Evaluating Water Quality of Mahrut River, Diyala, Iraq for Irrigation

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ABSTRACT

Water Quality of Mahrut River, passing through Muqdadiyah, a city in Diyala, Iraq, was evaluated for irrigation using the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI). Water samples were collected from six sites during two seasons, summer and winter at 2010-2011. Index scores were determined for fifteen constituents (pH, EC, HCO_3, Cl, Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC), Cd, Cr, Cu, Fe, Pb, Mn, Ni and Zn). The results of the calculated CCME WQI indicated that water quality of Mahrut River was marginal condition for irrigation in the 1st site while it was poor condition in the other sites. It is suggested that monitoring of the river is necessary for proper management to solve pollution problems in the river system.

Keywords: WQI, Mahrut River, SAR, SSP, RSC

تقييم نوعية مياه الري لنهر مهروت، ديالى، العراق

الخلاصة

تم تقييم نوعية مياه نهر مهروت الذي يمر في مدينة المقدادية في محافظة ديالى/ العراق، لاغراض الري باستخدام دليل نوعية المياه الكندي (CCME WQI). جمعت العينات المائية من ستة مواقع خلال موسمي الصيف والشتاء (2010-2011). تم تحديد نتائج مؤشر الدليل لخمسة عشر متغير (درجة الاس الهيدروجيني، التوصيلية الكهربائية، الكاربونات، الكلوريد، نسبة امتزاز الصوديوم، النسبة المؤية للصوديوم الذائب، كاربونات الصوديوم

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المتبقية، الكادميوم، الكروم، النحاس، الحديد، الرصاص، المنغنيز، النيكل والخارصين). بينت نتائج حساب دليل نوعية المياه ان مياه نهر مهروت هي من النوعية الهامشية (marginal) لاغراض الري في الموقع الاول الذي يقع شمال المدينة في حين انها مياه فقيرة (poor) في المواقع الاخرى. ان مراقبة نوعية مباه النهر تعد ضرورية للادارة المائية السليمة لحل مشاكل التلوث ضمن منظومة النهر.

INTRODUCTION

Water, **a** precious gift from **Allah** to human being, is going to be polluted with the increase of urbanization. Changes in water quality are primarily the result of human activities that would discharge water pollutants or alter water availability. However, the major source of surface water pollution is domestic sewage, industrial wastewater and agricultural run-off [1].

The term of water quality was developed to provide an indication of how suitable the water is for human consumption and is generally used in numerous scientific research related to the necessities of sustainable management [2,3].

A water quality index (WQI) is a single value indicator of the water quality determined through summarizing multiple parameters of water test results in a simple term for management and decision makers [4]. A number of indices have been proposed to summarize water quality data in an easily expressible and understood format [5-8].

Significant irrigation water quality parameters consist of a number of specific properties of water relevant in relation to the yield and quality of crops, maintenance of soil productivity and protection of the environment [9]. These parameters mostly consist of certain physical and chemical characteristics of water that are used in the assessment of irrigation water quality. Parameters such as EC, pH, HCO_3, Cl, Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP) and Residual Sodium Carbonate (RSC) were used to evaluate the suitability of water for irrigation [10]. Numerous water quality guidelines have been recommended by many researchers for using water in irrigation under different soil condition [11-14]. However, this research was conducted to evaluate the water quality of of the Mahrut River for irrigation.

