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CONSTRUCTION WATER SUITABILITY MAPS OF TIGRIS RIVER FOR IRRIGATION AND DRINKING USE

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ABSTRACT

The Tigris River is one of two major sources of surface water in Iraq, with 1900 km length, 1415 km of which are in Iraq. Increasing demands of the river water for beneficial uses lead to increase the concern about its quality.

World Health Organization (WHO, 2004) and Iraqi Quality Standards (IQS, 2001) have been adopted along the river to compare and examine the degree of permissibility of polluted parameters T.H, SO_4^{-2}, Cl^{-1}, and T.D.S for drinking use, whereas American Salt Laboratory Standards has been adopted basing on SAR and EC for irrigation use. Different international methods have been applied to classify the water quality index for the Tigris River at north of Baghdad station which are Brown (1970), Mecllelend (1974), and Bhargava (1983).

A general program was constructed to estimate the surface water quality variation with time and location for drinking and irrigation adopting Bahrgava,1983 method, since it is more effective in dealing with many sensitive functions related to the pollutant parameters through the analysis of T.H, SO_4^{-2}, Cl^{-1}, T.D.S, EC, Ca^{+2}, SAR, pH, and BOD which are the relative parameters to the previous mentioned beneficial uses.

The program use Visual Basic Studio, 2008 language as a tool because it is easy to operate automatically by engineers or the decision makers for the water quality assessment. Thirteen stations along Tigris River were taken in the analysis, starting at Feeshkabour and ending at Al-Qurna. The historical recorded data which were used had been selected through 2007/2008 as a monthly base.

In general, the results showed that the Tigris River is class I to II for irrigation use, while its class ranges from II –V for drinking use. According to these classes, the Tigris River is divided into two reaches as follows:

- From Feeshkhabour to Tarmiyah, the water quality index (WQI) is classified as class I for irrigation, and class II for drinking use.
- From North of Baghdad till Qurna, WQI is classified as class II for irrigation, and class IV for drinking use.

The results also indicate that there is an increase in T.H values leading to deterioration in water quality for drinking use; also, an increase in SO_4^{-2} parameter after Tarmiyah, and Cl^{-1} parameter after Kut that affects the suitability of water for irrigation use.

Finally, different suitability maps are constructed to classify water of 2007/2008 for irrigation and drinking use, which will be a base to trace the type of pollutants and their weight that cause the deterioration of the previously mentioned uses.

الخلاصة:

أن نهر دجلة احد المصادر الرئيسية للمياه في العراق حيث يبلغ طوله 1900 كم منها 1415 كم داخل العراق وبسبب الازدياد الحاصل في عدد السكان ونشاطاتهم ادى الى ازدياد الطلب على الموارد المائية للاستخدامات الحياتية المختلفة وبالتالي زيادة الاهتمام بنوعية المياه والسيطرة على مقدار التلوث فيها.

في هذا البحث تمت مقارنة نوعيه مياه نهر دجلة للسنة المائية 2007/2008 للعناصر المقاسة($T.H, SO_4^{-2}, Cl^{-1}, T.D.S$) مع مواصفات منظمة الصحة العلميه(WHO, 2004) و المواصفات العراقية(IQS, 2001) لاغراض الشرب واعتماد مواصفات مختبر الملوحة الامريكي الذي يعتمد في تصنيفه على قيم (SAR, EC) لمقارنة نوعية المياه لاغراض الري.

تم مقارنة ثلاث طرق عالمية مختلفة معتمدة في تصنيف المياه السطحية في محطة شمال بغداد لحساب مؤشر نوعية المياه (WQI) وهي (Brown/1970, Mccllend/1974, and Bhargava/1983) ومن ثم تم بناء برنامج بلغة Visual Basic Studio/2008 كوسيلة كفوءة وسهلة للمتابعة والاستفادة من قبل المهندسين لحساب (WQI) بالاعتماد على طريقة Bhargava/1983 لتصنيف صلاحية مياه نهر دجلة لإغراض الري والشرب.

تم تحليل العناصر الملحية($T.H, SO_4^{-2}, Cl^{-1}, T.D.S, EC, Ca^{+2}, SAR, pH, BOD$) كمعدلات شهرية للسنة المائية 2007/2008 واستخراج القيم المقابلة لوزن كل عنصر ومن ثم استخراج النسبة المئوية لمساهمة كل عنصر في صلاحية المياه لاستخدامات الري والشرب من خلال المنحنيات الخاصة المعتمدة لهذا الغرض.

تم تحليل ثلاثة عشر محطة على نهر دجلة وهي (فيشخابور, مقدم سد الموصل, الموصل, الشرقاط, تكريت, سدة سامراء, الطارمية, شمال بغداد, جنوب بغداد, العزيزية, الكوت, العمارة والقرنة).

وقد أوضحت النتائج المستحصلة من البرنامج إن تصنيف المياه لنهر دجلة بصورة عامة لاستخدامات الري تتراوح من رتبة (I) إلى رتبة (II) وللاستخدامات الشرب من رتبة (II) إلى رتبة (V) وقد تم تقسيم النهر على أساس المعدل السنوي للتحاليل إلى مقطعين بالاستناد إلى النتائج المستخرجة :

- من فيشخابور إلى الطارمية حيث يكون مؤشر نوعية المياه (WQI) للري رتبة (I) وللشرب رتبة (II) .
- من شمال بغداد إلى القرنة حيث يكون للري رتبة (II) وللشرب رتبة (IV).

بينت النتائج ان هنالك دورا لارتفاع تراكيز T.H على طول النهر أدى الى تردي نوعية المياه للاستخدامات الشرب إضافة لارتفاع تراكيز SO_4^{-2} بعد محطة الطارمية وتراكيز Cl^{-1} بعد محطة الكوت وأخيرا تم بناء خرائط تبين صلاحية مياه نهر دجلة للسنة المائية 2007/2008 لاستخدامات الري والشرب ؛ وهذه الخرائط ستكون قاعدة لاستنباع الملوثات ومعرفة وزن تأثيرها في التردي.

KEY WORD:
WQI, Drinking Water, Irrigation

INTRIODUCTION

Surface waters are facing an increasing problem through the disposal of pollutants due to the rapid growth of industrial and municipal activities because of the increasing of population growth as well as the increase of land drainage due to agricultural activities. Thus, there have been increasing concerns about the management of water quality all over the world.

A river can be classified into various grades indicating the beneficial use(s) to which it can be put to. The grades are based on the permissible limits of relevant pollution parameters (water quality variables) or standards, set by the various authorities. Depending on the quality of water in various stretches of a river, the river can be zoned according to stretch suitability for the beneficial use(s). It would be appropriate to base river classification on the ranges of an index representing the integrating effect of the concentrations and importance values of the relevant variables for a use.

The Tigris River is one of the major sources of surface water in Iraq; so, studying its quality and quantity and its management has become one of the major concerns. Thirteen stations on the River are taken in the analysis (Feeshkhabour, U/S Mosul Dam, Mosul, Shirkat, Tikrit, Samara Barrage, Tarmiyah, North of Baghdad, South of Baghdad, Al-Azeezia, Kut, Al-Amara, Qurna). The monthly historical recorded data includes nine pollutant parameters (T.H, SO_4^{-2}, Cl^{-1}, T.D.S, EC, Ca^{+2}, SAR, pH, and BOD) to evaluate the water quality for irrigation and drinking uses.

Objectives of the Research

- To study the variation of the water quality parameters for the Tigris River according to the beneficial uses.
- To construct a general program to classify surface water quality using Visual Basic language.
- To evaluate the importance of each pollutant parameters on the beneficial uses.
- To trace the cause of deterioration in water quality locally.
- To build suitability maps for irrigation and drinking use for Tigris River.

Literature Review

Water Quality Index(WQI) was first mentioned by **Horton (1965)**, which was considered as an effective tool for collecting various sorts of water quality data to enhance representing them by a principal parameter. He used the WQI to classify water and to identify eight physical and chemical determinants to estimate the degradation of water quality. Also, Horton proposed the rating scales and the weightings for the determinants to give the relative importance for each determinant in the water quality. The formula which he used is eq. (1):

$$WQI = \left[\frac{\sum_{i=1}^{n} Ci.Wi}{\sum_{i=1}^{n} Wi} \right] \cdot M_1 \cdot M_2 \qquad (1)$$

Where:
WQI: water quality index
C_i : the rating of the i th determinant
n: number of determinants
M_1, M_2: additional determinant parameters
W_i: the weighting of the i th determinant.

Brown et al., (1970) developed the theoretical idea of choosing the determinants of WQI in addition to determine the relative weights and the rating scales depending on the questionnaires which are distributed among water experts in the United States. They used the arithmetic weighted mean to determine the WQI as eq.2:

$$WQI = \sum_{i=1}^{n} q_i . w_i \qquad (2)$$

Where:
q_i: rating of the i th determinant, this value varies from (0-100);

W_i: weighting of the i th determinant and this value varies from (0-1) and $\sum w_i = 1$;
n: number of determinants.

