Assessment of the Irrigation Water Quality for Al-Kifl River in Al-Hindya City

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Abstract

The present study is an attempt to assessment the water quality of Al-Kifl river within Al-Hindiya city in Iraq for irrigation purpose. The total length of study reach was about 9 km, water samples were collected from three stations along the reach through two seasons, wet (January-February-March), and dry (July- August) during year 2015. The samples were test for EC, TDS, PH, Na^+, Ca^{+2}, Mg^{+2}, HCO_3^-, SO_4 and Cl^- parameters. According to irrigation water quality guidelines of Food and Agriculture Organization (FAO), the salinity, specific ion toxicity and miscellaneous effects problems were under the categories "slight to moderate" hazard for both seasons, While there was no infiltration hazard. Also, pH value and sulphate concentration were within accepted rang. The model of irrigation water quality index (IWQI) which developed in Brazil by Meireles et al. (2010) was used to evaluate the river water for irrigation, and values were found within the range (70-85) which classified as low restriction limit. Water in this category should be used in the light texture or moderate permeability soils and sodicity problem can appear in heavy texture soils.

Key words: Al-Kifl river, Irrigation water quality Index, FAO.

الخلاصة :

الدراسة الحالية هي محاولة لتقييم نوعية مياه نهر الكفل لإغراض الري ضمن قضاء الهندية في العراق. الطول الكلي لمنطقة الدراسة 9 كم، نماذج المياه أخذت من ثلاث محطات على النهر وخلال موسمين، رطب(كانون الثاني، شباط، آذار) وموسم جاف (تموز، آب) لسنة 2015. تم تحليل العينات من حيث الايصالية الكهربائية، الأملاح الذائبة الكلية، الرقم الهيدروجيني، الصوديوم، الكالسيوم، المغنيسيوم، الكاربونات، الكبريتات والكلورايد. طبقا لتعليمات منظمة الغذاء والزراعة FAO المتعلقة بنوعية مياه الري، فان مشكلة الملوحة، السمية، والتأثيرات الأخرى في مياه نهر الكفل لكلا الموسمين كانت تقع ضمن خفيف الى معتدل بينما لا توجد مشكلة بالنسبة لنفاذية مياه الري. ايضا كانت قيم الرقم الهيدروجيني وتركيز الكبريتات ضمن الحد المقبول في مياه الري. تم استخدام مؤشر نوعية مياه الري IWQI الذي طور في البرازيل من قبل Meireles واخرين عام 2010 لتقييم صلاحية مياه نهر الكفل للري وقد تراوحت قيمته ضمن المدى (70–85) والتي تصنف (تقييد منخفض). المياه ضمن هذا الصنف يجب ان تستخدم لري الترب ذات النسجة الخفيفة او النفاذية المعتدلة حيث ممكن ان تظهر مشكلة الصودية في الترب الثقيلة النسجة.

الكلمات المفتاحية: نهر الكفل، مؤشر نوعية مياه الري، الغذاء والزراعة

1. Introduction

The quality of irrigation water has a significant effect on the soil salinity, growth and yield of agricultural crops. In general, water used for irrigation always contains different concentrations of dissolved salts which are generated naturally (precipitation rate, weathering of the rocks and dissolving of other salt sources) or anthropological i.e. domestic and industrial sources (Jarvie *et. al*., 1998).

The most important criterion that need to be considered when assessing the quality of irrigation water are (Ayres and Westcot, 1994):

1- Salinity: if the total concentration of salts dissolved (TDS) in irrigation water is high enough to accumulate in the root zone of crops, the crop will have the additional difficulty in extracting sufficient quantities of water from salty soil solution. Salinity can lead to slow growth,low yield, and early symptoms of wilt. Commonly, the electrical conductivity (EC) parameter can be used to explain the salinity of water.

2- Permeability:irrigation water quality has an effect on reducing the soil permeability. Low salts and the relative high content of sodium to calcium and magnesium in water can reduce the rate of infiltration through the soil. So, the crop is not a sufficient supplied with water and yield is reduced. The most common water quality parameter which influences the natural rate of water infiltration is the relative concentrations of sodium, magnesium and calcium ions in water that is also known as the sodium absorption ratio (SAR).

3- Toxicity ions: the most toxic ions in the irrigation water are boron , chloride and sodium which are taken by the crop and concentrate in sufficient mounts that result in a reduced yield.

4- Other problems: such as the high bicarbonate concentration, suspected abnormalities indicated by an unusual pH of the water and excessive nitrogen in water.

