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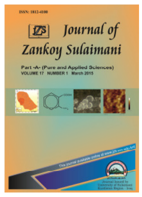

Quality of Kani-Ban water as a main tributary of Tanjero River for irrigation purposes

Nizar Yaseen Hamasalh[1] & Ali Bawasheakh Ahmad[1]

1 *Faculty of Agricultural Science-Sulaimani University, Bakrajo Street, Sulaimaniyah-Iraq*
E-mail: nizar.hamasalh@gmail.com

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Abstract

The current study was undertaken to evaluate the suitability of Kani-Ban stream water as one of the main tributary of Tanjero River in Sulaimani for irrigation purpose. Water samples were collected from (6) various locations from November (2013) to April (2014). Water samples were analyzed the various physico-chemical parameters, such as, pH, Electrical Conductivity (EC), Total dissolved solids (TDS), Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, CO_3^{2-}, SO_4^{2-}, Cl^-, B, and NO_3^-. The present work is a trial to evaluate and classify the water quality of Kani-Ban stream for irrigation purpose, by using the model of Irrigation water quality index (IWQI) developed in Brazil .The results obtained on (IWQI) for all sampling sites were within the class of use with no restrictions (excellent) for irrigation. According to the EC and SAR plotted on the US salinity diagram, it is illustrated that water samples of Kani- Ban stream fall in the class of (C_2-S_1) for locations (1, 2, 3, and 4) indicating medium salinity with low sodium hazards, while other locations (5 and 6) fall in the class of (C_3-S_1) indicating high salinity with low sodium hazards which can be used for irrigation. While as sodium adsorption ratio (SAR) , all the water samples fell under 'Low' class and as per salinity classification (US salinity diagram); all the irrigation water samples fell under low sodium hazards (S_1) class it means these water samples are suitable for irrigation. The residual sodium carbonate (RSC) values of all water samples under "Safe" category.

Introduction

According to Shalhevet & Kamburov (1976) ***[1]*** irrigation water quality is mainly defined by the total quantity of dissolved salts and its ionic composition depending on the water source, location and time of water sampling. Although Water Quality Index (WQI) is usually orientated to qualify urban water supply, it has been widely used by environmental planning decision makers. The quality of the irrigation water has to be evaluated to avoid or, at least, to minimize impacts on agriculture ***[2]***. The chemical constituents of irrigation water can affect plant growth directly through toxicity or deficiency, or indirectly by altering plant availability of nutrients ***[3]*** and ***[4]***. The quality of water reflects inputs from the atmosphere, soil, water rock, weathering and pollutant sources. Its use for irrigation depends upon the dissolved salts like Na, Ca, Mg and HCO_3 in water. The concentration of these salts and their ratio to one another are influence the quality of water for irrigation ***[5]***. Water used for irrigation can also vary greatly in quality depending upon the type and quantity of dissolved salts. In irrigated agriculture, the hazard of saline water is a constant threat. Poor-quality irrigation water becomes more concern as the climate changes from humid to arid conditions. Salts are originated from dissolution or weathering of rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals. These substances are carried with the water to wherever it is used ***[6]*** and ***[7]***.

Materials and Methods

A. Study area

Kani-Ban stream has been selected for the present investigation. This stream is fed by the sub-cathments in Bakrajo district *(Figure: 1).* Kani-Ban stream represents one of the two main tributaries of Tanjero River located south of Bakrajo by (3 km) and collects water from valleys and springs in Tasluja area around Baba-Ali bridge passing through Kani-Ban valley. Width of the stream ranges between (3 m) and (5 m) and the water depth grades from 0.3 m to 1 m.

