Evaluation of Water Quality Index of Tigris River for irrigation purposes in Amara city, Southern Iraq

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Abstract

The aim of the study was to determine the suitability of water for irrigation on the basis of the quality indices. The study was performed during the period October to December,2012. The quality of water was assessed by testing parameters such as sodium [Na^+], calcium [Ca^{++}], magnesium [Mg^{++}], bicarbonate [HCO_3^-] and chloride [Cl^-]. The quality indices were evaluated and ranged as Electrical Conductivity (EC) [97.0 to 115.0 $\mu S.cm^{-1}$], Total Dissolved Solid (TDS) [49.4 to 61.7 $mg.l^{-1}$], Sodium Adsorption Ratio (SAR) [3.63 to 4.41 $meq.l^{-1}$], Residual Sodium Carbonate (RSC) [-6.91 to -8.69 $meq.l^{-1}$], Kelly's Index (KI) [0.78 to 0.96 $meq.l^{-1}$], Permeability Index (PI) [58.07 to 63.48%] and Magnesium Ratio (MR) [22.39 to 37.44%]. The results were compared to the USEPA standard. All the water quality indices were suitable for irrigation. The calculated indices were well in agreement with USEPA. Waters of Tigris River were found within the permissible limits for irrigation purposes.

Keywords: water quality, Tigris River, Irrigation, Amara.

Introduction

The assessment of water quality status is important for socio-economic growth and development (10). The chemical composition of water is an important factor to be considered before it is used for domestic or irrigation purposes (24).

Irrigation water quality is related to its effects on soils and crops and its management, High quality crops can be produced only by using high-quality irrigation water. Characteristics of irrigation water that define its quality vary with the source of the water (12).

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 salt 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 (27).

Irrigation water with high salt content can bring about displacement of cations like Ca^{++} and Mg^{++} from the clay minerals of the soil, followed by replacement of cation by sodium (20). The main constituents affecting the quality of irrigation water are Ca, Mg, Na and alkalinity of water (29). The increased concentration of these constituents on irrigation water changes the soil quality and makes it unsuitable for cultivation of crop. Hence present assessment was undertaken to assess the suitability of water for irrigation (3).

To evaluate the quality of irrigation water, we need to identify the characteristics that are important for plant growth, and their acceptable levels of concentrations. Having the water testing by a reputable laboratory is the first step in this process. A knowledgeable interpretation of the results can help to correct water quality problems and / or choose fertilizers and irrigation techniques to avoid crop damage. To avoid problems when using these poor quality water supplies, there must be sound planning to ensure that the quality of water

available is put to the best use (12). The aim of this study was to determine the suitability of water of Tigris river in Amara city for irrigation purposes.

Materials and Methods

The study area is Tigris river at Amara city; it is located between latitudes 31°15′ N to 32°45′ N and longitudes 46°35′ E to 47°45′ E (Fig.1), and covers an area of about 16072 Km^2. Tigris river is important source of water for domestic, industrial and agricultural purposes, it is about 226 Km along (2).

Collection of Samples: Water samples were collected from 10 sites along the river (Fig.1). A plastic bottle [2L] rinsed with perchloric acid and distilled water were used for the sample collection and brought to laboratory. The water samples were collected from the water surface near the river bank (impact) by monthly during rainy season period (October to December), 2012.

Analysis of Water Samples : The major constituents [Calcium (Ca), Magnesium (Mg), Sodium (Na) and Chloride (Cl)] were determined according to the standard methods (4). Field parameters such as pH, EC and TDS were determined in the field using Multimeter Model (ECPCDWP 65044 K) for EC and TDS while pH was determined using pH Meter Model (PD-11). Bicarbonate was also determined by titration using Sexana method (22).

Water quality indices analysis: The assessment of water quality and its suitability for irrigation was carried out with the help of indices like Sodium Adsorption Ratio (SAR) (21), Residual Sodium Carbonate (RSC) (28), Kelly's Index (12), Permeability Index (PI) (30) and Magnesium Ratio (MR) (19).

