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Applied of CCME Water Quality Index for Evaluation of Water Quality of Euphrates river For Irrigation Purposes in Al-Nassiryia city

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Abstract

The present work describes the application of Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) for irrigation uses for the 4 stations located along with Euphrates river in Al-Nassiryia city, Iraq. The field work was conducted during the period from summer 2012 to spring 2013.CCME WQI was applied using eleven water quality parameter (Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Electric conductivity , pHvalue, Bicarbonate, Chloride Ion, Boron Ion, Lead, Iron, Cadmium, Copper). Based on the results obtained from the index, the values of water quality index for irrigation uses of Euphrates River ranged between ٤٧.٦٦-٦٧.٩٣ which indicate that river has Moderate quality for irrigation. The highest deviation occurred in SAR,Cl^-,EC,

Key word: Assessment, Water Quality Index, CCME WQI, irrigation, Euphrates river, Al-Nassiryia city, Iraq.

تطبيق دليل نوعية المياه (النموذج الكندي) لتقيم نوعية المياه في نهر الفرات لأغراض الري في مدينة الناصرية_العراق

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الخلاصة

تصف الدراسة الحالية تطبيق دليل نوعية المياه لأغراض الري المعتمد على الموديل الكندي لأربع محطات على نهر الفرات في مدينة الناصرية. تم أجراء العمل الحقلي من فصل الصيف٢٠١٢ إلى فصل الربيع٢٠١٣ . طبق دليل نوعية المياه بأستخدام أحدى عشر عامل(نسبة أمتزاز الصوديوم ،كاربونات الصوديوم المتبقية، التوصيلية الكهربائية، الرقم الهيدروجيني ، البيكاربونات،أيون الكلوريد، آيون البورون، الرصاص ، الحديد ،الكادميوم ، النحاس). أعتماداً على النتائج التي تم الحصول عليها من الدليل، فأن نوعية مياه نهر الفرات لأغراض الري تراوحت بين ٤٧.٦٦-٦٧.٩٣ والتي تشير إلى أن نوعية مياه النهر معتدلة لأغراض الري. الأنحراف المعياري الأعلى حصل في نسبة أمتزاز الصوديوم والكلوريد والتوصيلية الكهربائية.
الكلمات الافتتاحية: تقييم ، دليل نوعية المياه ، دليل نوعية المياه الكندي، الري، نهر الفرات، مدينة الناصرية،العراق.