Mcclelland et al., (1974) studied the WQI of Kansas River adopting Browen's study (1970). They concluded that the multiplicative weights were the most appropriate for this purpose, because of their sensitivity to the changes which occurred in the water quality. This method was later known as the Geometric Weighted Mean eq. (3):

$$WQI = \pi_{i=1}^{n} q_i^{wi} \qquad (3)$$

Bhargava (1983) studied the WQI to evaluate the water quality for several activities in Ganga River in India and Saigon River in Vietnam using the sensitivity function method. He transferred the values of variables according to the standard specifications on (0 – 1) scale. This index was used to classify rivers into five groups and to determine WQI for each activity of different water activities depending on the variables which affected that activity.

Al-Ansari and Al-Sinawi (1985) studied the water quality of the Tigris River in Baghdad City using multi-variate analysis. They had selected (9) variables (TDS, Ca^{+2}, Mg^{+2}, Na^{+1}, K^{+1}, Cl^{-1}, SO_4^{-2}, $HCO3^{-1}$, and CO_3^{-2}) with the discharge (Q) for the period 1967-1985 to evaluate the water quality of the river in Baghdad. Their results showed that, the continuous decrease of flow and the simultaneous increase in agricultural and industrial development with time, showed general deterioration in water quality of the Tigris River in Baghdad over the period of study.

Al-Ani (1988) studied the WQI of the Tigris River in Baghdad reach. He used the sensitivity function to convert the variables on scale (0 – 1) depending on a standard specification of water activities. He collected the results using the geometric mean according to Bhargava formula. He concluded that the Tigris River is classified as class I for irrigation and as class III for potable and industrial uses.

Al-Rawi and Shihab (1994) studied the WQI for the Tigris River in Mosul. They used the geometric mean previously used in Baghdad, India and Vietnam, depending on the sensitivity function on the range(0 – 1). The results of this study clearly showed that the water quality of excellent class was for irrigation and for the domestic and industrial uses; it was classified as class II.

Mohammad (1998) evaluated the Tigris River in Mosul City using WQI. Seventeen sections were selected along a stretch of the river from north of Mosul City to Hamam Al-Alil. Samples were collected and analyzed during a period of six months. The study showed that the Tigris River water quality for irrigation use falls within classes I and II; for industrial use it fell within class II; and for drinking water, it was classified in class III.

Al-Saffar (2001) has developed an expert system for the WQI for multi-uses for one year (2000) along the Tigris River using nine samples site (Mosul Dam, Mosul, Shirkat, Bejee, Samara, Baghdad, Al-Azeezia, Al-Kut, and Al-Amara). She concluded that Tigris water quality is classified as class II to class III for general uses at all sites except Al-Kut site which represents class II and III for general purposes and shifts to class IV for potable use and class V for industrial uses.

AREA OF STUDY (THE TIGRIS RIVER)

The Tigris is the second longest river in the Southwest of Asia at 1,900 km length of which 1415 km is in Iraq, it also has its springs in the highlands of Eastern Turkey, but the main contribution to the river comes from the tributaries in Iraq. The Tigris River follows a southeastern route in Turkey to the city of Cizre, forming a border between Turkey and Syria for 32 km before entering Iraq at upstream of Feeshkhabour City, where the Khabour tributary 160 km in length joins the main river course. In Iraq, it meets its tributaries: the Greater Zap, the Lesser Zap, the Adhaim, and Diyala. It joins the Euphrates in Qurna and continues its journey to Shatt Al-Arab after the extensive irrigation and diversification canals remove around 70-80 percent of its waters before forming Shatt al-Arab then falls to the Arabian Gulf. **(El-Fadel, et al., 2002)**

BENEFICIAL USES:

Drinking water (DR): Iraqi Quality Standard, 2001 (IQS) and World Health Organization, 2004 (WHO) as shown in **Table 1** are adopted along the river to compare it with the recorded data for (T.H, SO_4^{-2}, Cl^{-1}, and T.D.S) parameters through the year 2007/2008.

Table (1) Guideline for Drinking water after IQS and WHO

Characteristics	Units	IQS,2001	WHO,2004
- Calcium (Ca)	ppm	200	200
- Chloride (Cl)	ppm	600	250
- Total Hardness (T.H)	ppm as $CaCO_3$	500	500
- pH (Range)	---	6.5-8.5	---
- Sulfate (SO_4)	ppm	400	250
- T.D.S	ppm	1500	1000

Irrigation use (IRR): The Tigris River water quality is classified according Richard Classification, 1954**(Richard, 1954)** with respect to the value of SAR and EC in water (**Table 2 and 3)** for the year 2007/2008.

T**able (2)** Richard Classification, 1954 for irrigation use **(Richard, 1954)**

Water Class	SAR	Index	EC(ds/m)	Index
Excellent	≤ 10	S1	0.1-0.25	C1
Good	10-18	S2	0.25-0.75	C2
Fair	18-26	S3	0.75-2.25	C3
Poor	≥ 26	S4	≥ 2.25	C4

Table (3) Water classification acording to Richard Classification, 1954 for irrigation use **(Richard, 1954)**

Index	Water class	Index	Water class
C1S1	Excellent	C3S1	Approprate
C1S2	Good	C3S2	Acceptable
C1S3	Approprate	C3S3	Acceptable
C1S4	Poor	C3S3	Poor
C2S1	Good	C4S1	Poor
C2S2	Good	C4S2	Poor
C2S3	Acceptable	C4S3	Very Poor
C2S4	Poor	C4S4	Very Poor

VARIATION OF WATER QUALITY PARAMETERS:

Limitations of Water Quality for Drinking Use

The Tigris River water quality behaviour is classified into three different trends which divide the river into three reaches as compared with WHO/2004 and IQS/2001 standards as shown in **Figs. 1, 2, 3 and4**. The first reach starts from Feeshkhabour to Tarmiyah City (reach I) has low concentrations for each parameter so, it is within the acceptable limit. Reach II from Tarmiyah to Kut, where the concentrations of all parameters rapidly increases due to Tigris–Tharthar arm carrying salts from the stratification of the Tharthar Lake, which is same conclusion mentioned by **Nader, et.al, 1986 (Arabic Ref.)** this makes water unacceptable in some sites for drinking purposes. The last reach from Kut to Qurna, reach III with very high concentrations of the relative parameters, and this reach is also unacceptable for drinking.

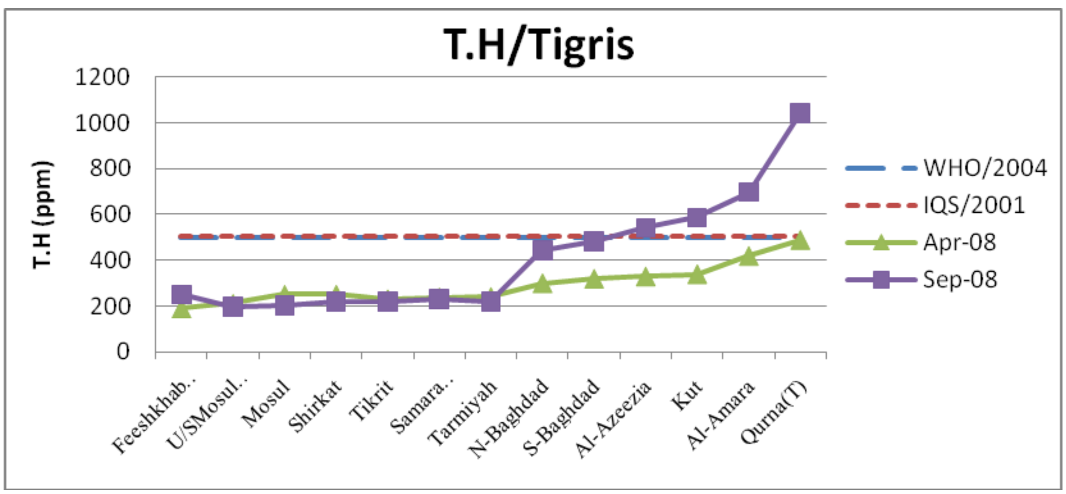


Figure (1) Comparison of T.H concentration according to WHO and IQS standards

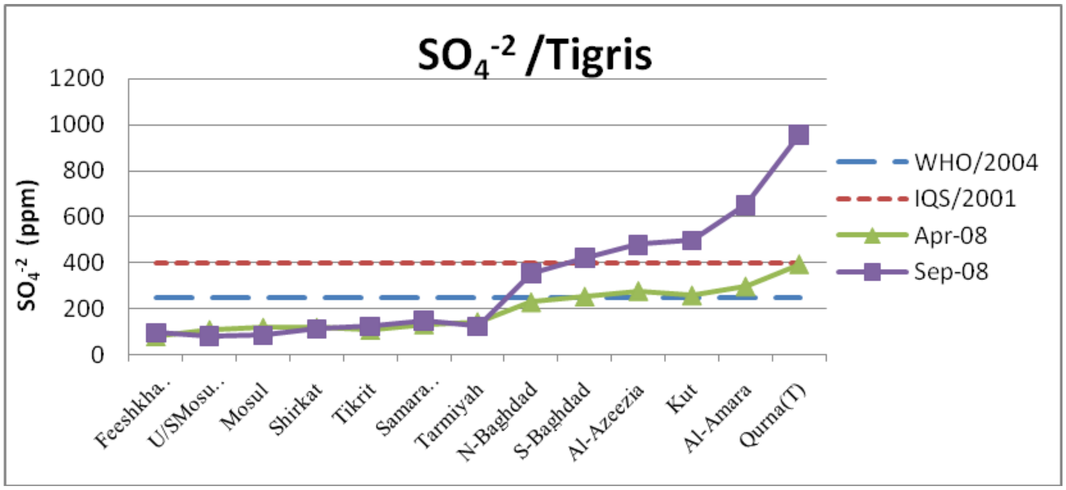


Figure (2) Comparison of SO_4^{-2} concentration according to WHO and IQS standards