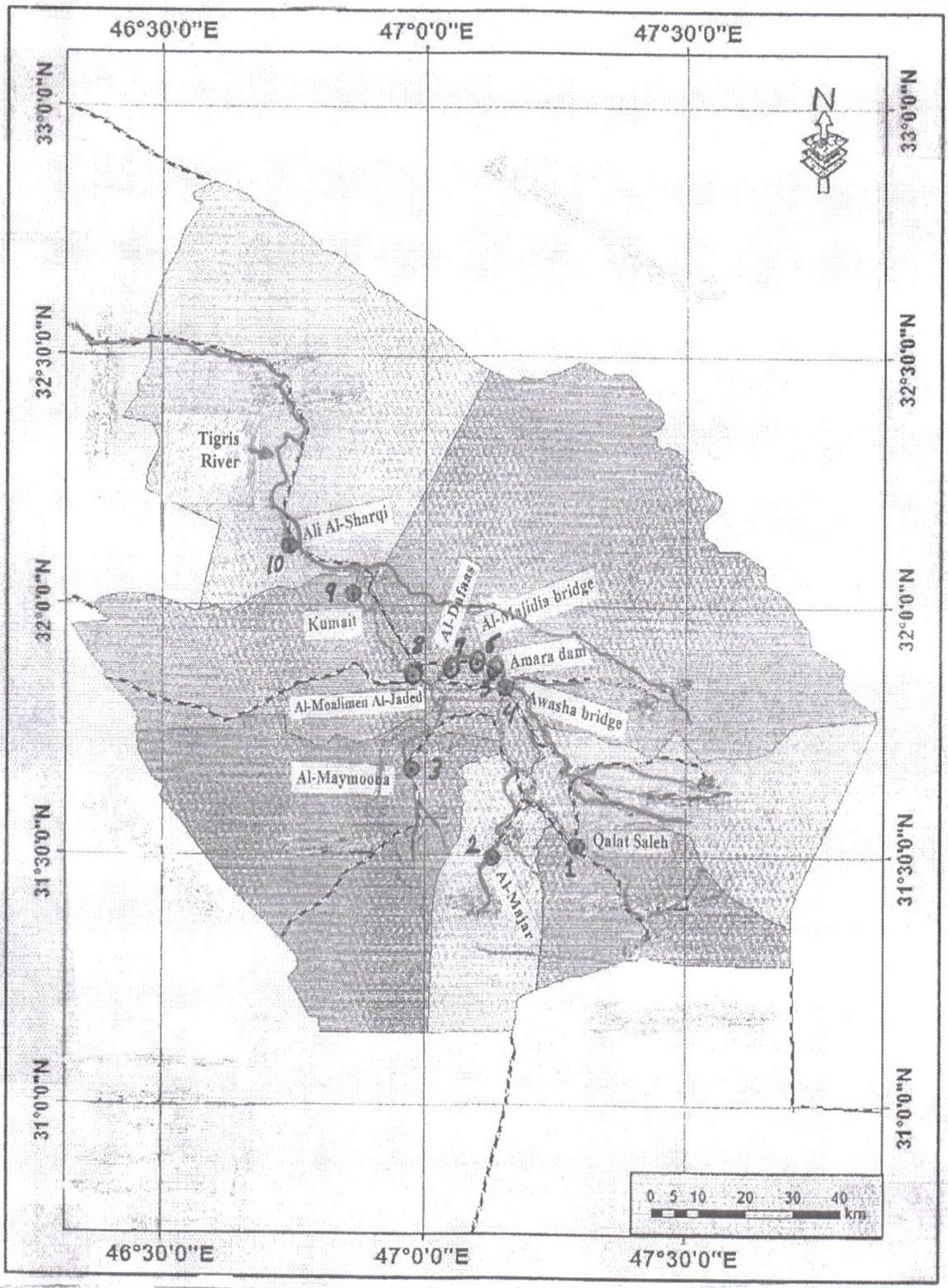

Fig. 1: Map of the study area with the location of sampling points (1-10) on the Tigris River

Table 1. Chemical properties of irrigation water of the study area.