Introduction

The Tigris & Euphrates Rivers in Iraq are main sources of water.It is used for strategically important water uses such as drinking, fishing, industrial, livestock and irrigation[1]. Agriculture is not only the greatest water user of the world in terms of volume, it is also a relatively low value, low efficiency and highly subsidized user . Irrigation agriculture is dependent on an adequate water supply of usable quality. Irrigation water quality is a key environmental issue faced by the agricultural sector as well as it is very important for every agricultural use, passing through such activities as irrigation to livestock watering, from safe household family drinkable water on farms, etc... . Agricultural water sources may be of poor quality because of natural causes, contamination or both, and often require treatment before it is acceptable for a given use [2,3] .The water quality in watershed is directly affected by vegetative cover and agriculture and other management practices [4]. The suitability of water for irrigation depends on a variety of factors, most relevant and important are; EC in irrigation water, which mainly affects crop yields,(element toxicity) concentration of certain ions, which may be toxic to plants or have unfavorable effects on crops, soils and public health and (sodicity) concentration of cations, which may cause deflocculation of clays in soils resulting damage to soil structure and permeability (SAR). The suitability of water for irrigation varies according to crops, types and permeability of soils and climate. Therefore irrigation water quality criteria developed by US salinity laboratory has received acceptance in many countries. [5,6]. One of the simplest methods to assess water quality conditions is by using water quality indices [7]. A water quality index (WQI) play an important role in such a translation process. It is a communication tool for transfer of water quality data[8]. It is important to note that the CCME WQI is not a substitute for detailed analysis of water quality data and should not be used as a sole tool for management of water bodies. Any number of water quality measurements can serve, and have already been used, as indicators of water quality. However, there is no single measure that can describe overall water quality for any one body of water, let alone at a global level. As such, a composite index that quantifies the extent to which a number of water quality measures deviate from normal, expected or 'ideal' concentrations may be more appropriate for summarizing water quality conditions across a range of inland water types and over time. Although there is no globally accepted composite index of water quality, some countries and regions have used, or are using, aggregated water quality data in the development of water quality indices. Most water quality indices rely on normalizing, or standardizing, data parameter by parameter according to expected concentrations and some interpretation of 'good' versus 'bad' concentrations [10].It was simply developed to provide a broad overview of environmental performance [9]. There have been numerous studies and reports on assessment of surface water, ground water and treated wastewater quality for irrigation in various states of the country[11] . found the surface and subsurface water in upper Urmil river basin suitable and hazard free for the crops grown.[12] investigated the water available from all the sources in the Chaka block can be used for irrigation purpose without any harm. [13], [14] and[15] found that most of the ground water samples are not suitable for irrigation uses. [16] found the wastewater qualities from both Karak and Mutah wastewater treatment plant are suitable for irrigation purposes in term of salinity and its high sodium content. [17] found the treated wastewater of Baghdad city can be used for irrigation on almost all types of soil.The Canadian Water Quality Index compared observations to a benchmark, where the benchmark may be a water quality standard or site specific background concentration [18-19-20]. The CWQI quantifies for one station, over a predate-rmined period of time (typically one year), the number of parameters that exceed a benchmark, the number of records in a dataset that exceed a benchmark, and the magnitude exceed of the benchmark. The index is flexible in terms of the benchmarks that are used for calculation, and depends on the information required from the index: that is, guidelines for the protection of aquatic life may be used (when available) if the index is being calculated to quantify ecological health of the water, or drinking water quality guidelines may be used if the interest in the index is in drinking water safety. Alternatively, information describing natural back-ground conditions for a station or region may be used as benchmarks when trying to quantify deviation from natural conditions. Sites at which water quality measurements never or rarely exceed the benchmark have high CWQI scores (near 100), whereas sites that routinely have measurements that exceed benchmarks have low CWQI scores (near 0). The CCME WQI was developed with the intent of providing a tool for simplifying the reporting of water quality data [18]. It is a tool that provides meaningful summaries of water quality data that are useful to technical and policy individuals as well as the general public interested in water quality results. As a summary tool, it provides a broad overview of water quality data and is not intended to be a substitute for detailed analysis of water quality data. The application of the CCME WQI requires Water Quality Guidelines (WQGs) or Water Quality Objectives (WQOs). The model essentially consists of three measures of variance from selected WQGs or WQOs (scope, frequency, amplitude) that combine to produce a value between 0 and 100 that represents the overall water quality. The use of appropriate WQGs or WQOs in the CCME WQI is critical to the computation of representative and accurate water quality indices [22]. Indices simplify and reduce the required raw and primary date for describing water quality and its spatial variation can show the particular water quality problems within a river body, allowing for many managerial decisions to be made. In a simple definition about indices it can be said that indices are proper and simple tools to determine conditions of water quality and, like any other tool, this requires knowledge about principles and basic concepts of water and related issues [23]. Due to the lack of expert study and inspection of the water quality of most rivers of Iraq.The main objective of the project is to research and develop a capability in Iraq that could potentially impact food safety of irrigation crops.

Material and Methods

Study area discrption:

The study area included 4 stations on Euphrates river in Al-Nassiryia city, the first station located at the entrance of the river to Al-Nassiria city and far from the second station by 10 km which located at convergence (junction) zone of hot water emerging from the thermal electric power station with the river. The third station located at convergence zone stream discharge waste water, while the fourth station located before the river leaving the city of Al-Nassiryia and far from the third station by 10 km. Fig.(1)