Therefore, the study of irrigation water quality has become essential because it shows whether the quality of the water suitable for irrigation and do not cause formation of saline or alkaline soils in addition to being an indicator of whether this kind of the water cause toxicity to plants and crops.

The most useful tool to monitor and assess the water quality is by using the Water Quality Index (WQI) which is a single number like a grade explains the total water quality at a certain area and time based on several water quality parameter (Al-obaidy *et. al*.,2010).It also assesses the suitability of the quality of the water for a variety uses such as irrigation, recreation, drinking water etc.(Cude,2001).

WQI was first proposed by Horton 1965, later, numerous of indices have been developed all over the world, such as Weight Arithmetic Water Quality Index (WA-WQI),National Sanitation Foundation Water Quality Index (NSF-WQI), Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI), British Columbia Water Quality Index, Oregon Water Quality Index(O-WQI)etc. (Kannel *et. al*. 2007; Shweta *et. al*., 2013).

Much research have been conducted to monitor and study water quality, Meireles *et. al*.,(2010) classify water quality in the Acarau Basin, in the North of the state of Ceara, Brazil for irrigation use. Al-Janabi *et. al*., (2012) apply the (CCME-WQI) for Tigris River within Baghdad city, Iraq using eleven water quality parameter. Al-Shujairi (2013) developed Iraqi river water quality index (IRWQI) which can be applied to assess the water quality of Tigris and Euphrates rivers for public uses. Nizar and Ali (2015) used the IWQI developed by Meireles *et. al*. 2010 to assess the suitability of Kani-Ban stream on Tanjero River in Sulaimani for irrigation purpose.

The main objective of this paper is to evaluate the irrigation water quality index of Al- Kifl river within Al- Hindya city in Karbala governorate by application of (IWQI) model developed by (Meireles *et. al*. 2010).

2. Study Area

Al- Kifl river is one of the important tributaries of Euphrates River in Iraq passing through Karbala and Hilla governorates. It starts to flow from the downstream of Al Hindiya barrage regulator, then it flows towards south in parallel to the left bank of the shatt Al-Hindiya for a distance about 69 km passing through an area famous for planting palm trees and fruits. The total length of the stream in Al-Hilla is about 35 km and it's end station is at Al-Kifl city in the same Province, the total area which is irrigated by the river is about 60814 acres (Azeez *et. al*.,2015).The Study area consists of three stations distributed along Al-Kifl river within Al-Hindya city between (32° 36 ′ 54" N, 44°14′ 7" E) and (32° 32′ 37.7" N, 44°14′ 3.5" E) and the study reach length is about 9 km as seen in fig.(1).The first station (S_1) is at distance 13 km downstream Al Hindiya barrage.

