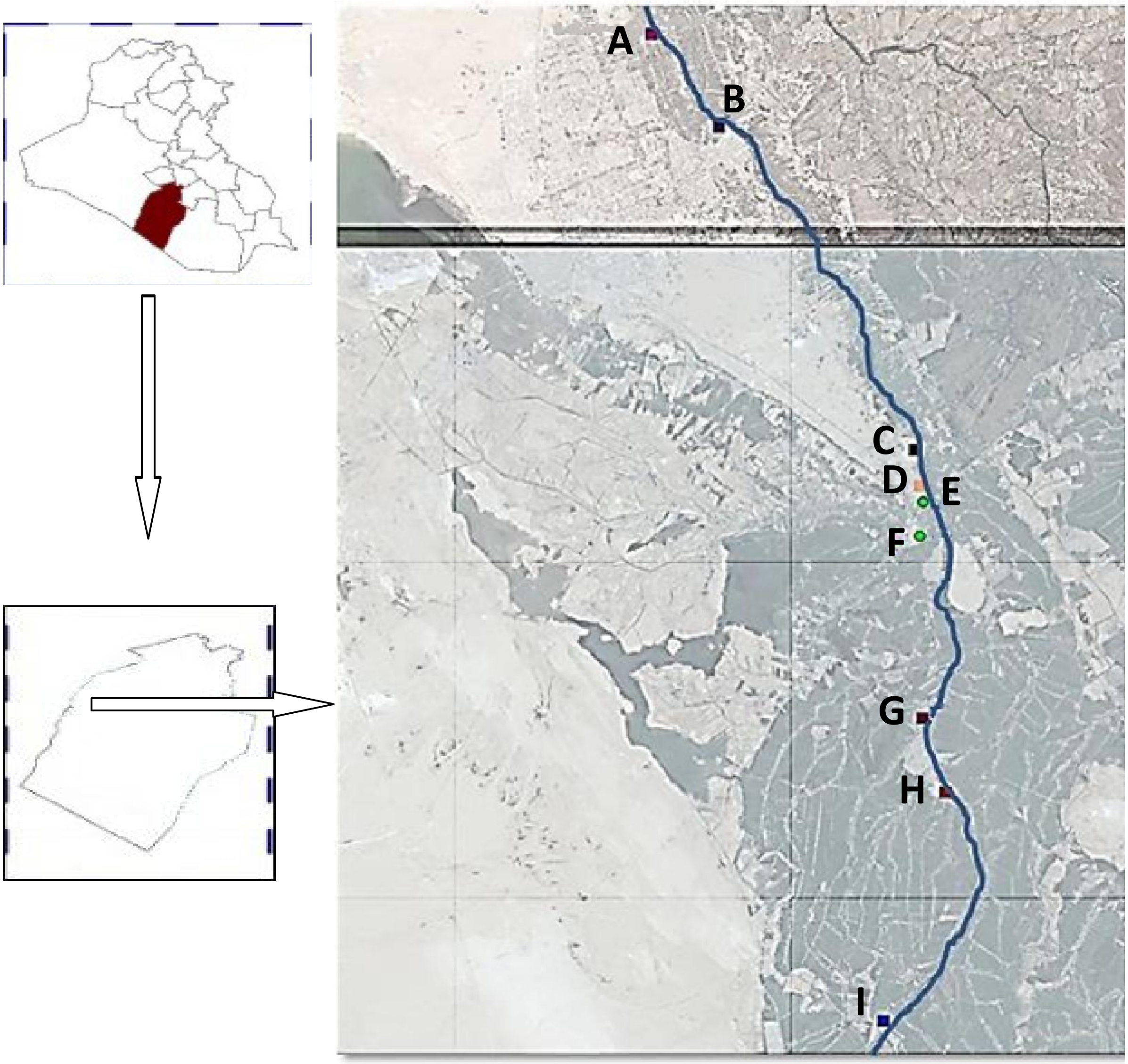


Fig. 1. Position of The Study Area in Iraq and Sampling Positions

Table 1. Selected Locations on Shatt Al- Kufa

No.	1	2	3	4	5	6	7	8	9
Symbol	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Location	Zerkh	Kufa	Manathira	Manathira	Hira	Hira	Mashkhab	Mashkhab	Qadisiya