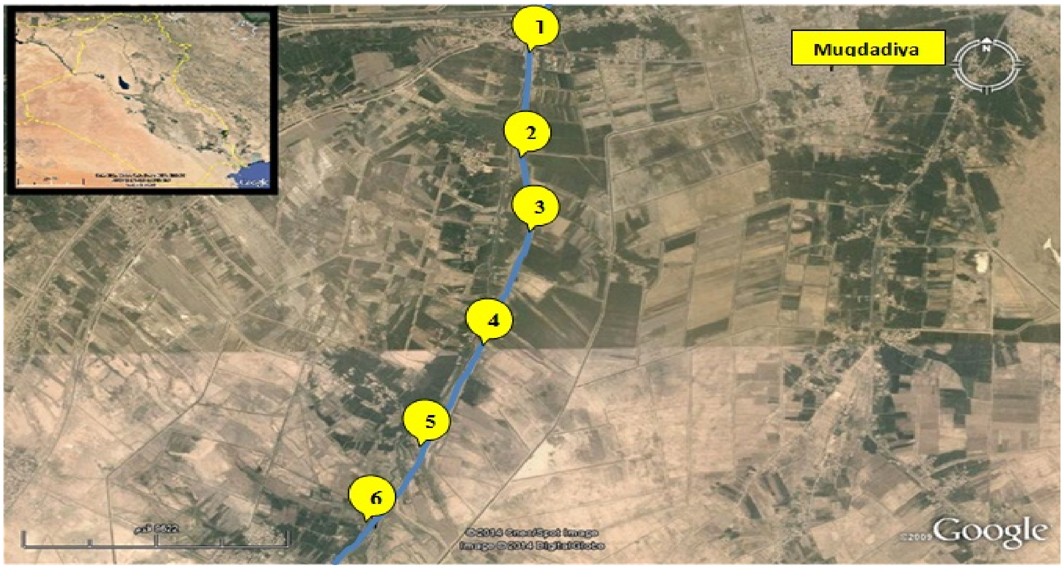
Material and Methods

Study Area

Muqdadiyah is a city in Diyala Governorate of Iraq. The city is located about 80 km northeast of Baghdad and 30 km northeast of Baquba, the capital of Diyala. It has a population of about 298,000 inhabitants. Mahrut River passes through Muqdadiyah and serves as a main source for irrigation water.

Sampling and Analysis

Water sample collection was made for two seasons, summer and winter of 2011 from six selected sites in the Mahrut River (**Figure 1**). Water samples were collected in stopper fitted polyethylene bottles and refrigerated at 4°C in order to be analyzed as soon as possible. Conductivity and pH were measured on the site using portable measuring devices. Procedures followed for analysis have been in accordance with the Standard Method for Examination of Water and Wastewater [15].



Figure(1): Map of Mahrut River illustrates the study sites

In this study, the water quality index (CCME) was applied and tested for the Mahrut River using the value guidelines for irrigation [16]. Index scores were determined for fifteen parameters: pH, EC, HCO_3, Cl, Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC), Cd, Cr, Cu, Fe, Pb, Mn, Ni and Zn. Several irrigation water quality guidelines have been developed [10,12,16]. However, these guidelines were used as objective values in applying the water quality index (**Table 1**).

Calculations of the WQI

The WQI equation is calculated using three factors as follows:

$$\textbf{WQI = 100 -} \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right) \quad \ldots(1)$$

F1 represents Scope: The percentage of parameters that exceed the guideline.

$$F_1 = \left(\frac{Number\ of\ \ failed\ \ parameter}{Total\ number\ of\ \ parameters} \right) \times 100 \quad \ldots(2)$$

F_2 represents Frequency: The percentage of individual tests within each parameter that exceed the guideline.

$$F_2 = \left(\frac{Number\ of\ \ failed\ test}{Total\ number\ of\ tests} \right) \times 100 \quad \ldots(3)$$

F_3 represents Amplitude: The extent (excursion) to which the failed test exceeds the guideline. This is calculated in three stages. First, the excursion is calculated by:

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Excursion = $\left(\dfrac{failed\ test\ value}{guideline\ value}\right) - 1$ …(4)

Note: in the case of pH where a minimum and maximum guideline is given, the excursion equation must be run as in equation 4 as well as in reverse i.e. guideline value/failed test value.

Second, the normalized sum of excursions (nse) is calculated as follows:

nse = $\dfrac{\sum excursion}{total\ number\ of\ tests}$ …(5)

At the third stage F_3 is then calculated using a formula that scales the nse to range between 1 and 100:

F_3 = $\left(\dfrac{nse}{0.01 nse + 0.01}\right)$ … (6)

The index equation generates a number between 1 and 100, with 1 being the poorest and 100 indicating the best water quality. **Table 2** shows the CCME WQI categorization schema [17].