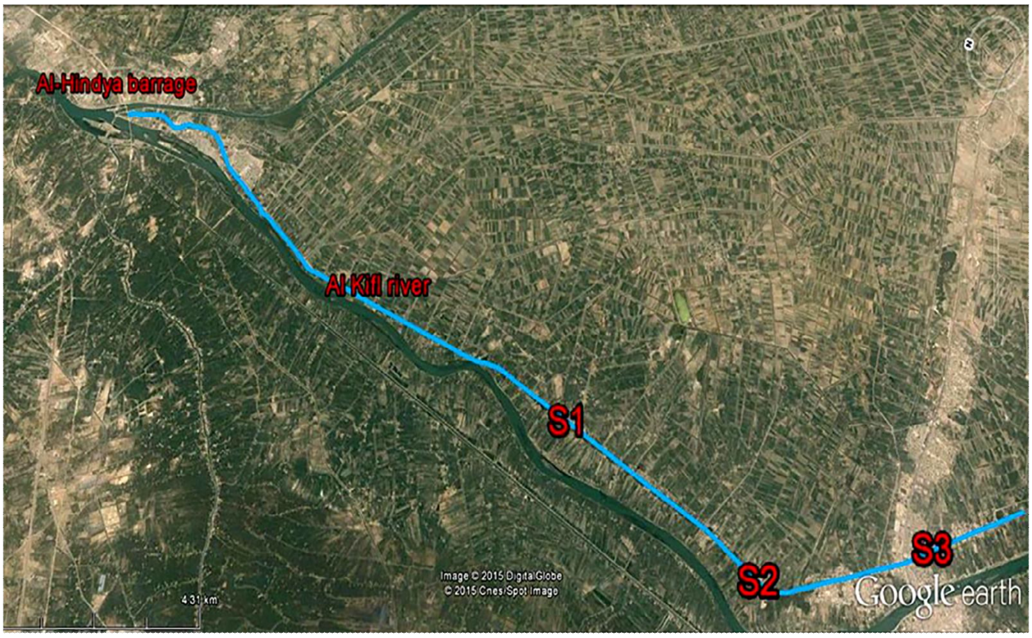

Fig. (1) The study reach of al-Kifl stream

3. Material and Methodology

Samples were measured monthly during wet season (January, February, March) and dry season (July, August) for year 2015 to evaluate the seasonal variations in irrigation water quality. Eight environmental parameters, which are the most essential on the use for irrigation water, were analyzed chemically according to the standard methods (APHA, 1995) (i.e. Ec, TDS, Ca, Mg, Na, HCO_3, Cl and SO_4). Sodium Absorption Ratio (SAR), was calculated based on some standard equation. This equation is as follows (Ayres and Westcot, 1999):

$$SAR = \frac{Na^{+1}}{\sqrt{Ca^{+2} + Mg^{+2}/_2}} \quad \ldots\ldots\ldots\ldots(1)$$

Chemical analysis of the samples has been done at the central laboratory of the Environmental directorate of Karbala.

4. The Model of Irrigation Water Quality Index (Iwqi)

The model of (IWQI) presented by Meireles et al. 2010 is applied in three steps:

1- Defining the parameters that contribute to most change in quality of irrigation water.

2- For each parameter, the values of quality measurement (Qi) and aggregation weights(wi) were established using the equation (2), based on the acceptance limits shown in table (1), which was setup according to irrigation water quality parameters proposed by the university of California committee of consultants (UCCC) and the criteria established by Ayers and Westcot 1999. Water quality parameters were represented by a non-dimensional number; the higher the value, the most appropriate water qualities.

$$Q_i = q_{i\,max} - [(X_{ij} - X_{inf}) * q_{iamp} / X_{amp}] \quad \ldots\ldots(2)$$

Where;

q_{imax} : the maximum value of q_i for the class (unit less).

x_{ij} : the observed value for the parameter.

x_{inf}: the equivalent value to the lower limit of the class to which the parameter refers.
q_{iamp} : the class amplitude; x_{amp} is class amplitude to which the parameter belongs.

For the last class of each parameter, to evaluate x_{amp}, the upper limit was considered to be the highest value obtained from physical-chemical and chemical analysis of the water samples.

Table (1): parameter limiting values for (qi) calculation (Ayers and Westcot, 1999).

q_i	EC (ds /m)	SAR $(meq/l)^{1/2}$	Na^+ (meq/l)	Cl^- (meq/l)	$HCO3^-$ (meq/l)
85 – 100	$0.20 \leq CE < 0.75$	$2 < SAR < 3$	$2 \leq Na < 3$	$Cl < 4$	$1 \leq HCO3 < 1.5$
60 – 85	$0.75 \leq CE < 1.50$	$3 \leq SAR < 6$	$3 \leq Na < 6$	$4 \leq Cl < 7$	$1.5 \leq HCO3 < 4.5$
35 – 60	$1.50 \leq CE < 3.00$	$6 \leq SAR < 12$	$6 \leq Na < 9$	$7 \leq Cl < 10$	$4.5 \leq HCO3 < 8.5$
0 – 35	$EC < 0.20$ or $EC \geq 3.00$	$SAR < 2$ or $SAR \geq 12$	$Na < 2$ or $Na \geq 9$	$Cl \geq 10$	$HCO3 < 1$ or $HCO3 \geq 8.5$

3- Defining the weight value (w_i) for each parameter according to table(2). As shown, the values were normalized such that their sum equals one.

Table 2**:** weights for the IWQI parameters (Meireles et al., 2010).

Parameters	w_i
EC	0.211
Na^{+1}	0.204
HCO_3^{-1}	0.202
Cl^{-1}	0.194
SAR	0.189
Total	1.000

4- Calculating the irrigation water quality index as:

$$IWQI = \sum qi\ wi \quad \ldots\ldots\ldots..(3)$$

IWQI is dimensionless parameter ranging from (0 to 100), qi is the quality of the i^{th} parameter, a number from (0 to 100), function of its concentration or measurement, w_i is the normalize weight of the i^{th} parameter, function of its significance illustrate the overall changeability in water quality. The categories are divided based on the proposed water quality index, which is developed according to existent water quality indexes. The hazard of water salinity, slow infiltration of soil water, in addition to toxicity to plants are summarized in the classifications developed by Bernardo, 1995 and Holanda and Amorim, 1997, which gives the restrictions for using irrigation water as shown in table(3).