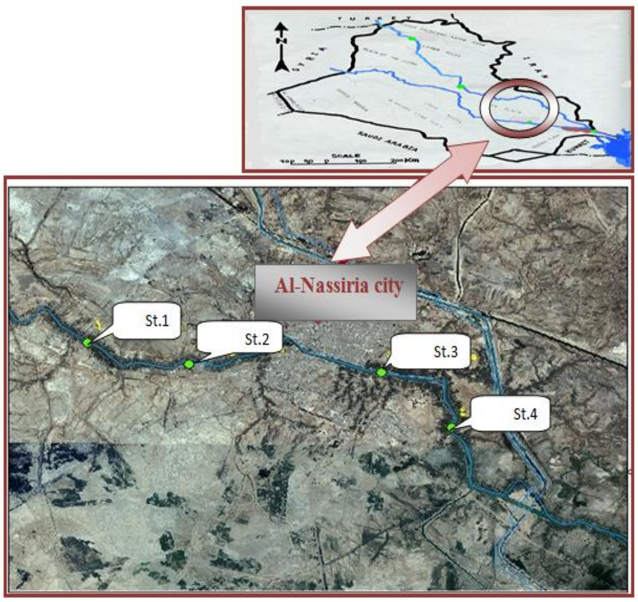

Fig.(1) Map of the study stations (St.)

-Sampling

Subsurface water samples were collected from the middle and two banks of the Euphrates river during summer 2012 to spring 2013, the samples were collected two samples per month from each station by using clean polyethylene bottles. Sampling were analyzed for chemical and physical properties immediately after collection(table 1).

Table (1) Material and Methods

parameter	Method or meter	Number of method	refrence
pH(mg/l)	Portable pH meter	$4500\text{-}H^{+}$ B	APHA2005
EC(µS/cm)	Portable Conductivity	2510- B	APHA2005
SAR milli equivalent /l)	Calculation method	-	Ay ers & Westcot, 1985
RSC(milli equivalent /l))	Calculation method		Eaton, 1950
Bicarbonate(mg/l HCO_3)	Tetration with(HCL)	-	Gupta& Saul, 1996
Chloride Ion(mg/l)	Argentometric method	4500- CT	APHA, 2005
Cd,Cu,Fe,Pb(µg/l)	Flame Atomic Absorption Spectrophotometer	3111B	APHA, 2005
Boron(mg/l)	Curcumine method UV-visible spectro.	4500-B	APHA,2005

The CWQI calculated by select a set of eleven parameters based on both importance and availability of data. these elvene parameter are Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Electric conductivity ,Total Disolved Solid, pHvalue, Bicarbonate, Chloride Ion, Boron Ion, Lead, Iron, Cadmium, Copper. CCME WQIs were computed for the four stations in the Euphrates River using sets of standard values (table 2) [23-24-25]. The [39] , [3] and [18] Guidelines based objectives were applied to categorize the water primarily for use irrigation.

Calculation of the CCME WQI

The CCME WQI model consists of three measures of variance from selected water quality objectives (scope, frequency, amplitude). These three measures of variance combine to produce a value between 0 and 100 (with 1 being the poorest and 100 indicating the best water quality) that rep resents the over all water quality. Within this range, designations have been set to classify water quality as poor, marginal, fair, good or excellent are shown(table 3). These same designations were adopted for the indices developed here [26].

Table (2) Standard Values

Parameter	US Salini Laboratory	Ayers & Westcot	*CCME*
pH (mg/l)	-	8.4 - 6.5	-
Electrical Conductivity(µS/cm)	-	<3000	-
Bicarbonate(mg HCO_3/L)	-	91.5	-
Chloride(mg/l)	-	-	100
Boron(mg/l)	-	<2	-
Sodium adsorption ratio SAR(milli equivale /l)	-	<9	-
Residual Sodium Carbonate	2.5	-	-
Cadmium(µg/l)	-	-	5.1
Copper(µg/l)	-	-	200
Iron (µg/l)	-	-	5000
Lead (µg/l)	-	-	200

Table (3)CCME WQI categorization schema [26]

WQI Value	Rank
95–100	Excellent
80–94	Good
65–79	Fair
45–64	Marginal
0–44	Poor

The detailed formulation of the WQI, as described in the Canadian WQI 1.0–Technical Report [9], is as follows:

$$F_1 = \left\{\frac{Number\ of\ failed\ Variables}{Total\ Number\ of\ Variables}\right\} \times 100$$

The measure for scope is F1(*Scope*). This represents the extent of water quality guideline non-compliance over the time period of interest.

$$F_2 = \left\{\frac{Number\ of\ failed\ Tests}{Total\ Number\ of\ Tests}\right\} \times 100$$

The measure for frequency is F2 (*Frequency*). This is represented the percentage of individual tests that do not meet objectives (failed tests).