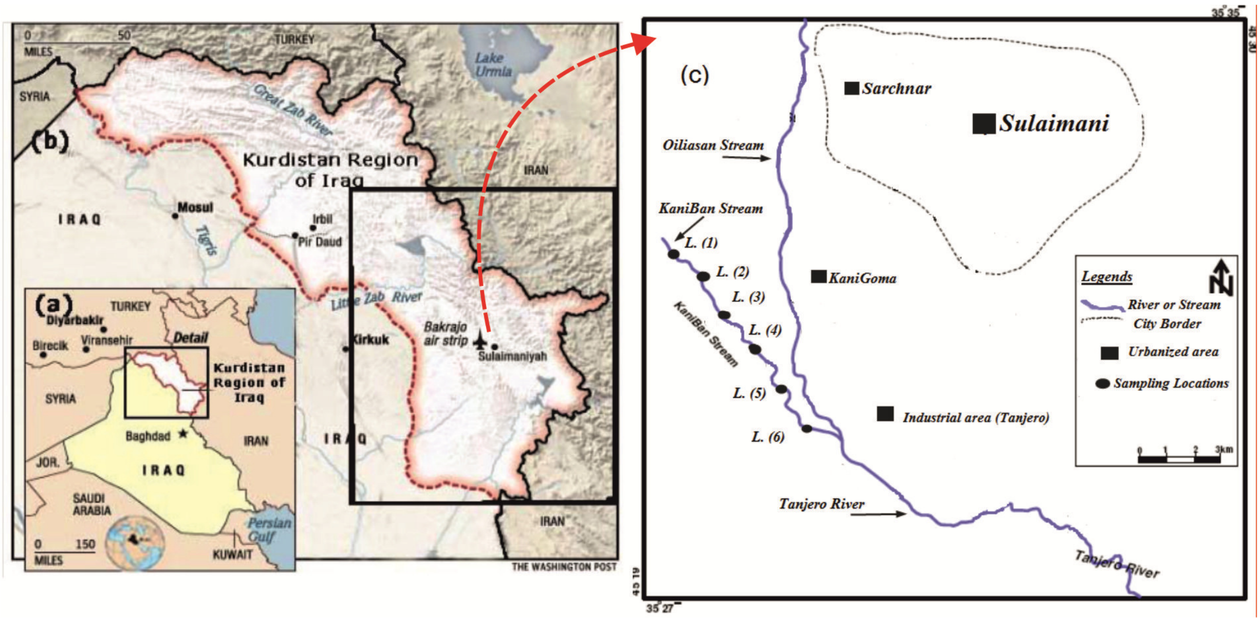

Figure-1: Map of the studied area showing; (a) Map of Iraq, (b) Map of Sulaimani City, (c) Sampling sites along the Kani-Ban stream.

B. Water Sampling and Analysis

Water samples from six sites along the Kani- Ban stream were taken in November (2013) and April (2014) for assessing seasonal variations of irrigation quality *(Figure: 1).* Samples from all locations were collected in acid-washed 250 and 500 ml polyethylene bottles, following the standard guidelines ***[8, 9,and 10]***. Also measured at the field are coordinates and elevation of each of the locations sampled using Global Position System (GPS) the results of X and Y axis were expressed in Universal Trensvers Mercator (UTM) system unit *(Table:1).* The samples were analyzed immediately for water acidity (pH) and electrical conductivity (EC), using portable pH-meter (HANNA pH 211) and EC-meter model (LF318) respectively. Total dissolved solids (TDS) were computed by multiplying the EC (in μScm^{-1}) by a factor of (0.64). The analysis for the physico-chemical parameters of the samples were carried out following the established analytical methods. Soduim (Na^{+})and Potassium (K^{+})were determined by flame photometry (Genway PFP7); Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Nitrates (NO_3^{-}), Sulfate (SO_4^{2-}) Chloride (Cl^{-}) and Boron (B) was determined using photoLab spectral instrument model (82362), (2005), WTW company-Germany). The sodium adsorption ratio (SAR) was estimated by the following equation using the values obtained for, Ca^{2+}, Mg^{2+} and Na^{+} , where all ionic concentrations are expressed in ($mmol_c\ L^{-1}$) ***[11].***

$$SAR = Na^{+} /[(Ca^{2+} + Mg^{2+})/2]^{1/2} \text{............} (1)$$

The residual sodium carbonate (RSC) was determined by the following equation using the values obtained for CO_3^{2-}, HCO_3^-, Ca^{2+} and Mg^{2+} ,where all ionic concentrations are expressed ($mmol_c\ L^{-1}$) ***[12].***

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \ldots (2)$$

The qualitative analyses were carried out at the Soil Chemistry laboratory of the Faculty of Agricultural Science/ University of Sulaimani.