Table 3 : the restrictions of water use based on irrigation Water Quality Index (Bernardo, 1995 and Holanda, 1997)

IWQI	RESTRICTIONS	RECOMMENDATION	
		PLANT	SOIL
(85-100)	No Restriction (NR)	No toxicity risk for most plants	May be used for the majority of soils with low probability of causing salinity and sodicity problems, being recommended leaching within irrigation practices, except for in soils with extremely low permeability
(70 – 85)	Low Restriction (LR)	Avoid salt sensitive plants	Recommended for use in irrigated soils with light texture or moderate permeability, being recommended salt leaching. Soil sodicity in heavy texture soils may occur, being recommended to avoid its use in soils with high clay
55-70	Moderate Restriction (MR)	Plants with moderate tolerance to salts may be grown	May be used in soils with moderate to high permeability values, being suggested moderate leaching of salts.
(40-55)	High Restriction (HR)	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 HCO_3 values	May be used in soils with high permeability without compact layers. High frequency irrigation schedule should be adopted for water with EC above 2000 dS m^{-1} and SAR above 7.0.
(0- 40)	Severe Restriction (SR)	Only plants with high salt tolerance, except for waters with extremely low values of Na, Cl and HCO_3.	Should avoid its use for irrigation under normal conditions. In special cases, may be used occasionally. Water with low salt levels and high SAR require gypsum application. In high saline content water soils must have high permeability, and excess water should be applied to avoid salt accumulation.

5. Results and Discussion

Statistical measurement for water quality parameters, such as minimum, maximum, mean and standard deviation, are found with help of EXCEL software for wet and dry periods as shown in tables (4) and (5) respectively. Depending on analysis of variance, there was no significant difference among stations.

Table (4): statistical analysis of water quality parameters for Al-Kifl river (wet season -2015)

Parameter	TDS mg/l	EC ds/m	Na^+ meq/l	Cl^- meq/l	SO_4 meq/l	HCO_3^- meq/l	Mg^{+2} meq/l	Ca^{+2} meq/l	SAR meq/l	IWQI
Min.	814	1.24	3.39	3.41	4.23	1.97	0.99	4.40	1.76	74.47
Max.	865	1.32	5.04	4.42	7.32	2.07	3.54	6.35	2.69	79.51
Mean	837	1.27	4.40	3.97	6.18	2.03	1.92	5.52	2.29	77.13
Std. dev.	20	0.03	0.67	0.43	1.02	0.04	0.98	0.66	0.40	1.92

Table (5): statistical analysis of water quality parameters for Al-Kifl river (dry season -2015)

Parameter	TDS mg/l	EC ds/m	Na^+ meq/l	Cl^- meq/l	SO_4 meq/l	HCO_3^- meq/l	Mg^{+2} meq/l	Ca^{+2} meq/l	SAR meq/l	IWQI
Min.	996	1.53	3.61	4.06	8.54	1.44	3.13	6.40	1.57	70.10
Max.	1086	1.67	4.22	4.17	10.04	1.71	4.12	7.35	1.85	73.00
Mean	1033	1.60	3.93	4.14	9.40	1.60	3.66	6.92	1.71	71.43
Std. dev.	40	0.06	0.28	0.05	0.60	0.09	0.39	0.43	0.13	1.25

6. Assessment of Individual Hazard Groups

6.1 SALINITY HAZARD

The salinity of irrigation water leads to the accumulation of salt in the root zone of crop, thus reducing the ability of plant to get sufficient water from the soil and causes yield reduction. There are many factors increase salinity in irrigation water such as evaporation, sewage effluent, dissolution of limestone and evaporate bedrock, and agricultural drainage (Al-Shujairi, 2013).

Electrical conductivity (EC) or the total dissolved solids (TDS) analysis could be used in monitoring the salinity of water because the conductance is a strong function of the total dissolved ionic solids. As Ec increases, the less water is available to plants. In this study, the average values of EC and TDS which were measured in the wet season was 1.27 ds/cm, 837 mg/l respectively, while in dry period these values were 1.60 ds /cm and 1033 mg/l. The increase of salinity in dry season is due to high rate of evaporation, Also the dilution process by rainfall through wet period reduces the salinity. According to (Ayers and Westcot 1994), irrigation water is severe to be used when EC > 3 ds/cm and TDS >2000 mg/l, therefore there is no salinity hazard in Al-Kifl river within the study reach and it falls within "slight to moderate" range. Fig.(2) illustrates the variation in electrical conductivity for the river during the months of study.