-Amplitude, F3

The measure for amplitude is F3. This represents the amount by which failed tests do not meet their objectives. This is calculated in three steps:

Step 1- Calculation of Excursion. Excursion is the number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective.

When the test value must not exceed the objective:

$$Excursion_i = \left\{\frac{Failed\ Test\ Value\ i}{Objective\ j}\right\} - 1$$

When the test value must not fall below the objective:

$$Excursion_i = \left\{\frac{Objective\ j}{Failed\ Test\ Value\ i}\right\} - 1$$

Step 2- Calculation of Normalized Sum of Excursions. The normalized sum of excursions, nse, is the collective amount by which individual tests are out of compliance. This is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives).

$$nse = \frac{\sum_{i=1}^{n} Excursion}{number\ of\ tests}$$

Step3- Calculation of F3. F3(*Amplitude*,)was calculated by an asymptotic function that scales the normalized sum of the excursions from objectives to yield a range from 0 to 100.

$$F_3 = \frac{nse}{0.01nse + 0.01}$$

The WQI is then calculated as:

$$CWQI = \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}$$

Result and Discussion

The indices have been primarily developed to reflect changes in the physicochemical quality of surface waters. However, they may be used as indicators of ecological change. Temporal variations occur within an aquatic system. by relating water quality to potential water use, the effect of this change on the system may be recorded [27]. Average values of CCME WQI for irrigation (range from 47.66 to 67.93) indicated that water quality for use irrigation can be rated between Marginal to Fair in all sites (Fig. 2). this is due to reflect the Discharge of pollutants to a water resource system from domestic sewege discharges, thermal of electric power station discharges, agricultural runoff and other sources, This is may be untreated, can have significant effects of both short term and long term duration on the quality of a river system [28]. The statistical analysis showed a significant difference among some season and was not among all sites (P< 0.05) except 4 site.

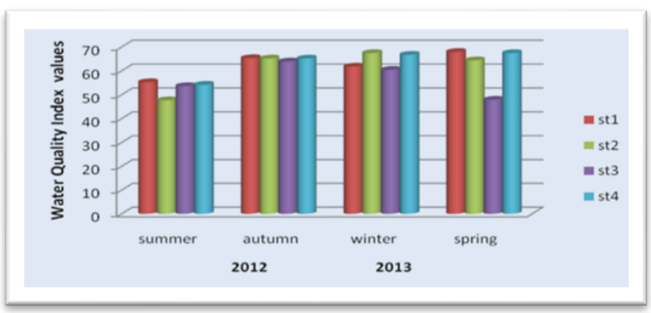

Fig.(2) season variations of Water Quality Index for irrigation for all station of the study