Site No.	Sampling area	Ph	EC $\mu S.cm^{-1}$	TDS $mg.l^{-1}$	Ca^{2+} $meq.l^{-1}$	Mg^{2+} $meq.l^{-1}$	Na^{+} $meq.l^{-1}$	Cl^{-} $meq.l^{-1}$	CO_3^{2-} $meq.l^{-1}$	HCO_3^{-} $meq.l^{-1}$
1	Qalat Saleh	7.2	105.8	52.7	8.09	2.33	8.28	8.61	Nil	3.51
2	Al-Majar	6.7	109.2	51.0	7.32	3.38	8.92	8.00	Nil	3.00
3	Al-Maymouna	7.2	115.0	57.0	7.16	3.33	10.08	9.26	Nil	2.59
4	Awasha bridge	7.6	110.3	55.2	8.26	2.57	8.81	7.79	Nil	2.90
5	Amara dam	7.6	108.3	54.0	6.82	4.08	8.53	7.59	Nil	3.00
6	Al-Majidia bridge	7.7	107.9	54.1	7.68	3.02	8.73	7.55	Nil	3.11
7	Al-Dafas	7.5	97.0	53.0	7.29	2.92	9.50	8.00	Nil	3.01

8	Al-Moulimen Al-Jaded Q.	7.7	114.6	61.7	7.21	3.27	10.00	9.20	Nil	2.50
9	Kumait	8.3	112.4	51.3	7.91	3.48	9.35	7.53	Nil	2.69
10	Ali Al-Sharqi	8.0	100.4	49.4	8.33	2.45	8.80	7.77	Nil	2.89
Min.		6.7	97.0	49.4	6.82	2.33	8.28	7.53	....	2.50
Max.		8.3	115.0	61.7	8.33	4.08	10.00	9.26	....	3.51
Mean		7.55	108.09	53.94	7.61	3.07	9.10	8.13	....	2.92

Results and Discussion

Water quality evaluation for agriculture

The water quality for irrigational practices is considered under the following :

Electrical Conductivity (EC)

The EC value of irrigation water of the study area ranged from 97.0 to 115.0 µS.cm^{-1} with an average value of 108.09 µS.cm^{-1} (Table 1), which according to Wilcox (32) falls within the irrigation water quality classification stand 'excellent'. In terms of the 'degree of restriction on use', EC value of < 700 µS.cm^{-1} refers the water to 'none (no effects on plants)'; 700-3000 µS.cm^{-1} 'slightly to moderate' and > 3000 µS.cm^{-1} 'severe' (27). It is easily presumable from the data in (Table 2) that in terms of EC value, the irrigation water of the study area is suitable for irrigation purposes as it falls under the category of none (27).

Total Dissolved Solids (TDS)

Total dissolved solids is also important to consider in water, because many of the toxic solid materials may be imbedded in the water which many cause harm to the plants (15). As EC and TDS values were interrelated, both the values are indicative of saline water in absence of non-ionic dissolved constituents (16). The TDS values of Tigris river are ranged from 49.4 to 61.7 mg.l^{-1} with an average 53.94 mg.l^{-1} (Table 1). It indicates that all values are quite suitable. In terms of ' Degree of restrictions on use', the TDS values < 450, 450-2000 and > 2000 mg.l^{-1} represent the irrigation water as 'none' ; 'slight to moderate' and 'severe', respectively (Table 2). So, like EC, the irrigation water of the study area, in term of TDS, is suitable for irrigation purposes.

Sodium Adsorption Ratio (SAR)

If water used for irrigation is high in Na^+ and low in Ca^{2+} the ion-exchange complex may become saturated with Na^+ which destroys the soil structure, due to the dispersion of the clay particles (26) and reduces the plant growth. Excess salinity reduces the osmotic activity of plants (23). The SAR is computed using the following equation :

$$SAR = (Na^{+}\ meq.l^{-1}) / \sqrt{[(Ca^{2+}\ meq.l^{-1}) + (Mg^{2+}\ meq.l^{-1}) / 2}$$

The SAR of water samples was ranged from 3.63 to 4.41 $meq.l^{-1}$ with mean of 3.94 $meq.l^{-1}$ (Table 3). The water having SAR< 10 is good for irrigation. It was observed that all the sites studied were good for irrigation (29). Sodium adsorption was stimulated when Na proportion increase as compared to Ca and Mg resulting in soil dispersion (8 , 9). The SAR was also expressed as sodium hazard (30). In SAR the Ca and Mg ions are important since they tend to counter the effects of sodium. Continued use of water having high SAR leads to breakdown of soil aggregates. Sodium would absorb and becomes attached to the soil particles. The soil then becomes hard and compact when dry and increasingly impervious to water penetration. The degree of which irrigation water tends to enter in to cations exchange reaction in soil can be indicated by the sodium adsorption ratio. Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure (17).