Table (1): Geographical coordinates along with the elevations of the sites from which samples were taken.

Locations	*(UTM) Geographical coordinates*		*Elevation (m)*
	X	*Y*	
1	*38531107E*	*3931361N*	*705 m*
2	*38531426E*	*3931290N*	*699 m*
3	*38531871E*	*3931065N*	*700 m*
4	*38532422E*	*3930693N*	*703 m*
5	*38532699E*	*3930235N*	*703 m*
6	*38533115E*	*3930180N*	*710 m*

All parameters are expressed in milligrams per liter ($mg\ L^{-1}$) and millimole sub charge per liter ($mmol_c\ L^{-1}$), except pH (units) and EC. The EC is expressed in microSiemens per centimeter ($\mu S\ cm^{-1}$) at 25°C.

C. Irrigation Water Quality Index (IWQI)

The model of (IWQI) developed by ***[13]*** was applied on the observed data according to the following steps:

Step1: Identified the parameters were considered more relevant to the irrigation use; EC, Na^+, $HCO3^-$, Cl^-, SAR°.

Step2: The values of quality measurement (Quality rating) (Qi) for each parameter were calculated using the equation (3), based on the tolerance limits shown in *(Table: 3)*, and the observed water quality results. *(Table: 3)* was consecrated according to irrigation water quality parameters proposed by (UCCC) and the criteria established by ***[14].***

$$Qi = qi_{max} - [(X_{ij} - X_{inf}) * qi_{amp}) / x_{amp}] \ldots\ldots (3)$$

Where qi_{max} is the maximum value of quality rating scale (Qi) for the class of *(Table :3)* ; xij is the observed value for the parameter; x_{inf} is the corresponding value to the lower limit of the class to which the parameter belongs; qi_{amp} is class amplitude; x_{amp} is class amplitude to which the parameter belongs .In order to evaluate x_{amp}, of the last class of each parameter, the upper limit was considered to be the highest value determined in the physical-chemical and chemical analysis of the water samples. Each parameter weight used in the (IWQI) was obtained by ***[13]*** as shown in *(Table: 2).* The irrigation water quality index (IWQI) was calculated as:

$$IWQI = \sum_{i=1}^{n} qi\ wi \ldots\ldots\ldots\ldots (4)$$

Table (2): Weights for the IWQI Parameters [13]

Parameters	**Weight (wi)**
EC	0.211
Na	0.204
HCO_3	0.202
Cl	0.194
SAR	0.189
Total	1.000

The irrigation water quality index is dimensionless parameter ranging from 0 to 100; *qi* is the quality of the ith parameter, a number from 0 to 100, function of its concentration or measurement; *w*i is the normalized weight of the ith parameter, function of its importance in explaining the global variability in water quality.

Table (3): Parameter limiting values for quality measurement (qi) calculation [14].

Qi	EC (µS cm $^{-1}$)	SAR°	Na^+ (mmol$_c$ L^{-1})	Cl^- (mmol$_c$ L^{-1})	HCO_3^- (mmol$_c$ L^{-1})
85 - 100	200 ≤ CE < 750	2 ≤ SAR° < 3	2 ≤ Na < 3	1 ≤ Cl < 4	1 ≤ HCO3 < 1.5
60 – 85	750 ≤ CE < 1500	3 ≤ SAR° < 6	3 ≤ Na < 6	4 ≤ Cl < 7	1.5 ≤ HCO3 < 4.5
35 - 60	1500 ≤ CE < 3000	6 ≤ SAR° <12	6 ≤ Na < 9	7 ≤ Cl <10	4.5 ≤ HCO3 < 8.5
0 - 35	EC < 200 or EC ≥ 3000	SAR° < 2 or SAR° ≥ 12	Na < 2 or Na ≥ 9	Cl < 1 or Cl ≥10	HCO3 < 1 or HCO3 ≥ 8.5

Table (4): Irrigation water quality index (IWQI) characteristics [15]

IWQI	Water use restrictions
85 ≤ 100	No restriction (Excellent)
70 ≤ 85	Low restriction (Good)
55 ≤ 70	Moderate restriction (Poor)
40 ≤ 55	High restrictions (Very poor)
0 ≤ 40	Severe restrictions (Unsuitable for irrigation)