The result of pH varied from (7.6- 8.13) in station 1 ,(7.8-8.14) in station 2 , (7.4-8) in station 3 and (7.9-8.3) in station 4 indicating that the water sampler are almost neutral to sub-alkaline in nature. pH is an important factor that determines the suitability of water for various purposes[29].The recorded range of pH values in present study were general in accordance with the pH values of fresh waters [30] and agree with Iraqi published data [31-32] and were in permissible level recommended by the Ayers & Westcot for irrigation water.The observed value of Electric conductivity was higher than the permissible level recommended by the Ayers & Westcot for irrigation water. It was for all stations ranged from (٣٢٨٠to ٤٩٣٠) µS/cm. EC was observed in station 1 in the range of (3280 to 3720) µS/cm ,wherase It was found in station 2 varied from (3380 to 3980) µS/cm. in station 3 between (3870-4930) µS/cm, while it was found in station 4 between (3450- 4020) µS/cm. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control[11]. The statistical analysis showed a significant difference among all sites and some season ($P< 0.05$) except 4 site. The observed some value of bicarbonate was higher than the permissible level recommended by the Ayers & Westcot for irrigation water . It was for all stations ranged from ٦٣.٤٦ to ١٠٩.٨٣ mg HCO3/l. bicarbonate was observed in station 1 in the range of 70.78 to 92.75 mg HCO3/l . It was found in station 2 varied from 73.22 to 97.63 mg HCO3/l. In station 3 between 87.86 - 109.83 mg HCO3/l, while it was found in station 4 between 63.46 - 90.75 mg HCO3/l. The statistical analysis showed a significant difference among all sites and some season ($P< 0.05$) except 1 site with 2 and 4 stations.The normal conduction of the alkalinity of natural waters are associated with carbon dioxide, bicarbonate, carbonate and hydroxide components. These factors are characteristics of the source of water and the natural processes taking place at any given time. For particular industrial and domestic use, it is often desirable to change these characteristic by treatments such as aeration, neutralization, softening, ect… [33]. Higher concentration of Cl- observed in winter at station 3 (٧٩٠mg/l). Cl- was observed in station 1 in the range of 600 to 650 mg/l , in station 2 varied from (630 to 700) mg/l, in station 3 between 700- 780 mg/l, while it was found in station 4 between 640- 720 mg/l. The observed values which were in all station higher than the permissible level recommended by the CCME, and there was significant difference ($P<0.05$) among all sites and some months except between 2 and 3 stations , indicating slight to moderate degree of restriction on the use with injury to sensitive Plants is not safe for all plants.Boron was is a major concern in some areas. While a necessary nutrient, high boron levels cause plant toxicity, observed in station 1 in the range of ٠.٠٥ to ٥.٢٥ mg/l. Higher concentration of Boron observed in summer at station 3 (٥.٢٥mg/l). The observed value which was higher than the permissible level recommended by the Ayers & Westcot for irrigtion water in some stations and months. and there was significant difference ($P<0.05$) among 1 and 2,3 sites , 2 and 3 sites, and between summer season with study seasons. Sodium concentrations in the samples of all stations varied from ١٨٩ to ٥٥٠ mg/l.Maximum was in the station 3 (٥٥٠mg/l), did not exceed the lower limit, indicating restriction on use .SAR in all stations ranged from ١٨ to ٤٣.٣٤ milli equivalent /l . Maximum was in the station 3 (٤٣.٣٤ milli equivalent /l) .Standard values reflects water is not suitable for irrigation in som sites. All samples have RSC less than zero and are suitable for irrigation purposes. The concentration of lead (Pb) exceeded the permissible level recommended by CCME, for irrigation water at all of the sites and seasons, and the higher concentration of lead was recorded (١٠٩µg/l) at station 3 in summer, The concentration of Iron (Fe) exceeded the permissible level recommended by CCME at all of the seasons and sites ,and the higher concentration of Iron was observed 170 µg/l at staion3 in summer. The concentration of Copper(Cu)exceededthepermissible level recommended by CCME at most of the seasons and the higher concentration of Copper was recorded at sation 3 (٠.٩ µg/l) in summer. Cadmium (Cd) exceeded the permissible level recommended by CCME at most of the seasons and the higher concentration of Cadmium was recorded at sation 3 ٨µg/l in summer.The statistical analysis of heavy metal showed a significant difference between almost site ($P<0.05$). Careless disposal of urban effluents, Runoff, atmospheric deposition and domestic and industrial effluent discharges are the major sources of aquatic pollution [34-35-36-37-38]. From the result we obtained the parameter that sometime exceed the standard value was, HCO3, SAR, Pb, Cd, , B, Na except Cl-, EC that were exceed the standard value all the time in all stations

Conclusion

Using water quality indices for particular consumption is considered as a simple method for the primary recognition of river water quality. The use of index of water quality will not only allow assessment of changes in water quality over time and space but also evaluate successes and short comings of domestic policy and inter-national treaties designed to protect aquatic resources. Overall, Euphrates river water can be classified with few exceptions as suitable for irrigation use.

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