Applicability of Overall Index of Pollution (OIP) for Surface Water Quality in Assessment of Tigris River Quality within Baghdad

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ABSTRACT

Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. In this study, an attempt has been made to assess the water quality of Tigris River within Baghdad using the overall Index of Pollution (OIP) for surface water and examine the applicability of OIP for Iraqi water bodies by comparison the results with previous scientific studies conducted for the same river. Twelve parameters were considered for estimation of OIP in Tigris River. It was found that mathematical equations given by OIP developers to estimate the index does not give a precise calculations, therefor, Microsoft excel (2010) for windows was used to extract value function curves for the individual parameter. According to OIP, the river water is heavily polluted at Al-Doura WTP and Al-Rasheed WTP and the total coliform bacteria (TC) was the major factor that affects the quality of the river. Based on previous scientific studies, it was noticed that the OIP is not quite applicable in assessment of Tigris river quality and even the previous studies that were conducted for the same river and used different water quality indices, it was found that some contrarieties and variations in the results of these studies when compared between each other. Therefore, develop a unique water quality index applicable to Iraqi water bodies is of a prime importance.

Keywords: Overall Index of Pollution (OIP), Surface Water, Tigris River, WQI.

ملائمة تطبيق مؤشر نوعية المياه السطحية (OIP) لتقييم نوعية مياه نهر دجلة في بغداد

الخلاصة

أن مؤشر نوعية المياه هي واحدة من أكثر الأدوات فعالية لنقل وتوصيل المعلومات على نوعية المياه إلى المواطنين المعنيين وصانعي القرار. أشتملت هذه الدراسة الوقوف على تقييم نوعية مياه نهر دجلة في بغداد بأستخدام مؤشر نوعية المياه السطحية (OIP) وأختبار مدى ملائمة تطبيقة للمسطحات

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المائية العراقية عن طريق المقارنة مع دراسات علمية سابقة أجريت على نفس النهر. تم الأخذ بعين الاعتبار 12 متغير لحساب مؤشر نوعية المياه السطحية في نهر دجلة. وقد وجد بأن المعادلات الرياضية التي وضعها مطورا المؤشر لحساب مخرجات الدليل لاتعطي نتائج دقيقة، لذلك تمت الأستعانة ببرنامج مايكروسوفت أكسل (2010) لأستخراج قيم المؤشر لكل متغير. وفقا لنتائج مؤشر نوعية المياه السطحية (OIP)، فأن مياه النهر شديدة التلوث في محطة الدورة والرشيد لتصفية مياه الشرب حيث كان العدد الكلي للبكتريا العامل الرئيسي الذي يؤثر على نوعية مياه النهر. وبناءاً على الدراسات العلمية السابقة فقد لوحظ بأن مؤشر نوعية المياه السطحية (OIP) لاينطبق تماماً في تقييم نوعية مياه نهر دجلة. أما الدراسات العلمية السابقة التي أجريت لنفس النهر والتي أستخدمت مؤشرات نوعية مياه مختلفة فقد وجد هناك بعض الأختلافات والتناقضات في نتائجها عندما يتم مقارنة بعضها البعض. لذلك أن تطوير مؤشر جديد لنوعية المياه، خاص بالمسطحات المائية العراقية يعتبر ذات أهمية قصوى.

INTRODUCTION

Water quality indices (WQI) have been widely used in literature to evaluate the quality of such water. There are many researchers have defined the water quality index. Probably, the most common definition is, "WQI is a mathematical instrument used to transform large quantities of water quality data into a single number, which provides a simple and understandable tool for managers and decision makers on the quality and possible uses of a given water body" [1]. Other definition of WQI is, "it is a single number like a grade that expresses the overall water quality at a certain area and time based on several water quality parameters". It is also defined as a rating reflecting a composite influence, on overall quality of water, of a number of water quality parameters [2]. Thus, it is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers [3]. It, thus, becomes an important parameter for the assessment and management of water.