Table 2. Statistical Information for Irrigation Parameters of Shatt Al- Kufa During The Study Period

Parameters +Standard *	Statistical Indices	Locations								
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Cl^{-1} FAO= 1065 mg/l	Mean	129.6	140.6	146.2	117.8	145	130.5	155.4	154.2	145.1
	SD	25.64	27.71	26.41	4.4	25.77	11.17	38.89	43.44	26.93
	Max.	194	209	190.1	122.6	188	152	224.4	225.2	180
	Min.	104.5	110.5	118	112	118	118	112	112	114
. SO_4^{-2} FAO = 960 mg/l	Mean	345.1	367.6	347.2	309.3	348.7	323	354.7	353	353.3
	SD	79.32	78.41	61.93	29.26	53.88	38.0	57.66	73.71	43.91
	Max.	512	543	431	342	422.5	378	445	486	409
	Min.	275	289	258	271	271	285	284	274	281
TDS FAO = 2000 mg/l	Mean	880.7	924.1	883.4	846	891.2	838	915.3	866	868.1
	SD	238.4	247.7	141.6	95.1	164.4	132.8	163.4	161.9	173.2
	Max.	1468	1522	1135	956	1155	1032	1186	1122	1170
	Min.	640	670	734	724	676	676	704	692	626
EC FAO= 3000 µmho /cm	Mean	1391	1469	1420	1321	1415	1369	1446	1421	1381
	SD	351	372.3	244.4	66.24	258.1	239.1	277.7	274.2	209.7
	Max.	2230	2364	1860	1388	1894	1829	1928	1826	1671
	Min.	1034	1087	1157	1231	1112	1114	1117	1125	1099
pH FAO = 6 – 8.5	Mean	7.68	7.67	7.69	7.7	7.6	7.7	7.63	7.68	7.88
	SD	0.14	0.19	0.21	0.082	0.11	0.172	0.14	0.18	0.26
	Max.	7.9	7.9	8	7.8	7.7	7.9	8	7.9	8.2
	Min.	7.5	7.3	7.4	7.6	7.4	7.4	7.5	7.4	7.45
Ca^{+2} FAO = 400 mg/l	Mean	90.53	100.2	97.29	102.1	97.1	94.7	95.46	97.07	102.6
	SD	15.04	20.89	17.83	6.76	16.09	13.44	16.86	19.79	16.18
	Max.	123.1	136.8	129.2	111.6	116.2	118	118.6	128.4	131.1
	Min.	70.73	73.79	72.8	96.4	72.38	76.3	73.54	74.98	79.3
Mg^{+2} FAO = 150 mg/l	Mean	43.05	50.13	45.94	34.7	47.7	43.87	47.78	46.5	46.1
	SD	13.37	9.61	6.68	2.83	7.65	8.3	7.12	7.33	5.9
	Max.	83.8	74.5	54.2	37.8	53.4	52.5	56.5	63.1	53.6
	Min.	31.6	38.3	34	29.3	29.3	32.9	35.1	38.2	37.5
Na^{+} FAO = 920 mg/l	mean	105.0	121.9	120.4	92.67	118.1	104.9	123.1	132.1	116.8
	SD	22.81	32.28	22.67	6.13	23.86	11.93	32.69	40.71	22.14
	Max.	160	185	158	100	152.5	124	176	195	150
	Min.	83	86	98	85	92	95.5	86	87	96
K^{+} FAO = 78 mg / l	mean	5.1	5.76	6.4	4.9	5.91	5.1	6.73	7	5.9
	SD	1.32	2.073	2	0.26	1.53	1.02	1.78	2.52	1.3
	Max.	8.2	12	10.5	5.1	8.5	6.5	9.25	12	8.05
	Min.	3.5	4.5	4.5	4.5	4	4	4.5	4.5	4.5