Residual Sodium Carbonate (RSC)

RSC has been calculated to determine the effect of carbonate and bicarbonate on the quality of water for agricultural purposes (1) and is determine from the following equation:

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

The sodium with alkaline and the quantity of bicarbonate and carbonate in accessed of alkaline also influenced the suitability of water for irrigation. 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 calcium and magnesium in the soil (7). Further, continued usage of high RSC waters affects crop yields (28).

The RSC value < 1.25 $meq.l^{-1}$ is safe for irrigation, a value between 1.25 and 2.5 $meq.l^{-1}$ is of marginal quality and a value > 2.5 $meq.l^{-1}$ is unsuitable for irrigation (28). In this study, the RSC value was ranged from -6.91 to -8.69 $meq.l^{-1}$ with mean of –7.76 $meq.l^{-1}$ (Table 3).

Table 2. Guideline for interpretation of water quality for irrigation (26).

Potential irrigation problem	Units	Degree of restrictions on use			Obtained results
		None	Slight to Moderate	Severe	
Salinity (affects crop water availability)					
EC	$\mu S.cm^{-1}$	< 700	700-3000	> 3000	97.0-115.0
TDS	$mg.l^{-1}$	< 450	450-2000	> 2000	49.4-61.7
Infiltration (affects infiltration rate of Water into the soil. Evaluate using EC and SAR together)					
SAR = 0.3 and EC =		> 700	700-200	< 200	

= 3-6	=	> 1200	1200-300	< 300	SAR= 3.63-4.41
= 6-12	=	> 1900	1900-500	< 500	
= 12-20	=	> 2900	2900-1300	< 1300	
= 20-40	=	> 5000	5000-2900	< 2900	

					Specific Ion Toxicity
Sodium (Na)	$meq.l^{-1}$	< 3	3-9	> 9	8.28-10.00
Chloride (Cl)	$meq.l^{-1}$	< 4	4-10	> 10	7.53-9.26
					Miscellaneous effect
Bicarbonate (HCO3)	$meq.l^{-1}$	< 1.5	1.5-8.5	>8.5	2.5-3.51
pH		normal range	6.5-8.5		6.7-8.3

Table 3. Water quality indices for irrigation

Site No.	SAR meq.l^{-1}	RSC meq.l^{-1}	KI meq.l^{-1}	PI (%)	MR (%)
1	3.63	- 6.91	0.79	63.02	22.39
2	3.86	- 7.69	0.83	60.78	31.62
3	4.41	- 7.89	0.96	61.61	31.71
4	3.80	- 7.88	0.81	59.76	23.34
5	3.65	- 7.90	0.78	59.34	37.44
6	3.78	- 7.58	0.81	60.97	28.21
7	4.21	- 7.19	0.93	63.48	28.57

8	4.37	- 7.97	0.95	61.07	31.17
9	3.92	- 8.69	0.82	58.07	30.53
10	3.79	- 7.88	0.82	59.74	22.73
Minimum	3.63	- 6.91	0.78	58.07	22.39
Maximum	4.41	- 8.69	0.96	63.48	37.44
Mean	3.94	-7.76	0.85	60.77	28.76

Kelly Index (KI)

Kelly index is used for the classification of water for irrigation purposes. Sodium measured against calcium and magnesium was considered by Kelly (14) for calculating Kelly index. KI is calculated by using the formula:

$$KI = Na^{+} / Ca^{2+} + Mg^{2+}$$

Where, all the ions are expressed in meq/l. The concentration of Na, Ca and Mg in water are represent the alkali hazard. The values of KI < 1 indicate good quality water for irrigation and > 1 indicate bad water (13). The values of KI in the study varied from 0.78 to 0.96 meq/l with mean of 0.85 meq/l. Therefore, according to KI values all water samples were suitable for irrigation (13).