Results and discussion

(Table: 6) presents the results of physico-chemical parameters of the irrigation water samples of the study area of Kani-Ban stream, While *(Table: 7)* shows the guidelines for Irrigation water quality index and interpretation of water quality for irrigation. The water acidity (pH) of all stations varies from (7.51 to 7.78), which indicate that pH is within normal range. It was also observed from *(Table: 6)* the electrical conductivity (EC) and total dissolved solids (TDS) for all the sampling sites varied between (657.01 and 850.99) µScm^{-1}, (420.48 and 544.63) mg L^{-1} respectively. In terms of the 'degree of restriction on use .It is easily presumable from the data in *(Table: 7)* that in terms of EC value, the irrigation water sample of the study area is suitable for irrigation purpose as it falls under category 'none' and 'slight to moderate'. Higher the EC, lesser is the water available to plants, even though the soil may appear to be wet. Due to increasing the osmotic pressure, usable plant water in the soil solution decreases dramatically as EC increases. Total dissolved solids like EC, the irrigation water of the study area, in term of TDS, is suitable for irrigation purpose. Salinity classification was done using a quality diagram *(Figure: 2)* given by the U. S. Salinity Laboratory ***[11].*** When the analytical data of EC and SAR plotted on the US salinity diagram, it is illustrated that water samples of locations (1, 2, 3, and 4) fall in the class of (C_2-S_1) indicating medium salinity with low sodium water, while water samples of other stations (5 and 6) fall in the class of (C_3-S_1) indicating high salinity with low sodium water ,which can be used for irrigation on almost all types of soil with only a minimum risk of exchangeable sodium. The water of this type can be used for plants having good salt tolerance ***[16]***.

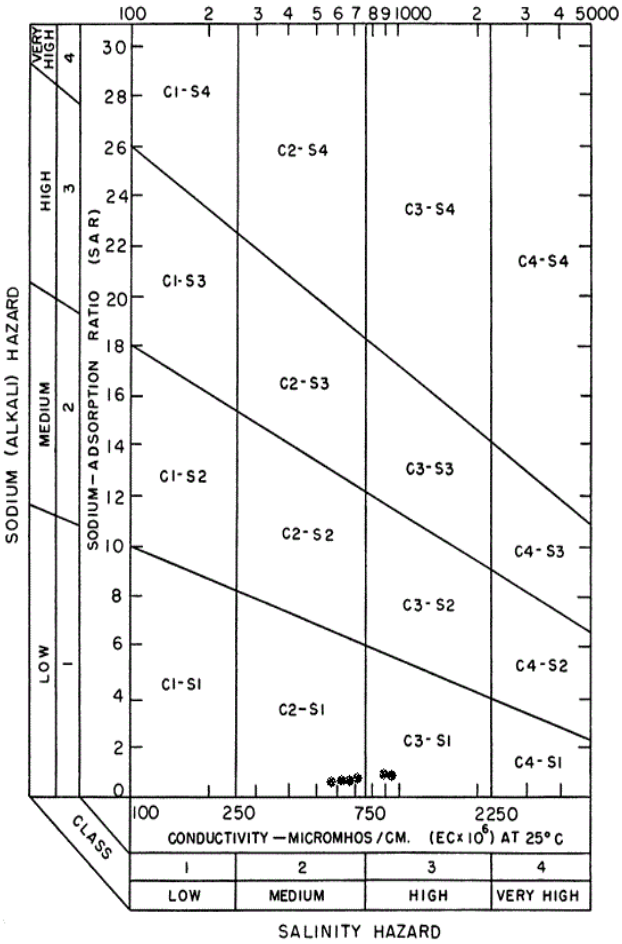

Figure-2: Salinity Classification of Irrigation Water sample **[11].**

Table (5): Physico-chemical analyses of water samples of Kani-Ban stream on November (2013) and April (2014).