* (FAO,1985)

Table 3. Annual SAR and SSP Values for The Selected Locations on Shatt Al- Kufa River

Location	A	B	C	D	E	F	G	H	I
SAR	2.268	2.472	2.512	2.015	2.447	2.227	2.558	2.75	2.398
SSP	36.66	37.211	38.32	34.19	37.447	35.86	38.69	40.43	36.823

4. Theoretical Side

5.1 Canadian Water Quality Index (CWQI):

The CWQI has adopted the conceptual model of British Colombia Water Quality Index (BCWQI) based on relative sub indices. There are three factors in the index, each of which has been scaled between 0 and 100. The values of the three measures of variance from selected objectives for water quality are combined to create a vector in an imaginary " objective exceedance" space. The length of the vector is then scaled to range between 0 and 100, and subtracted from 100 to produce an index which is 0 or close to 0 for very poor water quality, and close to 100 for excellent water quality **(Hadi, 2012)**.

The following six stages indicates the way to compute the Canadian Council of Ministry of the Environment (CCME WQI) **(Rahman and Fakhar Al- Deen, 2013)**. These stages includes the computation of F1, F2, Excursion, normalized state of excursion (nse), F3, then WQI.

1. F1= (Number of failed parameters / Total number of parameters) * 100 ……… (1)
2. F2= (Number of failed tests / Total number of tests) * 100 ……………… (2)
3. Excursion : There are two cases to calculate this step.

a. When test value must not exceed objective (limitation), then

Excursion= (failed test value / objective) -1…… ………………………………… (3)

b. When objective exceed test value, then:

Excursion = (objective / failed test value) –1………………………………….. (4)

4. normalized state of excursions (nse) = sum (excursion) / total of tests …… (5)
5. F3 = nse /(0.01 * nse + 0.01)……………. (6)
6. WQI =100- [($F1^2 + F2^2 + F3^2)^{1/2}$ / 1.732]... (7)

Table 4 is shown water quality classification according to CWQI.

Table 4.Water quality classification according to CWQI (CCME, 2001) (Rahman and Fakhar Al- Deen, 2013)

Class	Water Quality Index Value	Water Quality
I	95 - 100	Excellent
II	80 - 94	Good
III	65 - 79	Fair
IV	45 - 64	Poor (Marginal)
V	0 – 44	V. Poor(Poor)

4.2 Canadian Water Quality Standards:

The Canadian Water Quality Index (CWQI) is classified as one of the relative sub-indices, which depends on the water quality standards **(Al-Bahrani, 2012)**.

Six irrigation water quality parameters were compared with their standards which were taken from Canadian Water Quality Guideline. These water quality parameters which were used in this method were illustrated in Table 5 with their standards for irrigation use.

Table 5. Irrigation Water Quality Standards Used in The Canadian WQIS for Shatt Al- Kufa Locations Taken from The Canadian water quality guideline, 1999 (Al-Bahrani, 2012)

No.	Water Quality Determinant	Unit	Standard
1	Chlorides	mg/ l	250
2	Sulfates	mg/ l	1000
3	Total Dissolved Solid *	mg/ l	500
4	Electrical Conductivity**	ds / m	0.7
5	Hydrogen Power*	Unitless	6.5 – 8.5
6	Sodium Adsorption Ratio**	Meq / l	10

* California state water pollution control, 1952

** FAO guideline for agriculture, 1990

5. Results and Discussion

5.1 Results and Discussion of Physical-Chemical Parameters.

Table. 3. represents the results of the statistics of physic – Chemical parameters of Shatt Al –Kufa River water . The results illustrate that the annual mean values of all selected locations were within the maximum permissible limits of (FAO, 1985) as shown in the same table.