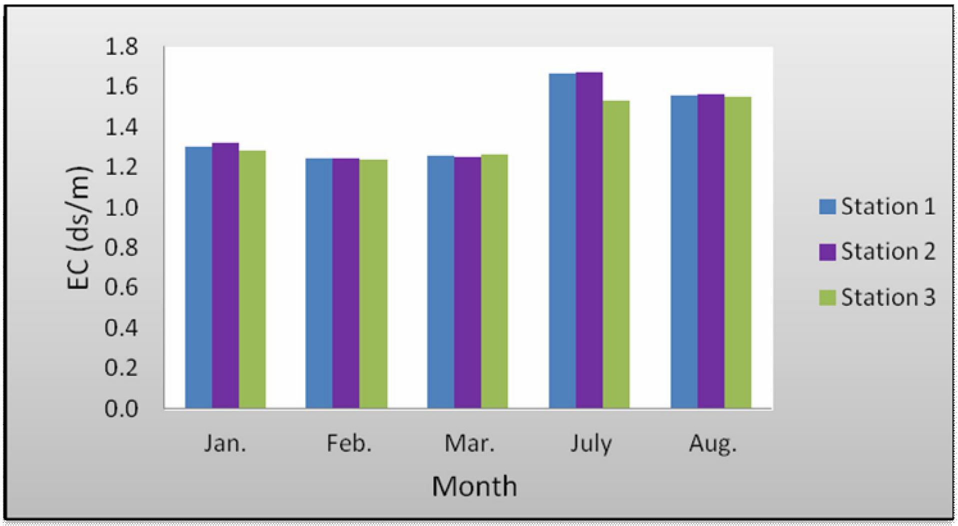

Fig.(2) : variation of EC parameter with month for stations

6-2 Infiltration Hazard

When the irrigation water can't enter the soil rapidly enough during a normal irrigation cycle, infiltration problem will appear and the water remains on the soil surface for a period causing poor supply of water to the crops. According to (Ayers and Westcot,1994),the rate of infiltration is affected by two parameters,the concentration of sodium absorption ratio (SAR) and salinity (EC) of irrigation water. In this study, the range of SAR values for wet and dry season were (1.76 to 2.69), (1.57 to 1.85) meq/l, while the range of EC were (1.24 to 1.32), (1.53 to 1.67) ds/m respectively. From the guidelines of Food and Agriculture Organization (FAO), there is no infiltration hazard when SAR between (0-3) and EC > 0.7, therefore, it seems clear from the results that the water of study reach is safe against infiltration problem.

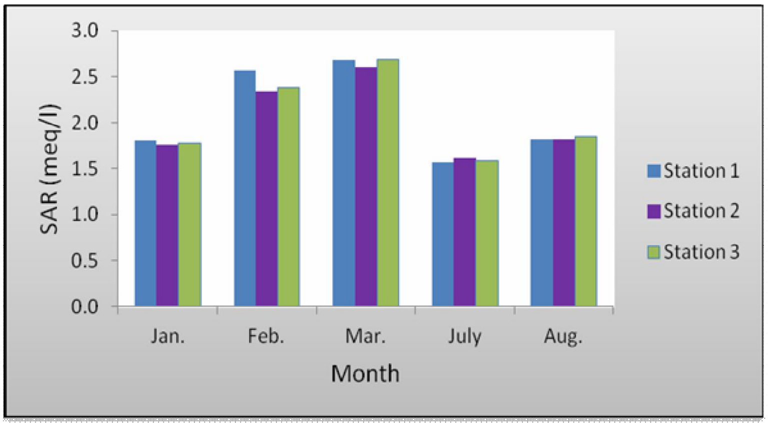

Fig.(3) : variation of SAR parameter with month for stations

6-3 Specific Ion Toxicity

Sodium and Chloride are defining the most common toxic ions which cause damage to plant when concentration in a high amount in irrigation water or soil. The sodium concentrations of water samples were ranged from (3.39 to 5.04) meq/l for wet season and (3.61 to 4.22) meq/l for dry time. The max. amount of sodium was recorded in May (5.04) meq/l, this is because of the increasing in water level which leads to dismantling of minerals from rock composition and washing the top soil of agriculture land by flood. Figs. 4 and 5 illustrate the variation in concentrations for Sodium and Chloride.