November (2013)

Locations	PH	EC (µS cm^{-1})	TDS (mg L^{-1})	NO_3^- (mg L^{-1})	B (mg L^{-1})	Ca^{2+} (mmol$_c$ L^{-1})	Mg^{2+}	Na^+	K^+	SO_4^{2-} (mmol$_c$ L^{-1})	Cl^-	HCO_3^-	CO_3^{2-}
1	7.46	665.35	425.82	3.1	0.71	5.85	12.96	0.7	0.03	0.5	0.9	5.2	0
2	7.19	701.25	448.8	3.7	0.79	6.2	15.61	0.76	0.03	0.9	0.87	5	0
3	7.69	675.21	432.13	2.8	1.27	6.1	15.91	0.71	0.03	0.56	0.76	5	0
4	7.63	682.96	437.09	2.6	0.88	5.9	13.33	0.74	0.03	0.63	0.85	4.9	0
5	7.47	920.45	589.08	2.5	0.59	5.85	16.15	2.24	0.30	0.98	1.66	5.9	0
6	7.53	905.61	579.59	1.3	1	6	12.2	2.21	0.30	0.94	1.58	6.1	0

April (2014)

Locations	PH	EC (µS cm^{-1})	TDS (mg L^{-1})	NO_3^- (mg L^{-1})	B (mg L^{-1})	Ca^{2+} (mmol$_c$ L^{-1})	Mg^{2+}	Na^+	K^+	SO_4^{2-} (mmol$_c$ L^{-1})	Cl^-	HCO_3^-	CO_3^{2-}
1	7.78	648.66	415.14	3.9	0.66	4.4	4.75	0.49	0.03	0.63	0.93	2.3	0
2	7.83	658.38	421.36	3.8	0.69	5.1	5.45	0.46	0.02	0.61	0.9	2.3	0
3	7.86	650.33	416.21	4.4	0.62	5.65	5.34	0.42	0.02	0.67	0.87	2.5	0
4	7.92	656.08	301.79	4.5	0.7	6.1	4.78	0.49	0.02	0.63	0.87	3	0
5	7.61	781.54	500.18	2.6	0.9	6.5	5.21	0.95	0.27	0.69	1.24	2.61	0
6	7.66	776.88	497.2	2.3	0.66	7.5	4.64	0.95	0.26	0.88	1.21	2.61	0

Table-6: Mean of the data of the table (5), SAR, RSC and IWQI of water samples of Kani-Ban stream on November (2013) and April (2014)

Locations	pH	EC ($\mu S\ cm^{-1}$)	TDS ($mg\ L^{-1}$)	NO_3^- ($mg\ L^{-1}$)	B ($mg\ L^{-1}$)	Cations ($mmol_c\ L^{-1}$) Ca^{2+}	Mg^{2+}	Na^+	K^+	Anions ($mmol_c\ L^{-1}$) SO_4^{2-}	Cl^-	HCO_3^-	CO_3^{2-}	SAR	RSC ($mmol_c\ L^{-1}$)	IWQI
1	7.62	657.01	420.48	3.50	0.69	5.13	8.86	0.60	0.03	0.57	0.92	3.75	0	0.23	-10.24	117.68
2	7.51	679.82	435.08	3.75	0.74	5.65	10.53	0.61	0.02	0.76	0.89	3.65	0	0.22	-12.53	117.88
3	7.78	662.77	424.17	3.60	0.95	5.88	10.63	0.57	0.03	0.62	0.82	3.75	0	0.20	-12.76	118.27
4	7.78	669.52	428.49	3.55	0.79	6.00	9.06	0.62	0.03	0.63	0.86	3.95	0	0.23	-11.11	117.35
5	7.54	850.99	544.63	2.55	0.75	6.18	10.68	1.60	0.26	0.84	1.45	4.26	0	0.55	-12.60	108.60
6	7.60	841.25	538.40	1.80	0.83	6.75	8.42	1.58	0.28	0.91	1.39	4.36	0	0.57	-10.81	108.36

Table (7): Guidelines for Interpretation of Water Quality for Irrigation according to **[3]** and **[11].**