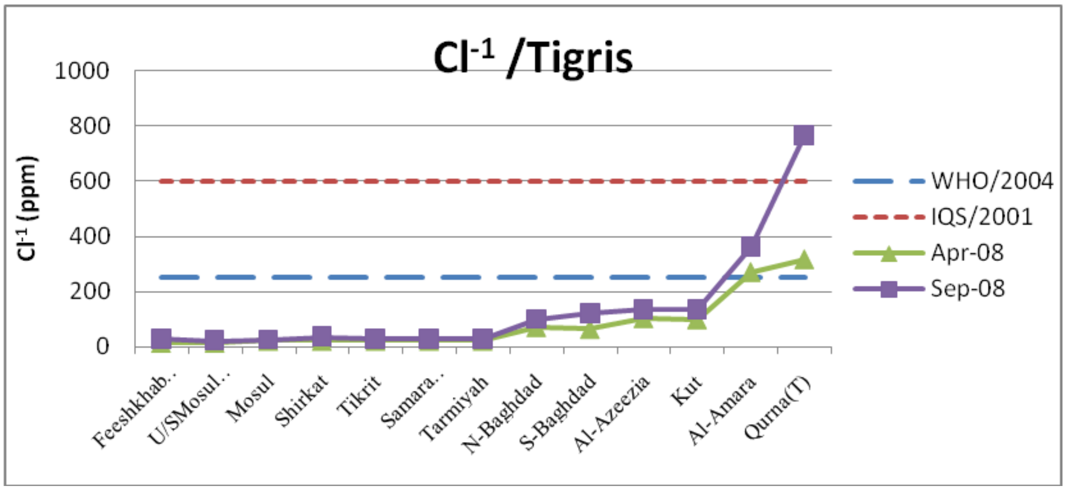


Figure (3) Comparison of Cl^{-1} concentrations according to WHO and IQS standards

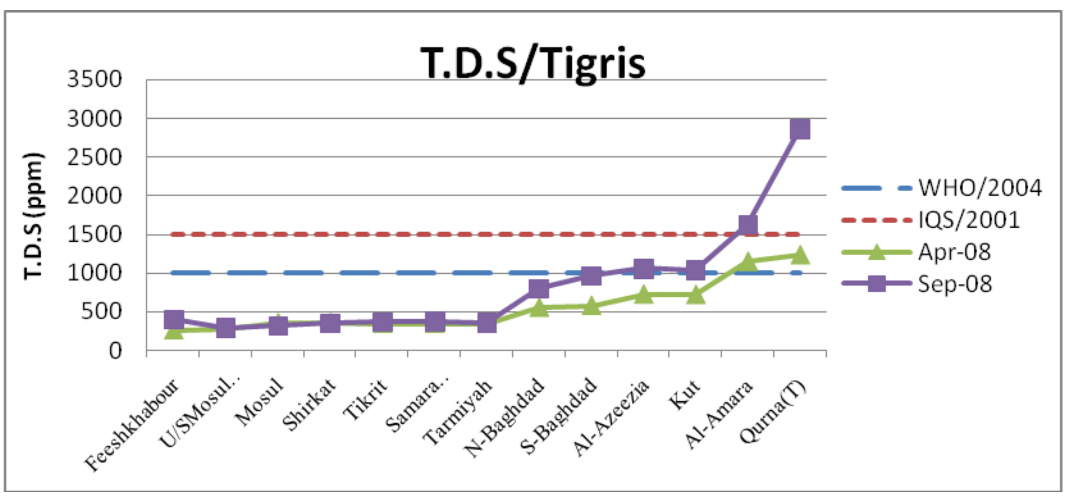


Figure (4) Comparison of T.D.S concentrations according to WHO and IQS standards

Limitations of Water Quality for Irrigation Use

In general, Tigris River is classified as (C2S1) from Feeshkhabour to Tarmiyah, so water is good for irrigation .From Tarmiyah to Qurna it is classified (C3S1) therefore; water is approprate for irrigation. In the three last months at Amara to Qurna the water quality is classified as (C4S2) as shown in Table 3. It is obvious that the value of SAR and EC increase after Tarmiyah because of the mixing with Tigris–Tharthar arm which contains high concantrations of salts **(Nader, et.al, 1986) (Arabic Ref.).**

Table (3) Classification of the Tigris water quality for irrigation use according To Richard Classification, 1954 for irrigation use

Station	Oct. 2007	Nov. 2007	Dec. 2007	Jan. 2008	Feb. 2008	Mar. 2008	Apr. 2008	May. 2008	Jun. 2008	Jul. 2008	Aug. 2008	Sep. 2008
Feeshkhabour	C2S1	C2S1	C2S1	-	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1
U/S Mosul Dam	C2S1	C2S1	C2S1	-	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1
Mosul	C3S1	C2S1	C2S1	-	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1
Shikat	C2S1	C2S1	C2S1	-	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1
Tikrit	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1
Samara Barrage	C2S1	-	C2S1	C2S1	-	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1
Tarmiyah	C2S1	-	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1	C2S1
N-Baghdad	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1
S-Baghdad	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1
Al-Azeezia	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1
Kut	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1	C3S1
Amara	C3S1	C3S1	C3S1	C3S1	C3S1	C4S1	C3S1	C3S1	-	C4S2	C4S2	C4S2
Qurna(T)	C3S1	C3S1	C3S1	C3S1	C3S1	C4S1	C3S1	C3S1	-	C4S2	C4S3	C4S3

NATIONAL METHODS SELECTION:

A comparison of three different national methods is applied to a selected station on Tigris River in the north of Baghdad to classify the water quality as shown in **Fig. 5**. It can be seen from the figure that the previous mentioned methods can be used for WQI analysis. Bhargava method is selected since it is more effective in dealing with many sensitive functions; and it gives a detailed description to analyze the WQI for irrigation and drinking uses.

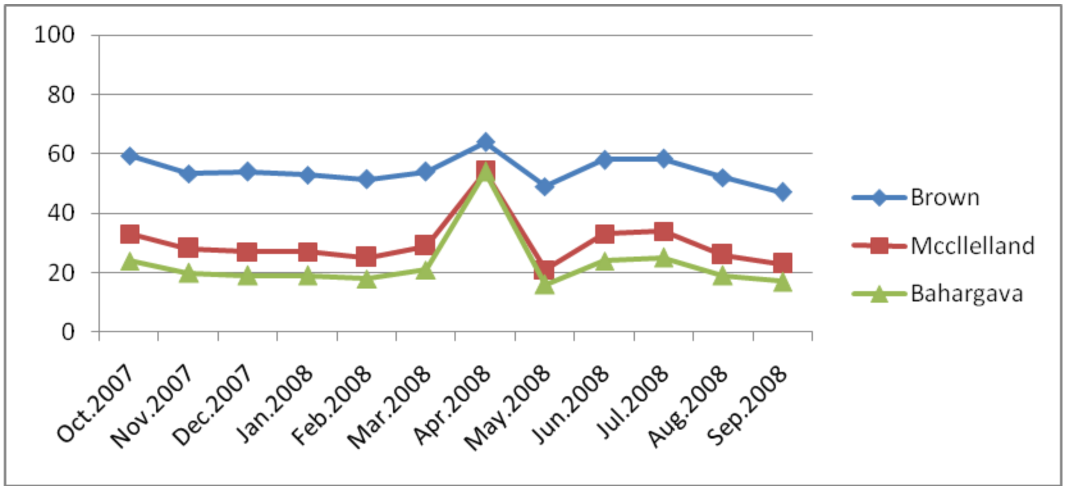


Figure (5) WQI at N-Baghdad for drinking use using different methods

BHARGEAVA METHOD:

Bhargava Method is one of the important methods which is used in many countries. It is easy to deal with relative parameters for different uses by using sensitivity functions curves which take the value between 0 and 1. The results are accumulated by using the geometric mean **eq. 4** to determine the WQI for each activity of water depending on the variables affecting that activity. This index classify rivers into five groups as shown in **Table 5**, that was formulated by the following equation***(*Abdul-Razzaq et al., (2001) (Arabic Ref.))**:

$$WQI = \left[\pi_{i=1}^{n}\ fi\left(P_i\right)\right]^{1/n} \quad *100 \qquad (4)$$

Where:

f_i (P_i) is the sensitivity function for each variable including the effect of variable weight concentration which is related to a certain activity and varies from 0 – 1.