Sodium Adsorption Ratio (SAR) is adopted by The salinity laboratory of the U.S. Department of Agriculture because sodium reacts with soil to reduce permeability of soil and infiltration of water. It is defined :

$$SAR = \frac{Na}{\sqrt{Ca+Mg)/2}} \quad \ldots\ldots \qquad (8)$$

The elements concentration are expressed in epm (milli equivalent per liter) **(Todd and Mays, 2005)**.

Water quality is classified into four level (S1, S2, S3, and S4) based on SAR values as shown in Table.6.

Table 6- Classification of irrigation water based on SAR values (Al – Maliki, 2013)

Level	SAR	Hazard
S1	< 10	No harmful effects from sodium
S2	≥ 10 < 18	An appreciable sodium hazard in fine-textured soils but could be used on sandy soils with good permeability.

S3	≥ 18 < 26	Harmful effects could be anticipated in most soils and amendments such as gypsum would be necessary to exchange sodium ions.
S4	≥ 26	Generally unsatisfactory for irrigation.

The test results showed that the annual SAR values in irrigation water varied from (2.015 – 2.75). Based on the classification of SAR, the result comparison showed that there is no harmful effects from sodium because all the values of SAR are less than ten.

Sodium concentration is important in classifying an irrigation water because sodium reacts with soil to reduce permeability. Percent Sodium (Na%) or Soluble Sodium Percentage (SSP) is usually used to express about Sodium content in irrigation water. It is defined **: (Tood and Mays, 2005)** :

$$\mathbf{SSP} = \frac{(\mathbf{Na+K})}{(\mathbf{Na+K+Ca+Mg})} \text{ X100} \quad \ldots\ldots(9)$$

The constituents concentration are expressed in (Meq / l). The classification of irrigation water based on SSP is as shown in Table.7.

Table.7. Classification of irrigation water based on SSP (Tood and Mays, 2005)

Water Class	SSP (Na%)
Excellent	< 20
Good	20 - 40
Permissible	40 - 60
Doubtful	60 - 80
Unsuitable	> 80

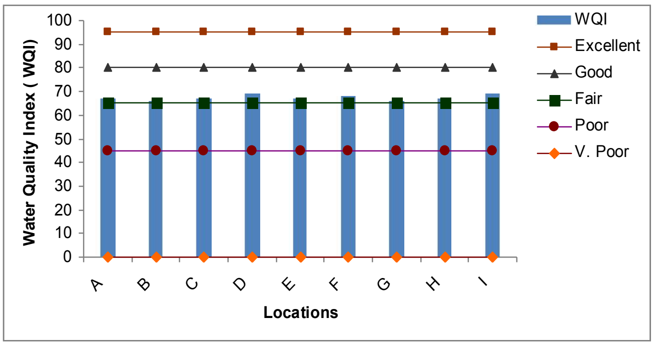
The results showed that the (Na%) values in irrigation water varied from (34.19 % – 40.43%). Based on the classification of (Todd, 2005) for (Na%) values, the results showed that all (Na%) values fall within the water class of good except one value of location **H** falls within the water class permissible.

5.2 Results and discussion of Canadian Method

Equations (1 to 7) were used to find the final results of the irrigation water quality index according to Canadian method for the nine selected locations on Shatt Al-Kufa River during the period from January, 2014 to October, 2014.

The average and seasonal water quality indices that were computed for all studied locations are represented graphically in Figs 2 to 6. These figures show that the average and seasonal WQIs for irrigation use were classified as Fair (65 – 79) for all studied locations compared with the five classifications of the Canadian method and their values were range between (66 – 72). The highest value (72) occurred in locations **A** in Summer season, location **F** in Summer and Autumn seasons and location **I** in Autumn season. The lowest value (66) occurred in locations **B** and **G** in Winter season.