Table (1): Objective Values used in applying WQI

Parameters	Values	References
pH	6.5- 8.4	10
EC (mS/cm)	2.25	12
HCO_3 (mg/L)	91.5	10
Cl (mg/L)	100	16
Na (SAR)	18	12
Na (SSP)	40	12
RSC (meq/L)	2.5	12
Cd (mg/L)	0.0051	16
Cr (mg/L)	0.008	16
Cu (mg/L)	0.2	16
Fe (mg/L)	5	16
Pb (mg/L)	0.2	16
Mn (mg/L)	0.2	16
Ni (mg/L)	0.2	16
Zn (mg/L)	1	16

Table (2). CCME-WQI categorization schema [17]

Rank	WQI Value	Notes
Excellent	95-100	All measurements are within the objectives virtually all of the time
Good	80-94.9	Conditions rarely depart from natural or desirable levels
Fair	65.9-79.9	Conditions sometimes depart from natural or desirable levels
Marginal	45-64.9	Conditions often depart from natural or desirable levels
Poor	0-44.9	Conditions usually depart from natural or desirable levels

Results and Discussion

Descriptive statistics of all measured parameters have been presented in **Table 3**.

Table (3): Statistical Summary of water quality data for all sites

Parameters	Winter				Summer			
	Min	Max	Mean	SD	Min	Max	Mean	SD
pH	6.77	7.33	7.03	0.25	7.07	7.33	7.20	0.11
EC (mS/cm)	0.55	0.58	0.56	0.01	0.68	0.71	0.69	0.01
HCO_3 (mg/L)	14.24	16.27	15.05	0.96	1.03	3.47	2.10	0.97
Cl (mg/L)	5.00	12.50	8.47	3.22	158.82	283.60	223.09	49.01
Na (SAR)	3.06	3.61	3.32	0.18	1.49	1.59	1.53	0.03
Na (SSP)	51.64	54.53	52.59	1.02	36.16	37.57	36.79	0.64
RSC (meq/L)	-1.09	-1.01	-1.04	0.03	-1.63	-1.55	-1.59	0.03
Cd (mg/L)	0.01	0.02	0.02	0.003	0.01	0.01	0.009	0.001
Cr (mg/L)	0.85	1.02	0.95	0.05	0.50	1.08	0.77	0.19
Cu (mg/L)	0.03	0.05	0.04	0.006	0.00	0.06	0.018	0.02
Fe (mg/L)	0.13	0.19	0.16	0.02	0.13	0.22	0.18	0.03
Pb (mg/L)	0.01	0.08	0.04	0.02	0.22	0.33	0.28	0.03
Mn (mg/L)	0.07	0.09	0.08	0.009	0.03	0.05	0.04	0.007
Ni (mg/L)	0.12	0.17	0.15	0.020	0.09	0.11	0.09	0.008
Zn (mg/L)	0.00	0.01	0.0038	0.003	0.00	0.01	0.006	0.002

The normal pH value for irrigation water is in the range 6.5 to 8.4 [10]. Irrigation water with a pH outside the normal range may cause nutritional imbalance or may contain toxic ions [10,18]. The values of pH varied from 6.77 to 7.33 for all sites, which indicates that the water is almost neutral to sub-alkaline in nature and in aggrement with the pH values of fresh waters [2,19].

Electrical conductivity (EC) is the most significant issue in determining the suitability of water for irrigation. Irrigation water with conductivity less than 2.25 mS/cm is allowable for irrigation [12]. The primary effect of high EC reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil [20]. EC values of the investigated samples varied from 0.55 to 0.71 mS/cm for all sites which suggests that this type of water is good for irrigation and widely used.