The relative parameters for irrigation are TDS, pH, $SO4^{-2}$, SAR, EC, and Cl^{-1}, while the relative parameters of drinking are TDS, T.H, Cl^{-1}, SO_4^{-2}, BOD, pH, and Ca^{+2}***(*Abdul-Razzaq et al., (2001) (Arabic Ref.))**.

Table (5) Water quality classification according to Bhargava

Class	WQI Value	Water Quality
I	100 - 90	Excellent
II	89 - 65	Good
III	64 - 35	Acceptable
V	34 - 11	Polluted
IV	Less than 10	Severe Polluted

DESCRIPTION OF THE CONSTRUCTED MODEL:

A general program has been constructed to classify surface water using Visual Basic Studio 2008 software adopting Bhargava method for irrigation and drinking use. The constructed program uses nine figures which were adopted by Bhargava to compute the sensitivity functions for irrigation and drinking use. The program works automatically and operates easily. It offers an easy base for the people who are dealing with water quality and need no high knowledge to run the program. Also it could be used as a management tool in water quality assessments. The program operating mechanism is listed below:

The main window will appear which contains six options, each performs when clicked on as shown in **Fig 6**, and these options are:

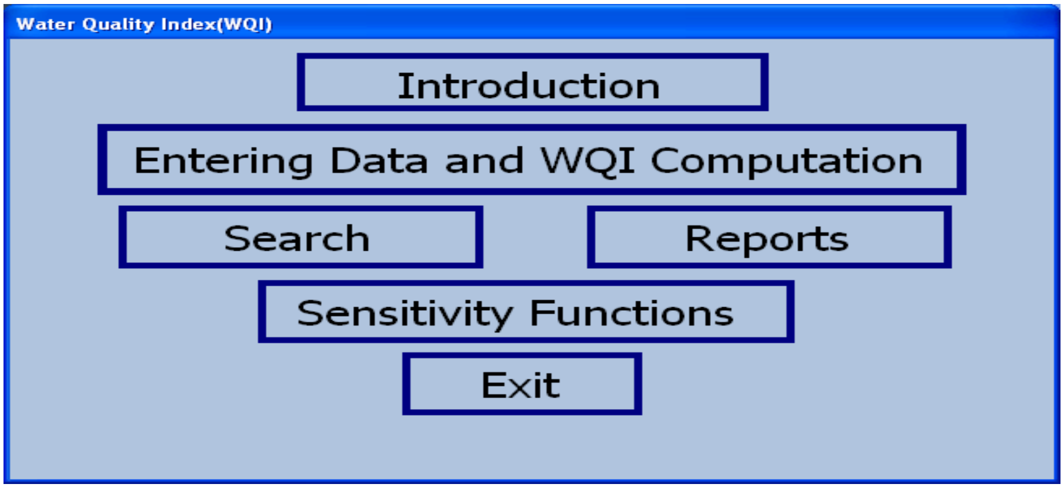


Figure (6) The main window

Fig. 7 shows the **Introduction,** a short definition of WQI and its classification.

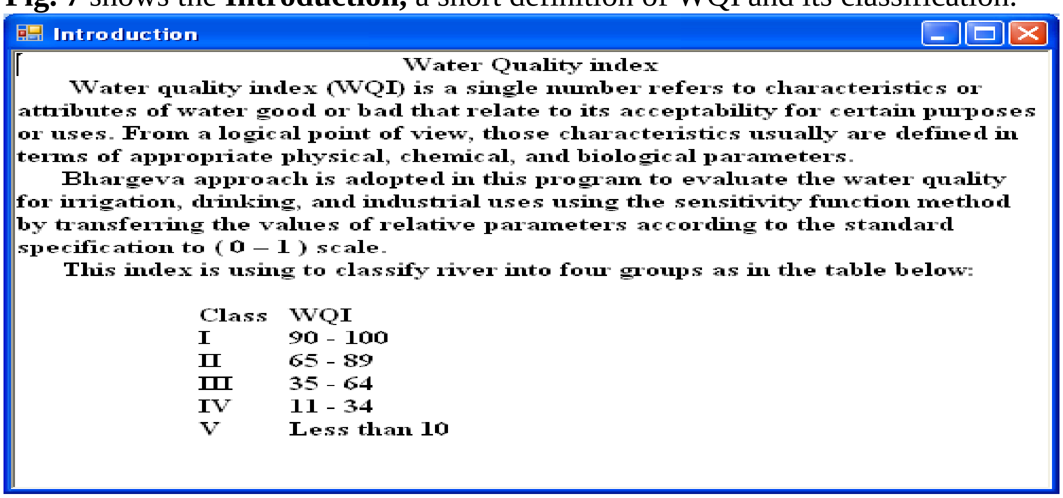


Figure (7) Introduction window

Entering Data and WQI Computation: The main purpose of this window is to enter any new data for any station along the river and calculating WQI then save it.

A detailed description of the operation of the option in the task bar is explained below:

A. Add new **(✚):** When clicking on this option, a new window will appear which is ready to receive any new data of any station as shown in **Fig. 8**.

B. Delete **(✕):** When clicking on this option, the data that are already entered before to the shown window will be deleted.

C. Save data **(🖫):** Clicking this option, the data that has been entered will be saved into data base figure.

D. Next **(⏵):** The program will move forward to the next saved data.
E. Back **(⏴):** The program will move back to the pervious saved data.
The main options of this window which work by clicking on it are as following:

1. WQI%**:** When clicking on this option, the program will calculate WQI for the entered data (station, river, date, and relative parameters) as shown in **Fig. 9**.

2. Back**:** The main window will appear as soon as clicking on it.
Note: The decimal for the number that represents WQI and sensitivity functions can be chosen by two options that can be seen in the bottom of this window.

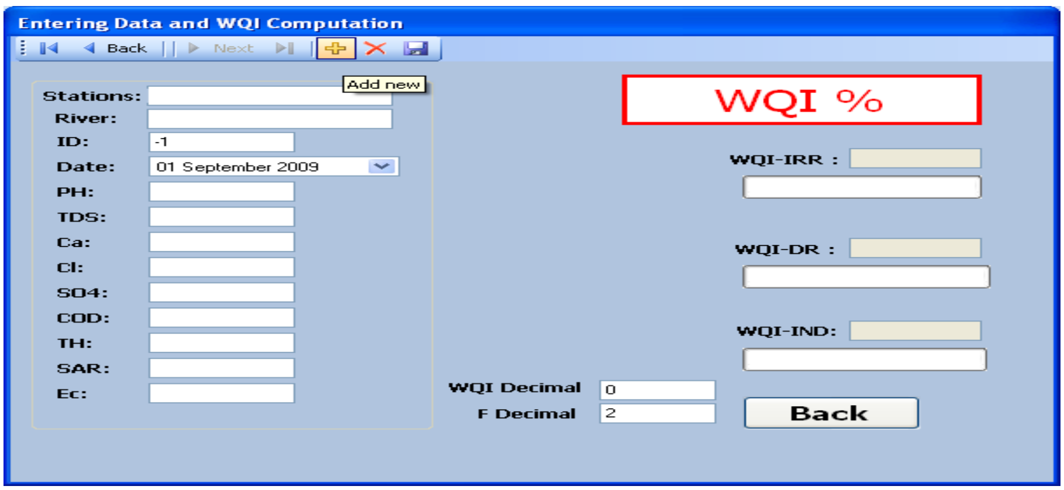


Figure (8) Entering new data window

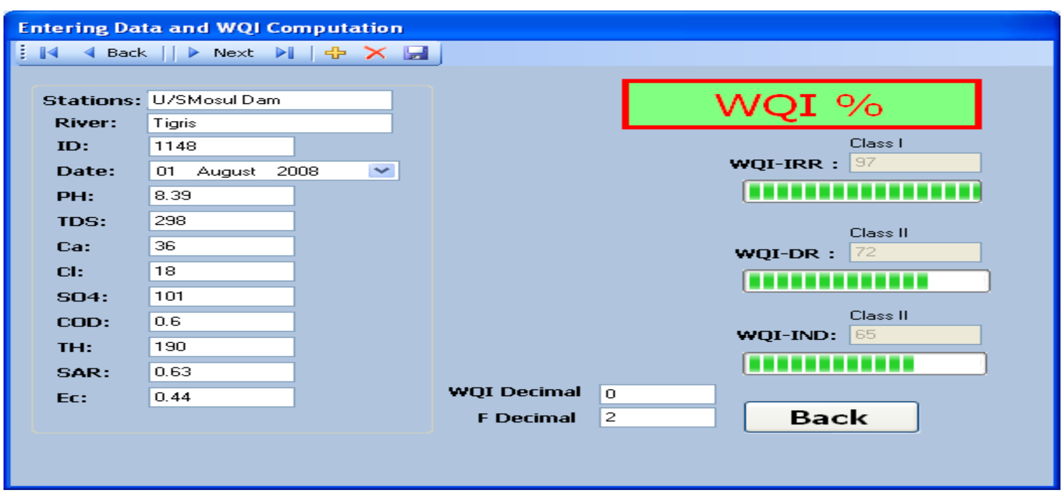


Figure (9) Entering data calculating WQI window

Search: This window prepares the model to search for any data which have been saved **(Figs. 10 and 11)**.
There are two ways to make search:

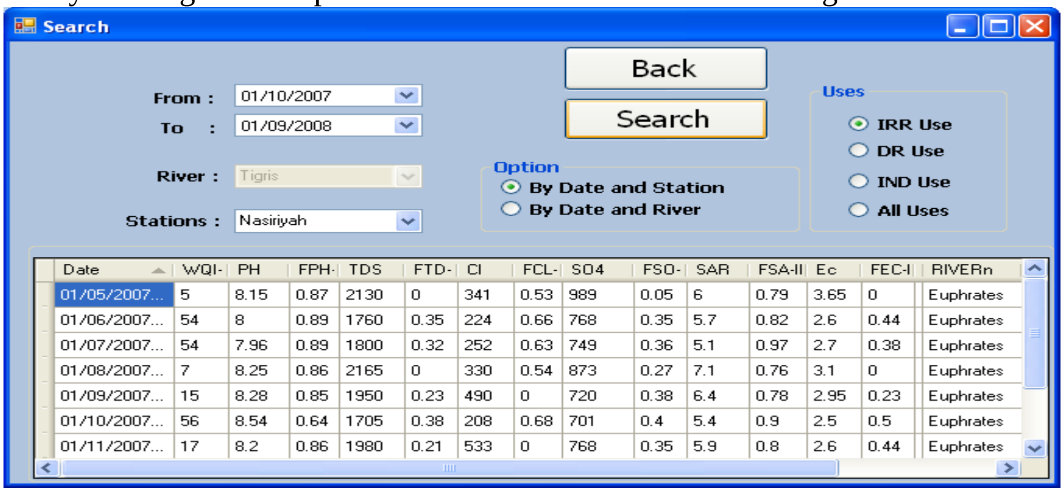
A. By date and station**:** in this option, the station can be selected by another option and the period of time from-to for a specific date can be chosen.

B. By date and river**:** in this option the river Tigris can be selected by another option and the period of time from-to for specific date can be chosen.

Those two options can be more specific by selecting particular use (irrigation, drinking, industrial, or all uses).

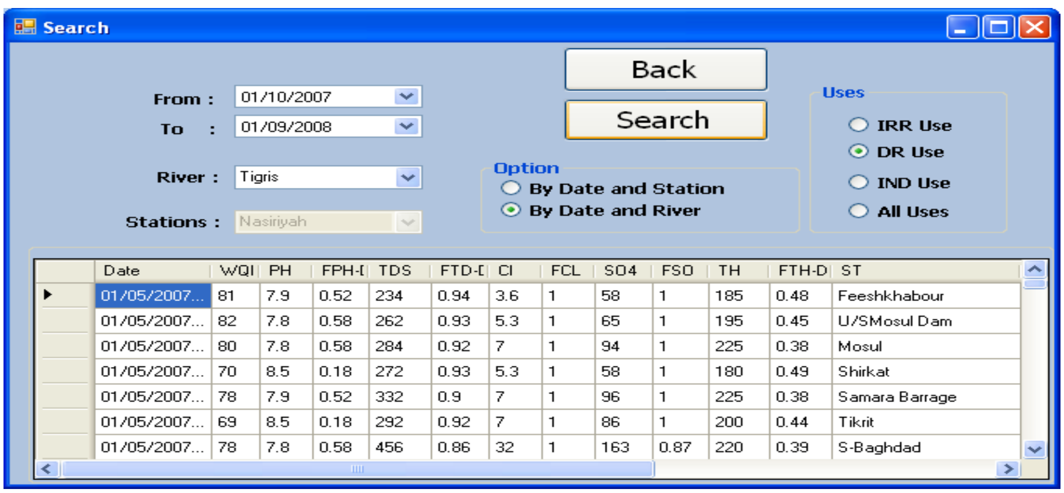
By clicking on:

1. Search: The search for all data for relative parameters, WQI, and sensitivity functions for the selected period will start.
2. Back: By clicking on this option the search window will close and go back to the main window.



Date	WQI-	PH	FPH-	TDS	FTD-	Cl	FCL-	SO4	FSO-	SAR	FSA-I	Ec	FEC-I	RIVERn
01/05/2007...	5	8.15	0.87	2130	0	341	0.53	989	0.05	6	0.79	3.65	0	Euphrates
01/06/2007...	54	8	0.89	1760	0.35	224	0.66	768	0.35	5.7	0.82	2.6	0.44	Euphrates
01/07/2007...	54	7.96	0.89	1800	0.32	252	0.63	749	0.36	5.1	0.97	2.7	0.38	Euphrates
01/08/2007...	7	8.25	0.86	2165	0	330	0.54	873	0.27	7.1	0.76	3.1	0	Euphrates
01/09/2007...	15	8.28	0.85	1950	0.23	490	0	720	0.38	6.4	0.78	2.95	0.23	Euphrates
01/10/2007...	56	8.54	0.64	1705	0.38	208	0.68	701	0.4	5.4	0.9	2.5	0.5	Euphrates
01/11/2007...	17	8.2	0.86	1980	0.21	533	0	768	0.35	5.9	0.8	2.6	0.44	Euphrates

Figure (10) Search by date and station for irrigation use window



Date	WQI	PH	FPH-I	TDS	FTD-I	Cl	FCL	SO4	FSO	TH	FTH-D	ST
01/05/2007...	81	7.9	0.52	234	0.94	3.6	1	58	1	185	0.48	Feeshkhabour
01/05/2007...	82	7.8	0.58	262	0.93	5.3	1	65	1	195	0.45	U/SMosul Dam
01/05/2007...	80	7.8	0.58	284	0.92	7	1	94	1	225	0.38	Mosul
01/05/2007...	70	8.5	0.18	272	0.93	5.3	1	58	1	180	0.49	Shirkat
01/05/2007...	78	7.9	0.52	332	0.9	7	1	96	1	225	0.38	Samara Barrage
01/05/2007...	69	8.5	0.18	292	0.92	7	1	86	1	200	0.44	Tikrit
01/05/2007...	78	7.8	0.58	456	0.86	32	1	163	0.87	220	0.39	S-Baghdad

Figure (11) Search by date and river for drinking use window

Reports: When clicking on this option another window will appear which contains three kinds of reports, each one performs when clicking on it:

A. Total review.
B. WQI review by station.
C. WQI review by date.

Back: To go back to the main window.

All reports have the same task bar which contains several icons as followes:

- Next **(⏵):** To move forward to a different page.

- Back (⏴): To move back to a pervious page.
- Print (🖶): To print the selected report.
- Print layout (🗎): To show the final shape of the report that will be printed.
- Page set up (🕮): When clicking on this icon, a sub window will appear to choose the size of the report paper that will be printed.
- Save (🖫): To save the report either as an Excel document or as an Acrobat (pdf) file.
- Zoom: To zoom the report.
- Search text: To make sub-search for any text inside the report by clicking on Find and move inside the sub-search by clicking on Next. **(Figs. 12, 13, 14, and15)**.