In recent years, the evaluation of Tigris river quality within Baghdad city has been extensively studied using different water quality indices. Al-Janabi et al. 2012 [4] have assessed the river water quality using Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) based on eleven parameters. They stated that the river has the worst quality due to effect of various urban pollutant sources. Aenab et al. 2012 [5] have considered twelve parameters for assessing the Tigris river quality using WQI with aid of C++. They conclude that all of WQI > 100 and the type of WQI is unsuitable for use. Rabee et al. 2011 [6] had used a new water quality index for environmental contamination contributed by mineral processing developed by [7]. Their study aimed at using nine ecological parameters in evaluating the quality of the Tigris River for public usage during four seasons. They concluded that the Tigris River was in class medium and the Tigris River water is relatively not suitable for direct public usage in all seasons. Alobaidy et al. 2010 [2] have also assessed the river water quality using index which was developed by [8] and they considered thirteen water quality parameters. Their results revealed that Tigris water not reached “Excellent” levels nor fallen to “Unsuitable” condition, except in occasional untreated water samples. AL Suhaili and Nasser, 2008 [9] had evaluate the river for different uses i.e. human contact use, indirect contact use and remote contact use. They stated that the river quality deteriorate south of Baghdad and the geological and hydrological conditions played the prime role relative to the agricultural and industrial activities within the catchments on the quality of Tigris river.

In the present study, the application of Overall Index of Pollution (OIP) was used to assess the Tigris river water quality. The Overall Index of Pollution (OIP) was developed by [10] for surface water quality assessment. This index was applied to Yamuna River at Delhi, India. Although, each institution, agency or researcher should to try to develop a unique water quality index applicable to that particular region and worldwide, the OIP index uses the weighted arithmetic average [11] and the modified weighted sum [12] provided the best results for the indexation of the general water quality. Similarly, the weighted geometrical average has been widely used, especially where there is a great variability among samples [13]. So that, this study aimed to (1) assess the Tigris river water quality using the OIP index, (2) find out the applicability of this index with Tigris River by comparison the results of this index with previous studies that used different water quality indices for the same river.

MATERIALS AND METHODS

Study area

The Tigris River is one of the largest rivers of the Middle East stretching for over 1,900 km, of which 1415 km are within Iraq, with a catchment area of 235000 km^2, sharing with Euphrates River as the main sources for man use, especially for drinking water since they pass the major cities in the country [14]. The Tigris River is the main river in Baghdad in which entering the city divided into two parts Karkh and Rasafa. The river water in Baghdad is used for both abstractive and in-stream purposes. The water is used as raw water source for seven drinking water treatment plants, irrigation purposes and for cooling by industries. Baghdad stretch of the Tigris River extends from Al-Fahama in the north to Al-Zafaraniah in the south before river confluence with Diyala River (Fig. 1). The length of the river within Baghdad is of almost 50 km. Baghdad, with its 6.5 million people, is considered to be the most populated and industrialized city in Iraq. The majority of its municipal and industrial wastes are discharged directly into the river without adequate treatment which makes the river water polluted [15, 16].

Overall Index of Pollution (OIP)

Sargaonkar and Deshpande, 2003 [10] have developed Overall Index of Pollution (OIP) for Surface water quality based on thirteen parameters i.e. pH, turbidity, color, dissolved oxygen, BOD, hardness, total dissolved solids, total coliforms, sulfate, nitrate, chloride, arsenic, and fluoride. Each water quality observation was scored as Excellent, Acceptable, Slightly Polluted, Polluted, and Heavily Polluted, according to Indian standards and other accepted guidelines and standards such as World Health Organization, European Community Standards and Criteria by [17].

A general classification as Excellent, Good, Slightly Polluted, Poor and Heavily Polluted water were scored in OIP. Excellent means water quality is pristine.

Acceptable needs only disinfection. Slightly Polluted requires filtration and disinfection. Polluted requires special treatment and disinfection. Heavily Polluted water cannot be used for any purpose. The OIP classification along with ranges of concentrations of these parameters is given in Table (1).