Salinity Hazard							
Degree of restriction on use			Irrigation water classification				
Severe	Slight to Moderate	None	Unsuitable	Permissible	Good	Excellent	Parameter
>3000	750-3000	< 750	2250-5000	750-2250	250-750	< 250	EC (μScm^{-1})
> 2000	450 - 2000	< 450	1500-3000	500-1500	200-500	< 200	TDS (mg/L)
			Very salt tolerant plants only	Salt tolerant plants only	Sensitive plants show salt stress	No detrimental effects	Effect on plants
Specific Ion Toxicity (affects sensitive crops)							
Degree of restriction on use			Degree of restriction on use				
Severe	Slight to Moderate	None	Very high	High	Medium	Low	
--	> 3.0	< 3.0	--	--	--	--	Na ($mmol_c\ L^{-1}$)
> 9.0	3-9	< 3.0	> 26.0	18-26	10-18	<10	Na (SAR)
2.0-10.0	0.5-2.0	< 0.5					Boron (mg/1)
Irrigation Water Classification							
> 10	4-10	<4	> 10	4-10	2-4	< 2	Chloride($mmol_c\ L^{-1}$)
Miscellaneous Effects							
Degree of restriction on use			Irrigation water classification				
Severe	Slight to Moderate	None	Unsuitable		Permissible	Safe	
--	--	--	>2. 5		1.25-2. 5	< 1.25	RSC ($mmol_c\ L^{-1}$)
>8. 5	1. 5-2.0	< 1. 5	--		--	--	HCO_3 ($mmol_c\ L^{-1}$)
>30	5.0-30	< 5.0	--		--	--	NO_3-N (mg/L)
Guidelines for interpretation of irrigation water quality of other parameters							
Normal range of irrigation water					Water parameters		
0 – 20					Ca^{2+} ($mmol_c\ L^{-1}$)		
0 – 5					Mg^{2+}($mmol_c\ L^{-1}$)		
0 – 1					$CO3^{2-}$($mmol_c\ L^{-1}$)		
0 – 20					$SO4^{2-}$ ($mmol_c\ L^{-1}$)		
0 – 2					K^+($mmol_c\ L^{-1}$)		
6.5 – 8.4					pH		

Sodium adsorption ratio (SAR) of water samples was ranged from (0.20 to 0.57). The water having SAR < 10 is good for irrigation. It was observed that all the sites studied were good for irrigation ***[5]***. Sodium adsorption was stimulated when Na proportion increases as compared to Ca & Mg resulting in soil dispersion ***[17]*** and ***[18].*** The SAR was also expressed as Sodium Hazard ***[5]***. According to *(Table: 7),* all the irrigation water samples fell under 'Low' class and as per salinity classification *(Figure: 2);* all the irrigation water samples fell under low sodium hazards (S_1) class. High value of SAR means sodium enhance the dispersion of colloids or clays when it comes in contact with the soil and may replace calcium and magnesium ions in the soil resulting in damage to the soil structure and reduction in its capacity to conduct water and air ***[19].***

Bicarbonate content of the water is considered in Residual Sodium Carbonate (RSC) .The (RSC) value was varied between (-10.24 and 12.76) ($mmol_c\ L^{-1}$). *(Table: 7)* clearly shows that all samples have RSC less than zero and are safe for irrigation purposes. In waters having high value of RSC there is tendency for calcium and magnesium to precipitate that can cause an increase in sodium content in the soil solution. This excess is denoted by residual sodium carbonate [RSC]. The water with high RSC has high pH and land irrigated by such waters becomes infertile owing to deposition of sodium carbonate as known from the black color of the soil ***[11].*** Further, continued usage of high RSC waters affects crop yields ***[10].***

In this investigation, the concentrations of calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+) and potassium (K^+) of the studied water were ranged between (5.13 and 6.75), (8.42 and 10.68), (0.57 and 1.60) and (0.02 and

0.28) ($mmol_c\ L^{-1}$) respectively *(Table: 6).* Results revealed that calcium, sodium and potassium ions concentration in all water samples was within permissible limit. While, magnesium ion concentration of all water samples of studied area is not within the permissible range *(Table: 7).* Higher concentration of magnesium in water sample may be resulted from the water is in contact with dolomite and dolomitic limestone of Qamchuqa Formation ***[20].***