The most regular toxicity is from chloride (Cl^-) in the irrigation water. Cl^- is not adsorbed or held back by soils, therefore it moves readily with the soil-water, and taken up by the crop, moves in the transpiration stream, and accumulates in the leaves [18]. The Cl^- ion concentration for irrigation water is 100 mg/L [16]. With exception in winter season, the obtained Cl^- concentrations of the tested samples were higher than the acceptable level recommended by the CCME for irrigation [16]. The possible sources of these ions may be anthropogenic and natural[9].

Sodium content is the major constituent and an important aspect of irrigation water quality assessment. Extreme sodium concentrations leads to development of an alkaline soil that can cause soil physical problems and reducing soil permeability [21].
Sodium hazard is typically expressed in terms of Sodium Adsorption Ratio (SAR) and Soluble Sodium Percentage (SSP), which can be calculated as follows:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \qquad \ldots(7)$$

Where
Na^{+}, Ca^{2+} and Mg^{2+} are in meq/L.
SAR is a significant parameter for the determination of the suitability of irrigation water because it is responsible for sodium hazard [22]. The SAR value of the samples ranged from 1.49 to 3.61. The comparison between SAR values and the standard value which is 18 recommended by US Salinity Laboratory [12] reflects water is suitable for irrigation.
The Soluble Sodium Percentage (SSP) was calculated by the following equation:

$$SSP = \frac{\left(Na^{+}\right) \times 100}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \qquad \ldots(8)$$

Where
all the ions are expressed in meq/L.
The standard value of SSP is 40 percent recommended by US Salinity Laboratory [12]. The calculated sample values of SSP for all sites varied from 36.16% to 54.53%, which represent medium to a high degree of limitation for irrigation. Water with high percent of SSP may cause sodium accumulation in the soil profile and affect the physical properties of soil [12].

To qualify the effect of CO_3^{-} + HCO_3 in water over the sum of Ca^{2+} and Mg^{2+}, an experimental parameter termed as Residual Sodium Carbonate (RSC) [11] could be used. It can be calculated as follows:

$$RSC = (CO_3^{2-} + HCO_3^{-}) + (Ca^{2+} + Mg^{2+}) \qquad \ldots(9)$$

All ion concentrations are reported in meq/l.
US Salinity Laboratory [12], reported that RSC value less than 2.5 meq/L is safe for irrigation; a value between 1.25 and 2.5 meq/L is of acceptable quality and a value more than 2.5 meq/L is unsuitable for irrigation. RSC values of the tested samples varied from (-1.63 to -1.01) for all sites. The results indicated that all samples have RSC less than zero and are suitable for irrigation uses.

For the heavy metals the results indicated that the mean values of Cd and Cr concentration exceeded the permissible level (0.0051 mg/L and0.008 mg/L respectively) recommended by the CCME for irrigation [16] all sites. While the mean value of Pb concentrations exceeded the permissible level (0.2 mg/L) recommended by CCME for irrigation in the summer season only.

Average values of CCME WQIs ranged from 43.17 to 45.11 indicating that the water quality index for irrigation can be rated as marginal condition in the 1st site which is situated at the north of the study area while in the other sites it is rated as poor conditions (**Table 4**). This may reflect the Discharge of pollutants to the water resource system from domestic sewers, storm water discharges, industrial waste discharges, agricultural runoff and other sources, all of which may be Untreated and can have significant effects on the river system causing low water quality for irrigation.

Table (4): CCME WQI values of Mahrut River

Locations	WQI values
Site 1	45.11
Site 2	44.42
Site 3	44.11
Site 4	44.36
Site 5	43.17
Site 6	43.50

Conclusions

The overall CCME WQIs values which ranged from 43.17 to 45.11 indicate that the water quality for irrigation uses can be rated as marginal conditions in the 1st site which is situated at the north of the study area while the water quality of the other sites can be categories as poor conditions. This may reflect the Discharge of pollutants to the water resource system from domestic sewers, storm water discharges, industrial waste discharges, agricultural runoff and other sources, all of which may be untreated, can have significant effects of a river system.

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