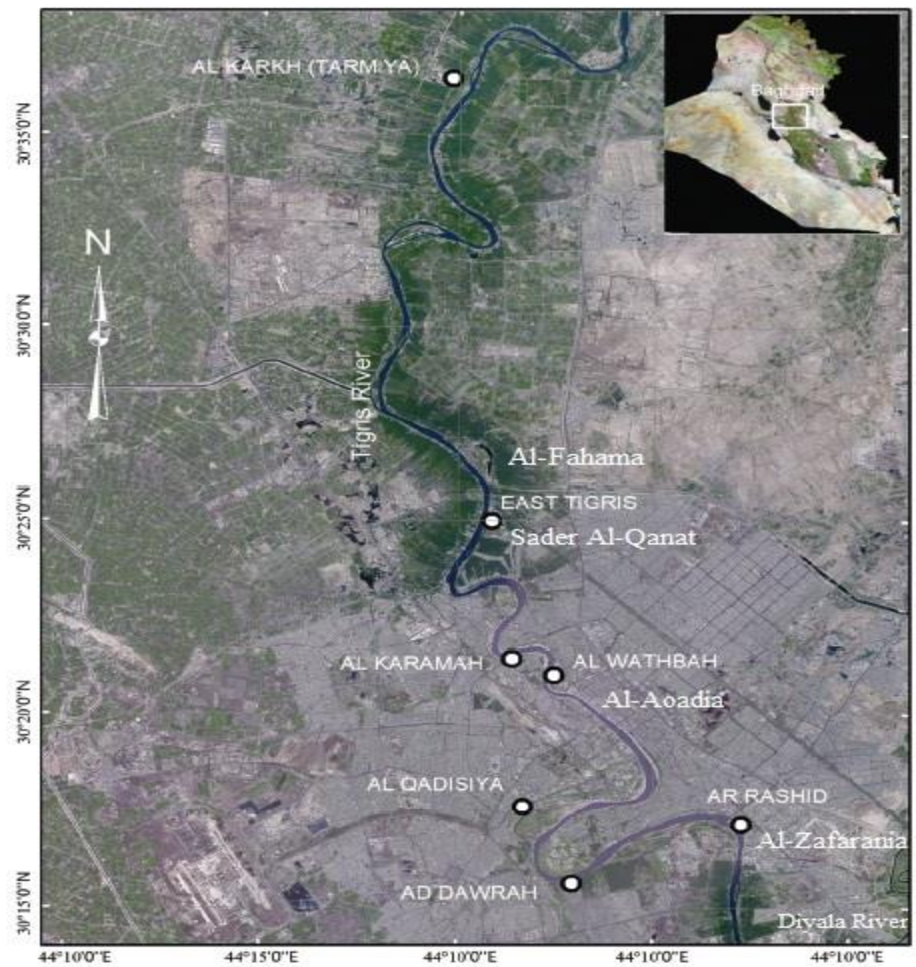

Figure (1) description of study area with sampling stations (modified from [2]).

The OIP involves an integer value which assigned to each of the classes Excellent water quality (C1), Good water quality (C2), Slightly Polluted (C3), Poor (C4) and heavily polluted (C5), in geometric progression i.e. 1, 2, 4, 8 and 16 respectively, where, the number termed as class index indicates the level of pollution in numeric terms. This forms the basis for comparison of water quality from Excellent to Heavily Polluted Table (1).

In order to obtain the numerical values it can be use the mathematical expressions for each of the parameter concentration levels called an index (P_i) indicating the level of pollution for that parameter Table (2). Figure (2) shows the value function curves of OIP. These curves give the pollution index (P_i) for individual pollutants. For any particular concentration, the corresponding index can be read directly from these curves. The index value up to 1 indicates Excellent water quality, between 1 and 2 indicates Acceptable water quality, between 2 and 4 indicates Slightly Polluted, between 4 and 8 indicates Polluted water quality and between 8 and 16 indicates Heavily Polluted water.

Table (1) Overall Index of Pollution (OIP).

Classification	**Excellent C1**	**Good C2**	**Slightly Polluted C3**	**Poor C4**	**Heavily polluted C5**
Class Index	**1**	**2**	**4**	**8**	**16**
Parameters	**Concentration ranges**				
Turbidity (NTU)	5	10	100	250	>250
pH	6.5-7.5	6-6.5 and 7.5-8	5-6 and 8-9	4.5-5 and 9-9.5	<4.5 and >9.5
Color (Hazen Unit), max	10	150	300	600	1200
DO (%)	88–112	75–125	50–150	20–200	<20 and >200
BOD_5 (20Cº), max	1.5	3	6	12	24
TDS (mg/l), max	500	1500	2100	3000	>3000
Hardness as CaCO3, max	75	150	300	500	>500
Cl, max	150	250	600	800	>800
NO_3, max	20	45	50	100	200
SO_4, max	150	250	400	1000	>1000
Total coliform (MPN), max	50	500	5000	10000	15000
As, max	0.005	0.01	0.05	0.1	1.3
F, max	1.2	1.5	2.5	6.0	> 6.0