For samples, the chloride concentrations were within the range of (3.41- 4.42) meq/l for wet season and (4.06-4.17) meq/l for dry season. The results indicate there are slight to moderate hazard of toxicity for both Sodium and Chloride concentrations as the range of "slight to moderate" risk for sodium and chloride are (3-9) and (4-10) meq/l respectively (Ayers and Westcot, 1999).

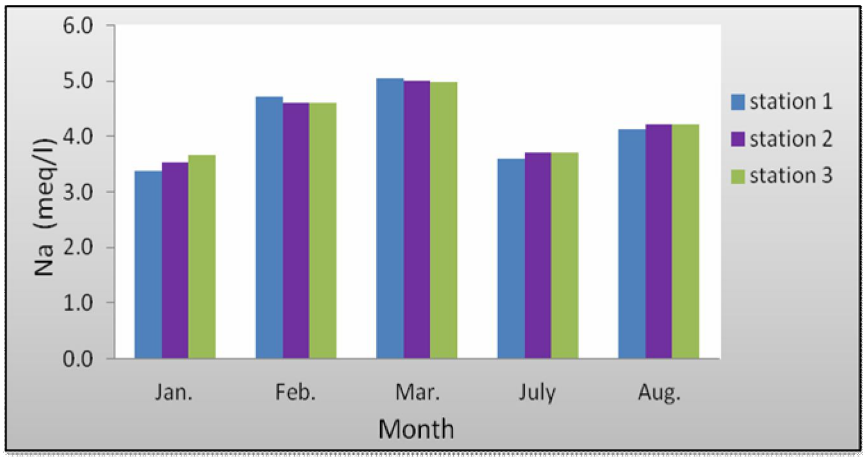

Fig.(4) : variation of Na^+ parameter with month for stations

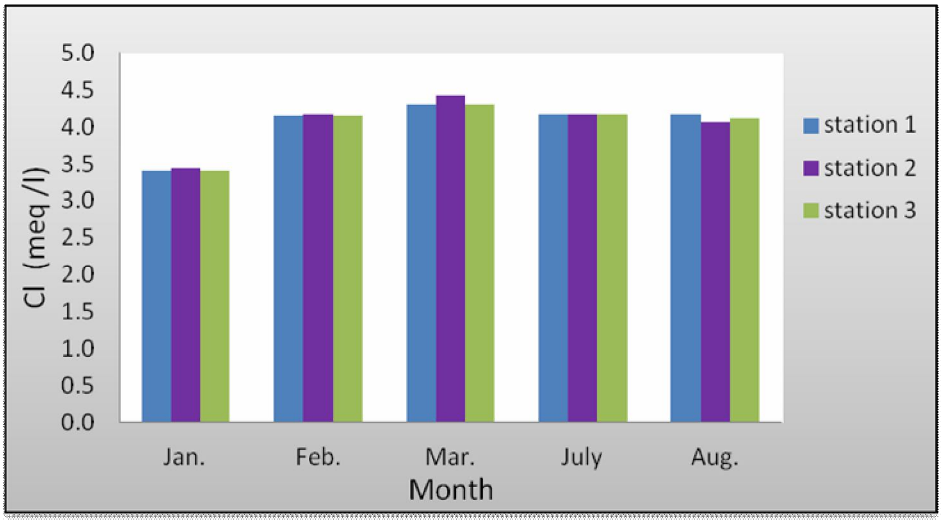

Fig.(5) : variation of Cl^- parameter with month for stations

6-4 Various Effects

In addition to the above parameters, there are other criteria which must be taken in account when assessing the quality of irrigation water:

1- pH: is an important parameter to measure the acidity or alkalinity of irrigation water. As shown in table, the mean values of pH for samples in two seasons are within the normal range for water irrigation which is (6.5 to 8.4). Irrigation water with up normal range of pH may cause a nutritional imbalance or may contain a toxic ion. . Fig (6) shows the variation in pH parameter with time.