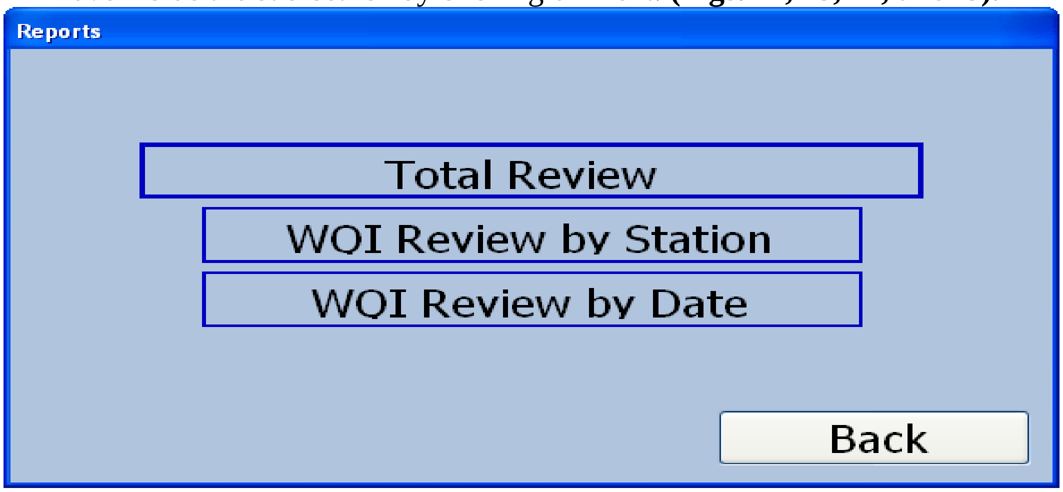
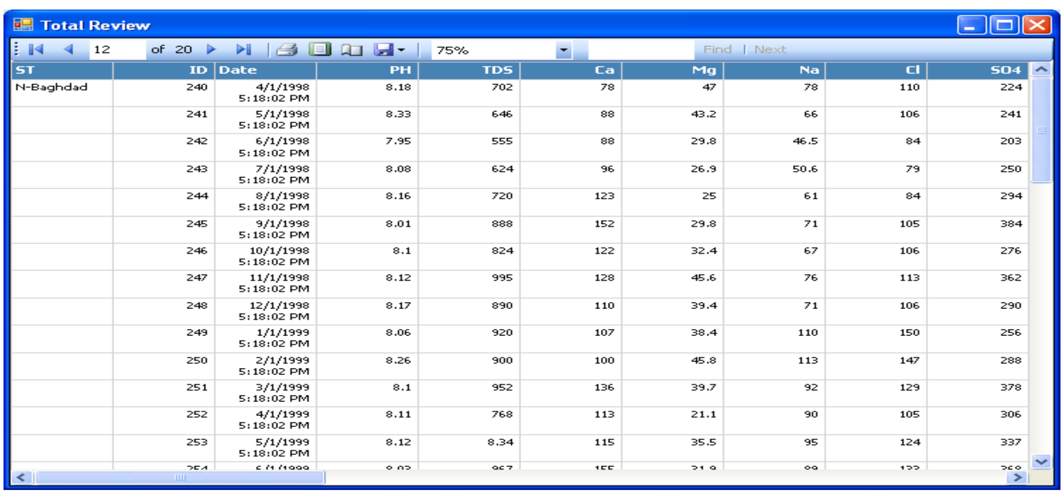
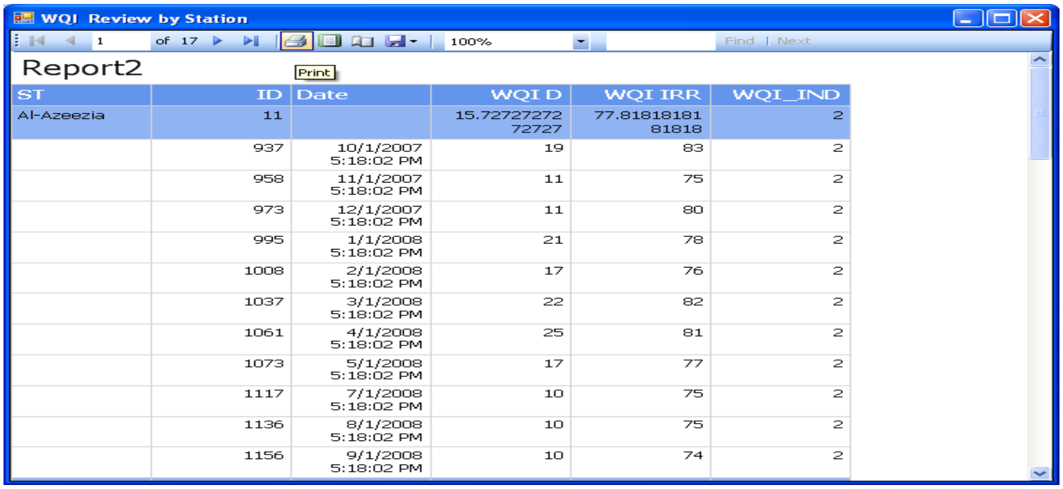


Figure (12) Reports window



ST	ID	Date	PH	TDS	Ca	Mg	Na	Cl	SO4
N-Baghdad	240	4/1/1998 5:18:02 PM	8.18	702	78	47	78	110	224
	241	5/1/1998 5:18:02 PM	8.33	646	88	43.2	66	106	241
	242	6/1/1998 5:18:02 PM	7.95	555	88	29.8	46.5	84	203
	243	7/1/1998 5:18:02 PM	8.08	624	96	26.9	50.6	79	250
	244	8/1/1998 5:18:02 PM	8.16	720	123	25	61	84	294
	245	9/1/1998 5:18:02 PM	8.01	888	152	29.8	71	105	384
	246	10/1/1998 5:18:02 PM	8.1	824	122	32.4	67	106	276
	247	11/1/1998 5:18:02 PM	8.12	995	128	45.6	76	113	362
	248	12/1/1998 5:18:02 PM	8.17	890	110	39.4	71	106	290
	249	1/1/1999 5:18:02 PM	8.06	920	107	38.4	110	150	256
	250	2/1/1999 5:18:02 PM	8.26	900	100	45.8	113	147	288
	251	3/1/1999 5:18:02 PM	8.1	952	136	39.7	92	129	378
	252	4/1/1999 5:18:02 PM	8.11	768	113	21.1	90	105	306
	253	5/1/1999 5:18:02 PM	8.12	8.34	115	35.5	95	124	337

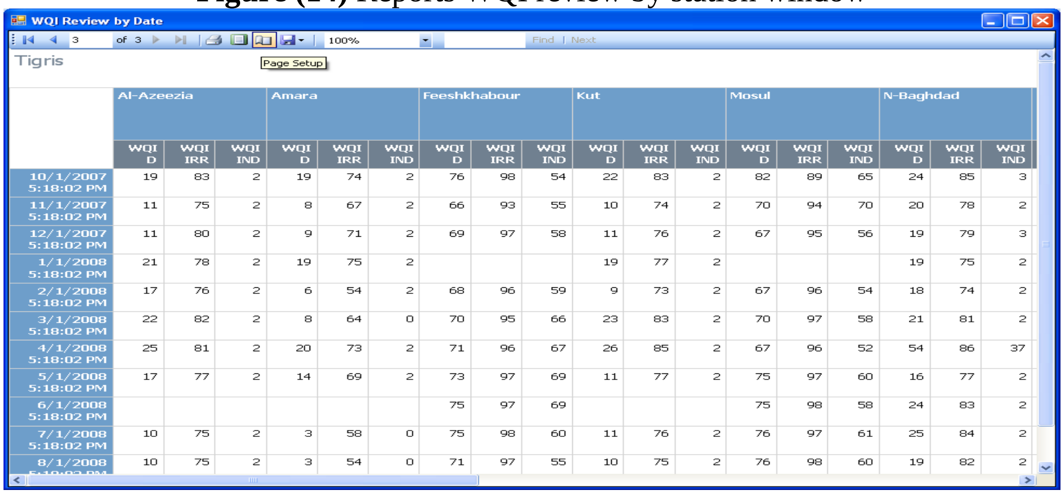
Figure (13) Reports total review window


WQI Review by Station

Report2

ST	ID	Date	WQI D	WQI IRR	WQI_IND
Al-Azeezia	11		15.72727272 72727	77.81818181 81818	2
	937	10/1/2007 5:18:02 PM	19	83	2
	958	11/1/2007 5:18:02 PM	11	75	2
	973	12/1/2007 5:18:02 PM	11	80	2
	995	1/1/2008 5:18:02 PM	21	78	2
	1008	2/1/2008 5:18:02 PM	17	76	2
	1037	3/1/2008 5:18:02 PM	22	82	2
	1061	4/1/2008 5:18:02 PM	25	81	2
	1073	5/1/2008 5:18:02 PM	17	77	2
	1117	7/1/2008 5:18:02 PM	10	75	2
	1136	8/1/2008 5:18:02 PM	10	75	2
	1156	9/1/2008 5:18:02 PM	10	74	2

Figure (14) Reports WQI review by station window


WQI Review by Date

Tigris

	Al-Azeezia			Amara			Feeshkhabour			Kut			Mosul			N-Baghdad		
	WQI D	WQI IRR	WQI IND	WQI D	WQI IRR	WQI IND	WQI D	WQI IRR	WQI IND	WQI D	WQI IRR	WQI IND	WQI D	WQI IRR	WQI IND	WQI D	WQI IRR	WQI IND
10/1/2007 5:18:02 PM	19	83	2	19	74	2	76	98	54	22	83	2	82	89	65	24	85	3
11/1/2007 5:18:02 PM	11	75	2	8	67	2	66	93	55	10	74	2	70	94	70	20	78	2
12/1/2007 5:18:02 PM	11	80	2	9	71	2	69	97	58	11	76	2	67	95	56	19	79	3
1/1/2008 5:18:02 PM	21	78	2	19	75	2				19	77	2				19	75	2
2/1/2008 5:18:02 PM	17	76	2	6	54	2	68	96	59	9	73	2	67	96	54	18	74	2
3/1/2008 5:18:02 PM	22	82	2	8	64	0	70	95	66	23	83	2	70	97	58	21	81	2
4/1/2008 5:18:02 PM	25	81	2	20	73	2	71	96	67	26	85	2	67	96	52	54	86	37
5/1/2008 5:18:02 PM	17	77	2	14	69	2	73	97	69	11	77	2	75	97	60	16	77	2
6/1/2008 5:18:02 PM							75	97	69				75	98	58	24	83	2
7/1/2008 5:18:02 PM	10	75	2	3	58	0	75	98	60	11	76	2	76	97	61	25	84	2
8/1/2008	10	75	2	3	54	0	71	97	55	10	75	2	76	98	60	19	82	2

Figure (15) Reports WQI review by date window

Sensitivity Functions: The main purpose of this window is to view the sensitivity functions for all uses to show the relative parameters that have affect on WQI. **(Fig. 16)**

The task bar contains the following icons:

A. Back (**◀**)**:** When clicking on this option, the program will move back to the pervious saved sensitivity functions.