It was noticed that the index decreased in Winter and Spring season and improved in Summer and Autumn season. The effective reason which decrease the index was the presence of high values of EC (1034 – 2364) and high concentrations of TDS (626-1522) ppm in all locations, which it refers to high concentrations of salts because of bad irrigation management and mixing with salty drains water. The water is failed by these parameters, so it must be done a good drainage to the irrigated soils which supplied with this water.



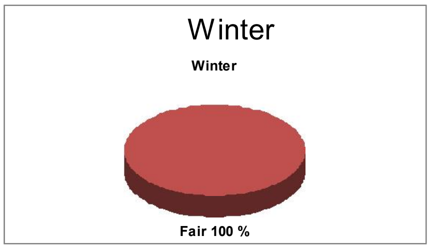
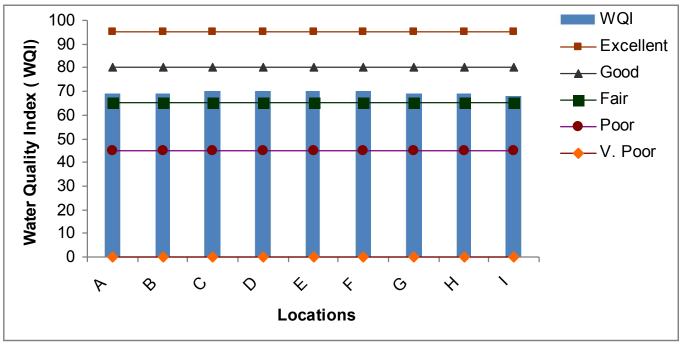


Fig. 2. Water Quality Index (WQI) for Irrigation Use According to The Canadian Method for Locations of Shatt Al-Kufa River During Winter Season



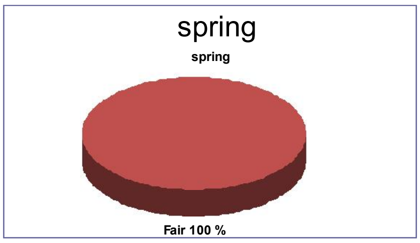


Fig. 3. Water Quality Index (WQI) for Irrigation Use According to The Canadian Method for Locations of Shatt Al-Kufa River During Spring Season.

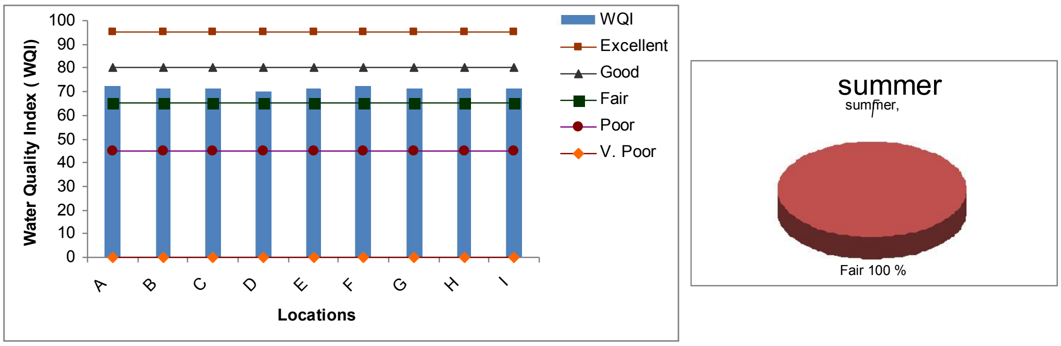


Fig. 4. Water Quality Index (WQI) for Irrigation Use According to the Canadian Method for Locations of Shatt Al-Kufa River During Summer Season