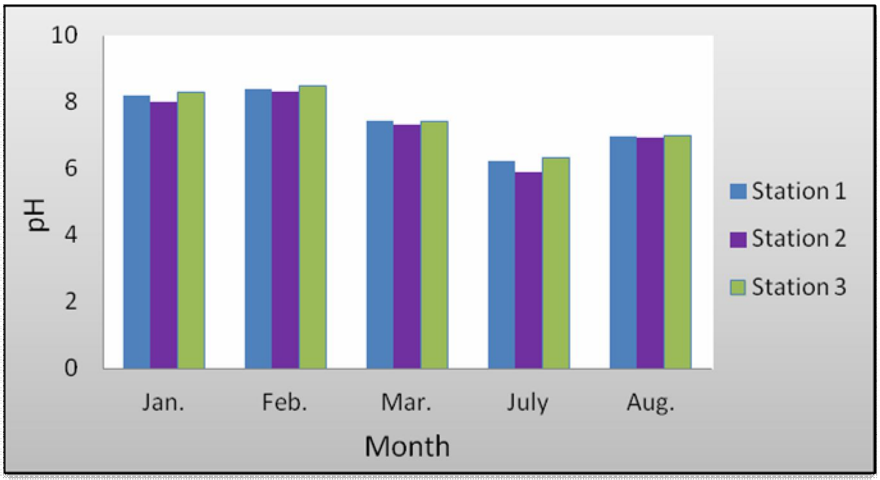

Fig.(6) : variation of pH parameter with month for stations

2- Bicarbonate: in dry condition, bicarbonate and carbonate ions, which are the main components of alkalinity, merged in soil with calcium or magnesium precipitates calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$). So,the concentration of calcium or magnesium decreases relative to sodium and as result the SAR parameter will increase causing alkalinity and large pH value. Water with high bicarbonate can leave a deposition of white lime on crop leaves irrigated in a hot season with overhead sprinkler, so the irrigation water may need acid treatment before using the crops (Lazarova and Bahri, 2004). In this study, the average concentration of bicarbonate in wet and dry seasons are 2.03 and 1.6 meq/l consecutively. These values fall also within the range "slight to moderate" hazard which is "1.5-8.5". Fig.(7) illustrates the variation of Bicarbonate concentrations for study reach.

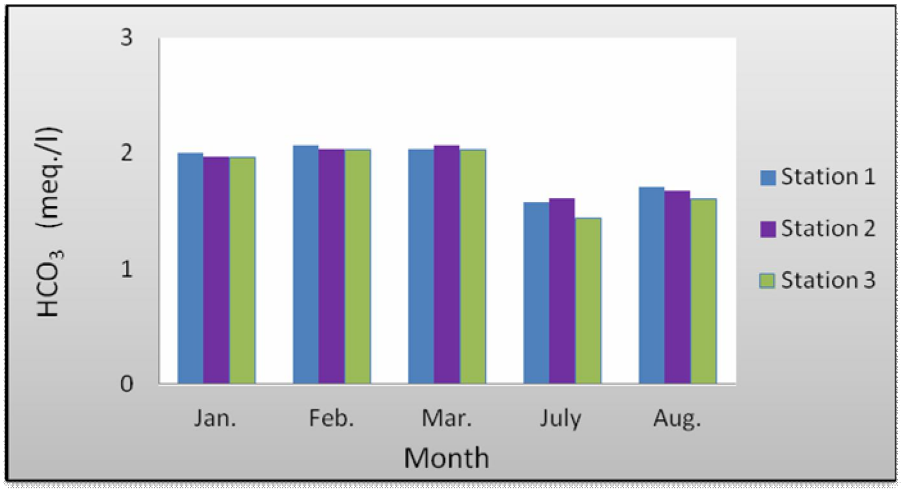

Fig.(7) : variation of HCO_3 parameter with month for stations

3- Sulfate: the sulfate ion is a main contributor to the total salt content in irrigation waters and has fertility benefits for crops but high sulfate ions in irrigation water can reduces phosphorus availability to plants. The sulfate (SO_4^{-2}) values in the water sample varied from (4.23 to 7.32) (mq/l) for wet season and (8.54 to 10) (mq/l) for dry season they fall within the acceptable range which is (0-20) mq/l according to (Ayers and Westcot ,1994). Fig (8) shows the concentration of Sulfate parameter in stations.