B. Next (**▶**)**:** When clicking on this option the program will move forward to the next saved sensitivity functions.

Back: To go back to the main window**.**

Exit: To close the main window and shut down the program.

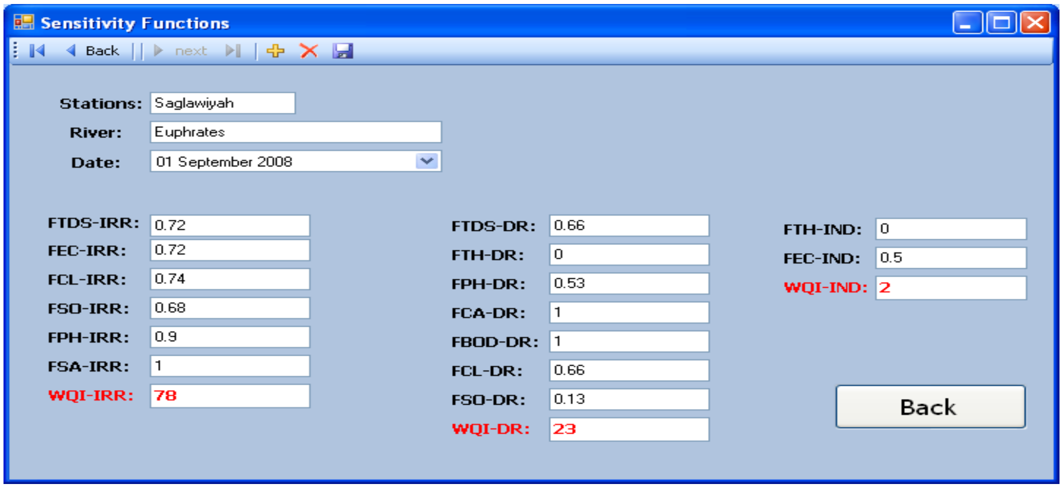


Figure (16) Sensitivity functions window

RESULTS AND DISCUSSION:

Different historical data for thirteen stations along Tigris River were adopted in the program for calculating the WQI to evaluate the water quality through one year 2007/2008 and the data are recorded on monthly base.

WQI for Tigris River (2007/2008):

Tigris River is classified for irrigation use as class I from Feeshkhabour to Tarmiyah reach, after Tarmiyah till Qurna, WOI shifts from class I to class II. In the last three months in addition to March WQI is classified as class III – V in Kut-Qurna reach due to high concentrations of T.D.S, Cl^{-1}, SO_4^{-2}, and EC. **Fig. 17** represents the average suitability maps for the Tigris River for irrigation use and shows the parameter(s) which are the most dominant (i.e. responsible for water quality deterioration that has sensitivity function less than 0.5).

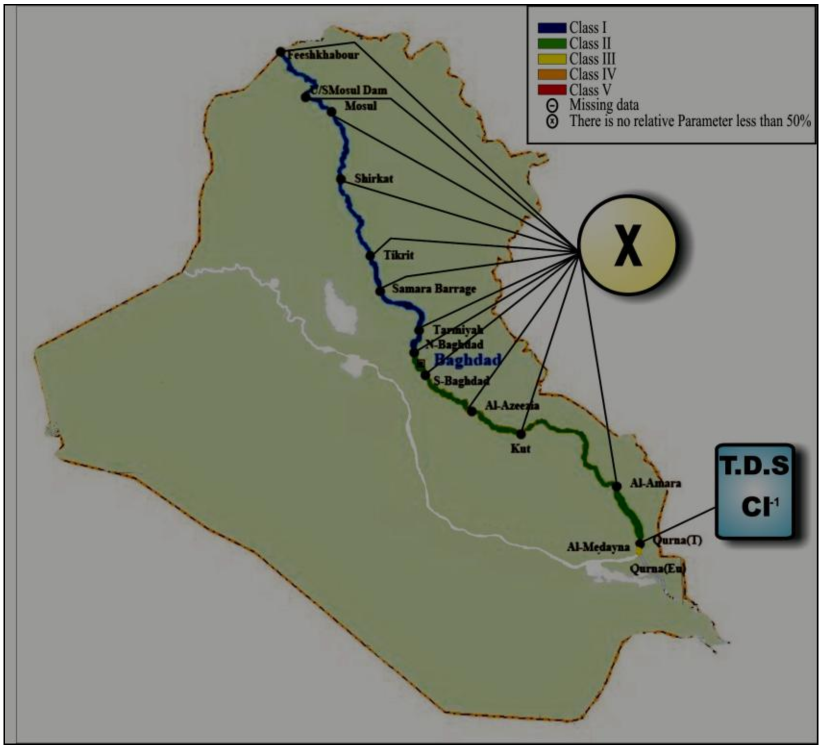


Figure (17) Average suitability map of Tigris River for irrigation use (2007/2008)

Fig. 18 represents the percentage of the deterioration of SO_4^{-2} parameter (100 - f (SO_4^{-2}) %) along the Tigris River for irrigation in 2007/2008 as one parameter from seven that affect the WQI.

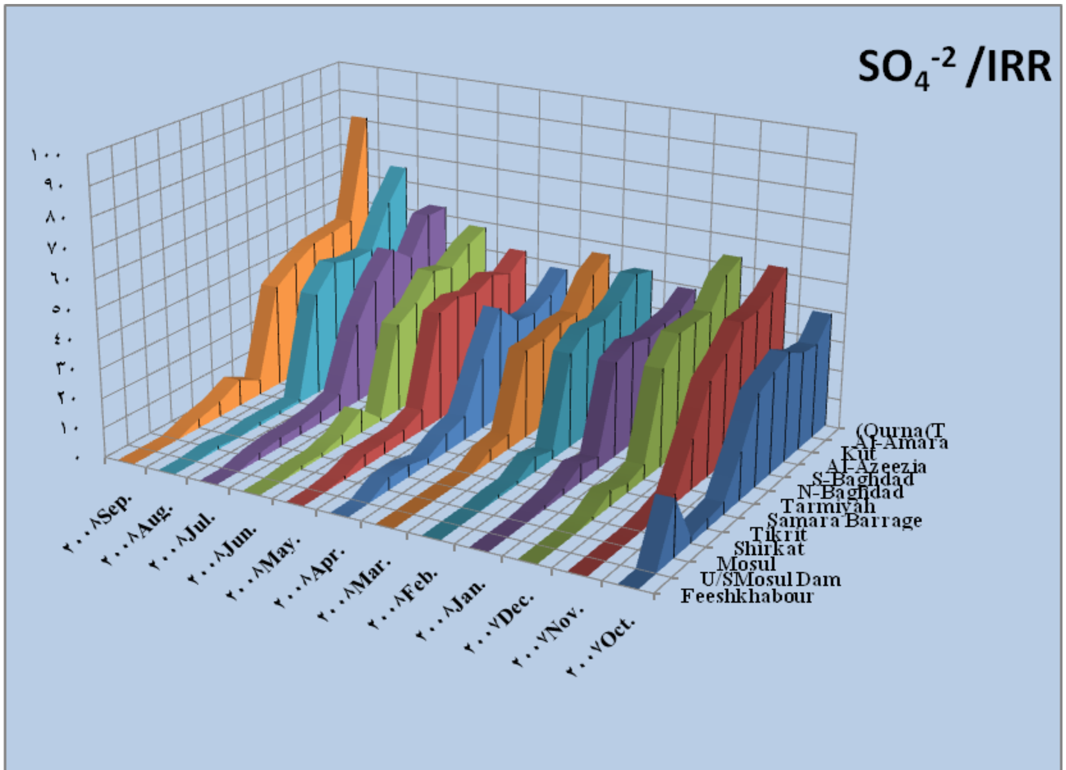


Figure (18) The percentage of the deterioration of SO_4^{-2} parameter for irrigation use

Tigris River within Feeshkhabour –Tarmiyah reach**,** in general is classified for drinking use as class II except at Tarmiyah in November, 2007 which is classified as class IV, due to T.H and pH. From Tarmiyah to Al-Azeezia, the reach is classified as class IV due to high concentration of SO_4^{-2} in addition to T.H and pH. After Al-Azeezia till Qurna, water quality is classified as class IV–V and this is mainly because of the higher increase in the relative parameters as mentioned to the sequence, T.H, SO_4^{-2}, T.D.S, pH, and, Cl^{-1}.

Fig. 19 represents the average suitability maps for the Tigris River for drinking water and shows the parameter(s) with sensitivity function less than 0.5.

Figs 20 and 21 show the percentage of the deterioration of the SO_4^{-2} (100 - f (SO_4^{-2}) %) and T.H (100 - f (T.H) %) parameters along Tigris River for drinking use in 2007/2008 as two polluted parameters from six that affect the WQI.