The chloride (Cl^-) concentration of the water samples was within a wide range of (0.82 to 1.45) ($mmol_c\ L^{-1}$). As shown on *(Table: 7),* all values of chloride are less than (4) ($mmol_c\ L^{-1}$), indicating creating no problem in irrigation. Chloride is a common ion in most of the irrigation waters. Although chloride is essential to plants in very low amounts however, it can cause toxicity to sensitive crops at high concentrations ***[21].***

The sulfate (SO_4^{2-}) values in the studied water sample varied from (0.57 to 0.91) ($mmol_c\ L^{-1}$). The sulfate ion is a major contributor to salinity in many of the irrigation waters. As with boron, sulfate in irrigation water has fertility benefits, and most often irrigation water has enough sulfate for maximum production for most crops. Exceptions are sandy fields with <1 percent organic matter and <10 mg L^{-1} SO_4-S in irrigation water ***[21].*** According to *(Table: 7)* all the studied stations have acceptable level of sulfate.

Carbonate (CO_3^{2-}) ions were not detected in any of the samples. Bicarbonate (HCO_3^-) ions concentration was found in the range of (3.65 to 4.36) ($mmol_c\ L^{-1}$). According to *(Table: 7)*, all water samples of the study area fell into 'slight to moderate' degree of restrictions on use ***[3].*** Mandel and Shiftan (1981) ***[22]*** reported bicarbonate content more than (1) ($mmol_c\ L^{-1}$). or (60) mg L^{-1} (ppm) in the water is necessarily attributed from the biological activities of plant roots, from the oxidation of organic matter included in the soils and in the rock, and from various chemical reactions.

In this study, the nitrate (NO_3^-) ion concentrations of water sample ranged from (1.80 to 3.75) mg L^{-1}. The nitrate value obtained in all sites fall within the permissible limit, which indicating none restriction on use. Nitrogen in irrigation water (N) is largely a fertility issue, and nitrate-nitrogen (NO_3-N) can be a significant N source as it is found in most of the wastewaters throughout the world. The nitrate ion often occurs at higher concentrations than ammonium in irrigation water ***[21]***.

The concentration of boron (B) of irrigation water samples of the study area ranged from (0.69 to 0.95) mg L^{-1} *(Table: 6)*, all water samples of the study area fell into 'slight to moderate' degree of restrictions on use ***[3]*** (*Table: 7).* Boron, unlike sodium, is an essential element for plant growth (Chloride is also essential but in such small quantities that it is frequently classed non-essential.) Boron is needed in relatively small amounts; however, if present in amounts appreciably greater than needed, it becomes toxic. For some crops, if (0.2) mg L^{-1} boron in water is essential, (1 to 2) mg L^{-1} may become toxic ***[21]***.

Irrigation Water Quality Index (IWQI)

In order to develop the proposed IWQI, EC, Cl^-, Na^+, HCO_3^- and SAR parameters were used. Henceforth, the weight of each parameter was based on the variance of the first factor associated to the explainability of each parameter, in relation to this factor. The normalized weights, Wi, computed through Equation (3), are listed in *(Table: 2)*. The irrigation water quality index which calculated based on equation (4) is shown in *(Table: 6)*.

The (IWQI) values for Kani-Ban stream water samples are recorded in *(Table: 6),* it was observed that 117.68, 117.88, 118.27, 117.35, 108.60 and 108.36, respectively. The results obtained on (IWQI) for all sampling sites were within the class of use with no restrictions (excellent) for irrigation *(Table: 4).*

Conclusions

Different physico-chemical properties of irrigation water of Kani-Ban stream were compared with the national and international water quality standards set for irrigation. The US salinity diagram illustrates that water samples of Kani-Ban stream fall in the class of (C_2-S_1) for locations (1, 2, 3, and 4) indicating medium salinity with low sodium water, while water samples of other stations (5 and 6) fall in the class of (C_3-S_1) indicating high salinity with low sodium water which can be used for irrigation. Another one classification with respect to SAR , all the water samples fell under 'Low' class and as per salinity classification (US salinity diagram); all the irrigation water samples fell under low sodium hazards (S_1) class and the water is suitable for irrigation purpose. The residual sodium carbonate (RSC) values of all water samples were under "Safe" category. The results obtained on (IWQI) for all sampling sites were within the class of use with no restrictions (excellent) for irrigation.

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