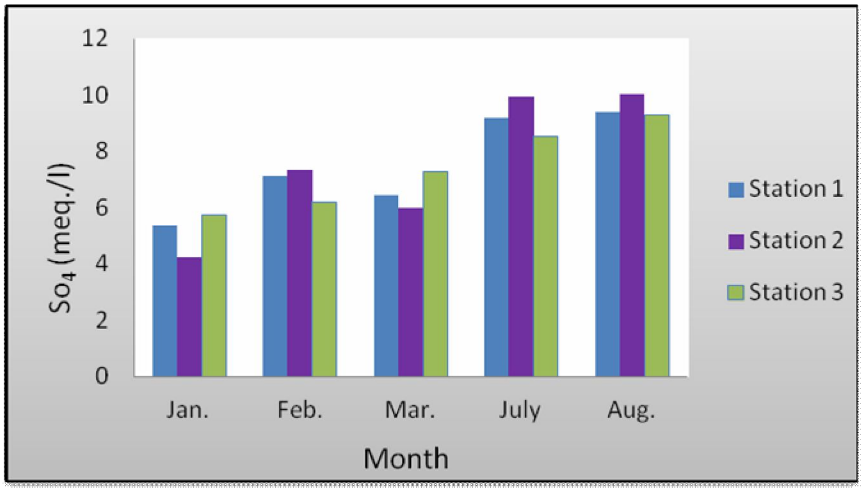

Fig.(8) : variation of SO_4 parameter with month for stations

The dominant cation trend in Al-Kifl river is $Ca^{+2} > Na^{+} > Mg^{+2}$, while the predominant order of the major anions is in the following: $SO_4 > Cl > HCO_3$. Therefore, the study area is characterized by a high sulfate ion and Calcium cation content in two seasons.

7. Irrigation Ater Quality Index (Iwqi)

Parameters such as Na^+, Cl^-, HCO_3, EC and SAR were used to develop the proposed IWQI depending on (tables:1,2) and equation (2). From (tables:4,5) and fig.(9), the IWQI value in the dry months (July, Aug.) ranged between (70.1-73) and it is less than the value obtained from winter period which is (74.47 to 79.51), this is because of the low river discharge rate and the high temperature at dry season which increase evaporation rate that lead to the increase of salts concentrations in the river.

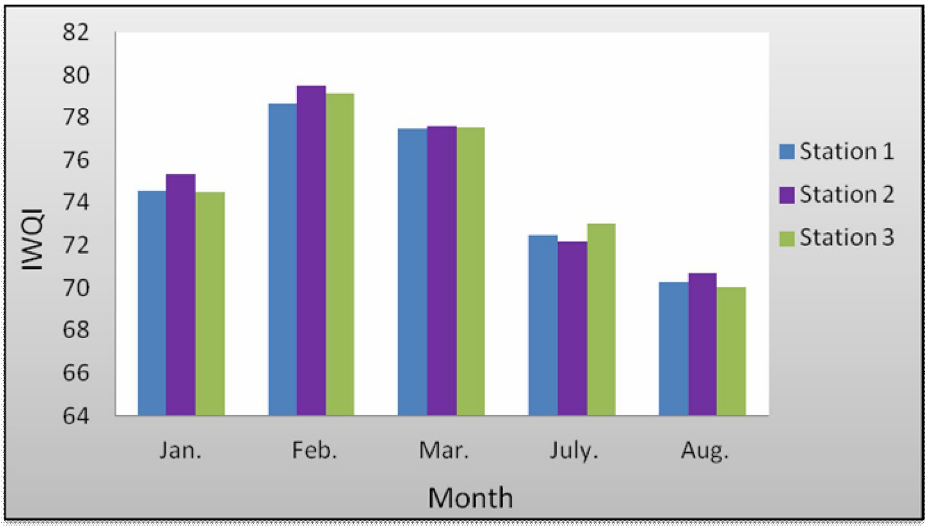

Fig.(9) : variation of IWQI parameter with month for stations

According to table (3) the (IWQI) for both seasons falls under the second class (low restrictions) for irrigation purposes, so the water of Al-Kifl river is suitable to irrigated soils with light texture or moderate permeability, its use is avoided in soils with high clay (heavy texture) because soil sodicity may appear and salt leaching is required. Also salts sensitive crops such as Peas, Beans, Apple and Peach must not grow in study area (Teang, 2012).

8. Conclusion

The main objective of this study is to evaluate the irrigation water quality for AL-Kifl river in Hindya city in Iraq.

1- According to FAO irrigation water quality guidelines, salinity, specific ion toxicity and miscellaneous effects problems in Al-Kifl river within the study area were under the categories "slight to moderate" hazard, while there was no infiltration hazard. Also, the water was characterized as a high sulfate ion and Calcium cation content in two seasons.

2- It was observed that IWQI of River improved more at wet season comparing with summer season and it ranged between (70-85) for both season so, it falls under the (low restrictions) set for irrigation purpose .

3- The water of al-Kifl river is suitable to be used in light texture or moderate permeability soil. Salt leaching is required when it is used in clay soil.

4- The assessment of irrigation water should not depend on laboratory test only, but it must include studying the soil properties, type of grown crop, climate factor and efficiency of irrigation and drainage network.

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