Permeability Index (PI)

The permeability of soil is affected by long-term use of irrigation water and is influenced by sodium, calcium, magnesium and bicarbonate contents in the soil (30). Doneen (6) evolved a criterion for evaluating the However, water is suitable for irrigation in RSC point of view. Further, RSC values is negative at all sampling sites, indicating that there is no complete precipitation of calcium and

magnesium (20).

suitability of water for irrigation based on PI. PI is calculated using the following equation :

$$PI = [(Na^{+} + HCO_3^{-}) / (Ca^{2+} + Mg^{2+} + Na^{+})] \times 100$$

The PI values computed for the area ranged from 58.07 to 63.48 % with mean of 60.77% (Table 3). According to Nagaraju et al., (18), waters can be classified into class1, 11 and 111 based on PI values, and class 1 and 11 waters are categorized as good for irrigation with 75% or more maximum permeability. Class 111 waters are unsuitable with 25% of maximum permeability. Therefore, according to PI values all water samples were suitable for irrigation.

Magnesium Ratio (MR)

Generally, calcium and magnesium maintain equilibrium in most waters (11). In or more mg^{2+} in

waters will adversely affect crop yield (17). The measure of the effect of magnesium in irrigated water is expressed as magnesium ratio. Paliwal (18) developed an index for calculating the magnesium hazard (MR). MR is calculated using the formula:

$$MR = [Mg^{2+} / (Ca^{2+} + Mg^{2+})] x100$$

The computed MR values in the study area ranged from 22.39 to 37.44% with mean of 28.76% (Table 3). The values of MR < 50 indicate suitable water for irrigation and > 50 indicate unsuitable (5). Therefore, according to MR values all water samples were suitable for irrigation.

Conclusions

1- The water quality indices studied showed water is suitable for irrigation and agricultural uses.

2- The indices like TDS, SAR, RSC, KI, PI and MR are within the permissible limits for irrigation (28).

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تقييم دليل نوعية مياه نهر دجلة لأغراض الري في مدينة العمارة , جنوب العراق

بشار جبار جمعة الصباح

قسم وقاية النبات – كلية الزراعة – جامعة ميسان – العراق

المستخلص

الهدف من هذه الدراسة هو تقييم نوعية مياه نهر دجلة ومدى ملائمتها للأغراض الزراعية بالاعتماد على بعض المعايير والأدلة المستخدمة في تقييم نوعية المياه . أجريت الدراسة خلال الفترة من تشرين الأول لغاية كانون الأول من العام 2012. قدرت تراكيز بعض الايونات مثل الصوديوم [Na^+] والكالسيوم [Ca^{++}] والمغنيسيوم [Mg^{++}] والبيكاربونات [HCO_3^-] والكلورايد [Cl^-], كما تم قياس قيم التوصيل الكهربائي (EC) (97.0 – 115.0 مايكروسيمنز/سم) , الأملاح الذائبة الكلية (TDS) بين (49.4–61.7 ملغم/لتر) , نسبة أمتزاز الصوديوم (SAR) بين (3.63 – 4.41) ملي مكافئ/لتر , كاربونات الصوديوم المتبقية (RSC) بين (8.69-)]-[(6.91-) -ملي مكافئ/لتر , دليل Kelly (KI) بين (0.78-0.96) ملي مكافئ/لتر , دليل النفاذية (PI) بين (58.07-63.48%) ونسبة المغنيسيوم (MR) بين (22.39-37.44%) . أظهرت النتائج أن جميع الأدلة المستخدمة في تقييم نوعية مياه نهر دجلة هي ملائمة لإغراض الري وضمن الحدود المسموح بها وفقاً للمعايير القياسية لوكالة حماية البيئة الأمريكية USEPA .

كلمات مفتاحية : نوعية المياه , نهر دجلة , الري, مدينة العمارة .