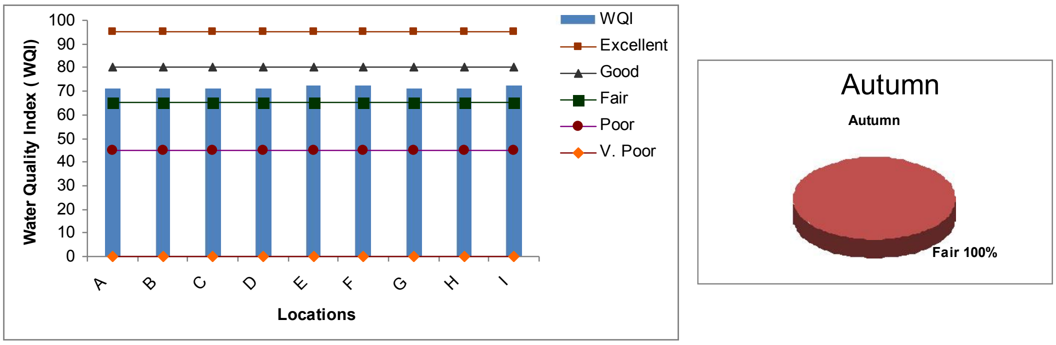


Fig. 5. Water Quality Index (WQI) for Irrigation Use According to The Canadian Method for Locations of Shatt Al-Kufa River During Winter Season

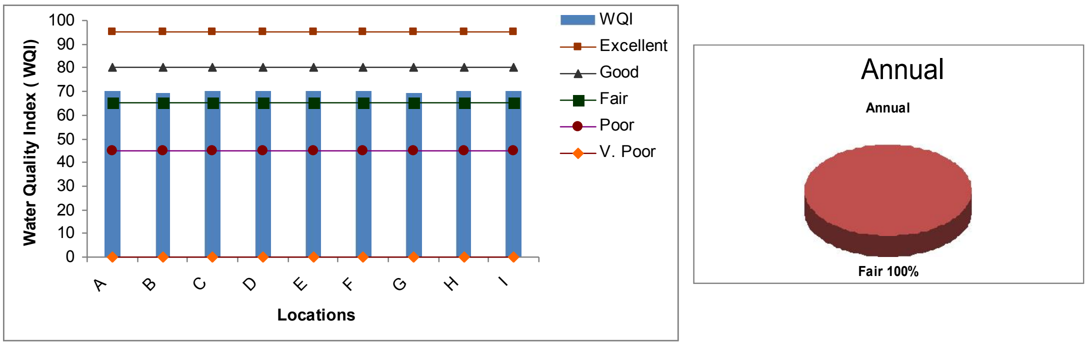


Fig. 6. Annual Water Quality Index (WQI) for Irrigation Use According to The Canadian Method for Locations of Shatt Al-Kufa River

6.Conclusions

1. The mean values of parameters for all selected locations were within the highest allowable of FAO classification. The values of EC were ranged between (1034 - 2364) µmho /cm , while TDS values were between (626 -1522) ppm. The concentrations of Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} were between (70.73- 136.8) ppm, (29.3- 83.8) ppm, (83 – 195) ppm and (3.5- 12) ppm, respectively. The sulfate concentrations were ranged

between (258 –543) ppm were as the chloride concentrations were between (104.5-225.2) ppm.

2. Based on the (SAR) classification, the water was within level S1 and there was no harmful effects from sodium because all the values of (SAR) were less than ten. SAR values varied from (2.015 –2.75) in Shatt Al – Kufa water.
3. According to the Todd classification of irrigation water based on SSP, all (Na %) values fall within the water class of good except one value (value of location **H**). SSP values varied from (32.69 % – 40.43 %) in Shatt Al – Kufa water.
4. Average and seasonal water quality indices were classified as Fair class (65 – 79) in all studied locations.
5. The index decreased in Winter and Spring seasons and improved in Summer and Autumn seasons.
6. The effective reason which decrease the index was the presence of high values of EC and high concentrations of TDS in all locations , which it refers to high concentrations of salts because of bad irrigation management and mixing with salty drains water.

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