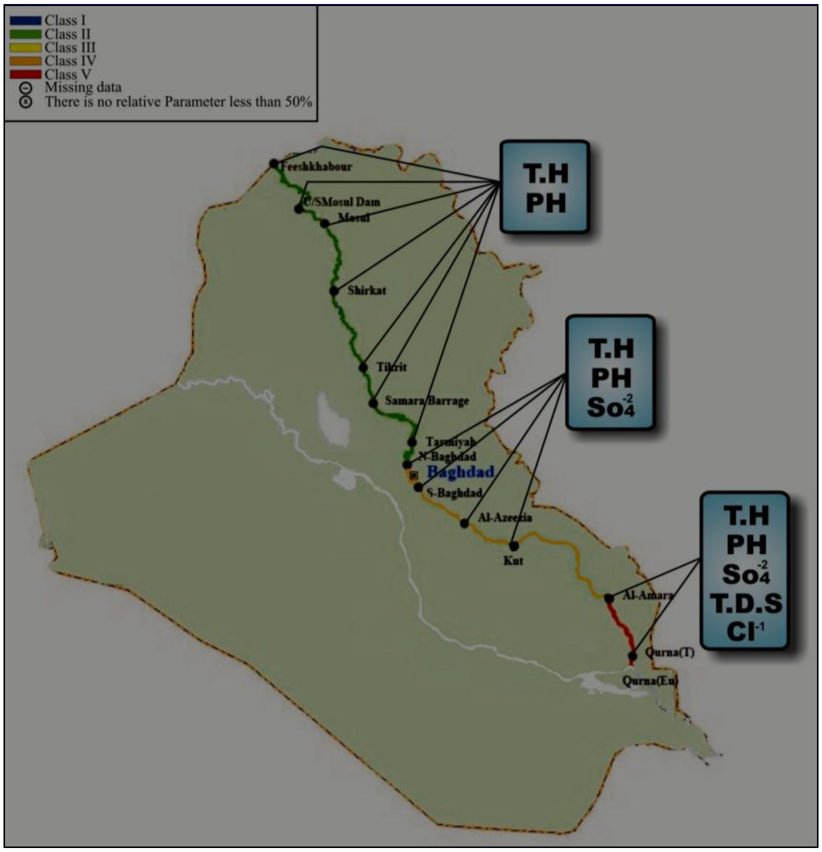


Figure (19) Average suitability map of Tigris River for drinking use (2007/2008)

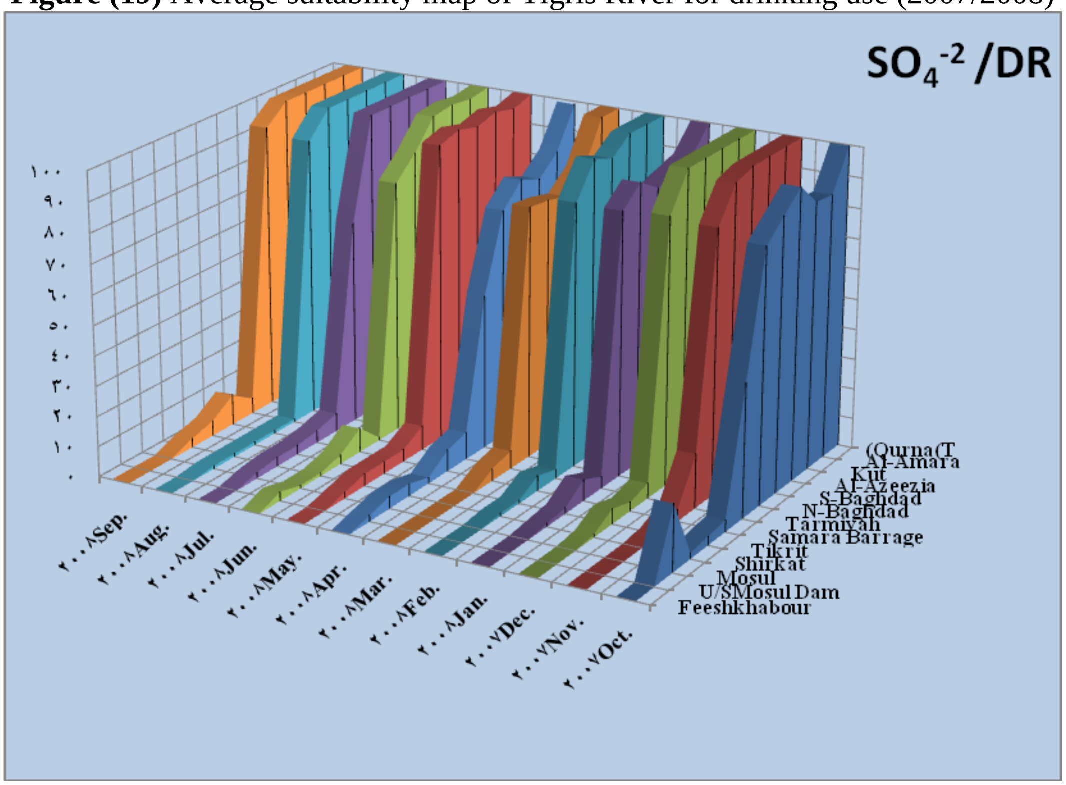


Figure (20) The percentage of the deterioration of the SO_4^{-2} parameter along Tigris for drinking use

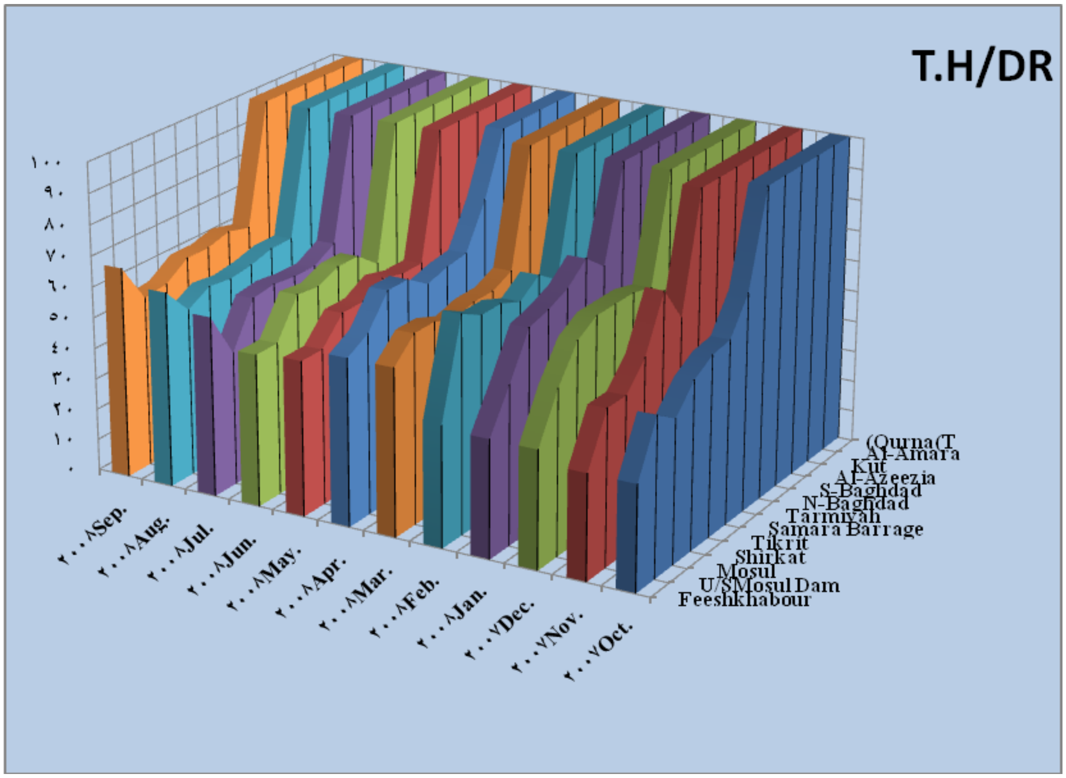


Figure (21) The percentage of the deterioration of the T.H parameter along Tigris River for drinking use

CONCLUSIONS:

- In general, WQI in the Tigris River grades for irrigation use from class I to class II, while for drinking use it is classified as class II to class V.
- In general, the deterioration in water quality along the Tigris River starts after Tarmiyah for beneficial uses due to the effect of Tigris-Tharthar arm.
- The river suitability for irrigation use is better in its classification as compared with drinking use.
- The Effect of the Total Hardness (T.H): very high concentrations which badly affects the drinking use along the Tigris and becomes worse after Tarmiyah station.
- The effect of sulfate (SO_4^{-2}) for drinking use, it can be noticed after Tarmiyah to shift WQI from class II to class IV, while for irrigation use, it can be considered an acceptable.
- The chloride (Cl^{-1}) effect on drinking use is noticed after Kut while for irrigation use it is the main cause in the deterioration in water quality in the last three months in Qurna(T) .
- In general, Calcium (Ca^{+2}) values are accepted for drinking use except in the last three months in (2007/2008) after Kut in Tigris River.
- Sodium Adsorption Ratio (SAR) and the electrical conductivity (EC) values are acceptable for irrigation use.

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