Notes: (1) Except for pH and DO, the maximum concentration value indicated is to be included in that class (and not in the next class). (2) In case of DO, upper and lower limits are to be included in that class. (3) In case of pH, lower and upper limit of C1 are included in C1. In all other classes (C2–C5) lower limit of lower range and upper limit of upper range are included in that class, but upper limit of lower range and lower limit of upper range are excluded from that class. All values in mg/L except color, pH, TC (CFU/100 ml) and TBR (NTU) Once categorized, each observation was assigned a pollution index value and the OIP was calculated as the average of each index value given by the mathematical expression:

$$OWQI = \frac{\sum iPi}{n} \qquad \dots (1)$$

Where P_i = pollution index for ith parameter. i = 1, 2,. . ., n and n = number of parameters. The interpretation of OIP values to determine the pollution status is done on similar lines to that for the individual parameter index defined earlier.

The OIP is simple to estimate and flexible to the addition or deletion of parameters. However, comparative assessments of water quality at different places or at different times can be made only when the parameters included in the OIP are the same, and accordingly recommendations may be made regarding the specific use of water. The numerical estimate of OIP corresponds to following classes:

0–1: Excellent (Class C1).
1–2: Acceptable (Class C2).
2–4: Slightly polluted (Class C3).
4–8: Polluted (Class C4).
8–16: Heavily polluted (Class C5).

In case of Polluted and Heavily Polluted classes, more stringent measures for abatement of pollution are necessary to avoid any severe effects on human health, vegetation and aquatic life.

Data Collection

For easy comparison with previous studies, the data of this study were collected from quality control of Baghdad Water Supply Administration for the year 2004 (Table 3). Seven sampling stations were considered along Tigris River, these stations are shown in Figure (1). The analyses of water samples were done by the laboratories of the Baghdad Water Supply Administration. The routine analytical methods were used to analyze the physico-chemical and bacteriological water parameters.

Table (2) Mathematical equations of OIP for value function curves.

Parameters	**Mathematical equations**
Turbidity ≤5	x=1
5-10	x= (y/5)
10-500	x = (y + 43.9)/34.5
pH 7	x = 1

>7	$x = \exp((y - 7.0)/1.082),\ y > 7$
<7	$x = \exp((7 - y)/1.082),\ y < 7$
Color 10–150	$x = (y + 130)/140$
150–1200	$x = y/75$
%DO <50	$x = \exp(-(y - 98.33)/36.067)$
50–100	$x = (y - 107.58)/14.667$
≥100	$x = (y - 79.543)/19.054$
BOD <2	$x = 1$
2-30	$x = y/1.5$
TDS ≤500	$x = 1$
500–1500	$x = \exp((y - 500)/721.5)$
1500–3000	$x = (y - 1000)/250$
3000–6000	$x = y/375$
Hardness ≤75	$x = 1$
75–500	$x = \exp(y + 42.5)/205.58$
>500	$x = (y + 500)/125$
Cl ≤150	$x = 1$
150–250	$x = \exp((y/50) - 3)/1.4427)$
>250	$x = \exp((y/50) + 10.167)/10.82$
NO_3 ≤20	$x = 1$
20–50	$x = \exp((y - 145.16)/76.28)$
50–200	$x = y/65$
SO_4 ≤150	$x = 1$
150–2000	$x = ((y/50) + 0.375)/2.5121$
Coli ≤50	$x = 1$
50–5000	$x = (y/50)* 0.3010$
5000–15000	$x = ((y/50) - 50)/16.071$
>15000	$x = (y/15000) + 16$
As ≤ 0.005	$x = 1$
0.005–0.01	$x = y/0.005$
0.01 –0.1	$x = (y + 0.015)/0.0146$
0.1 –1.3	$x = (y + 1.1)/0.15$
F 0 –1.2	$x = 1$
1.2 –10	$x = ((y/1.2) - 0.3819)/0.5083$

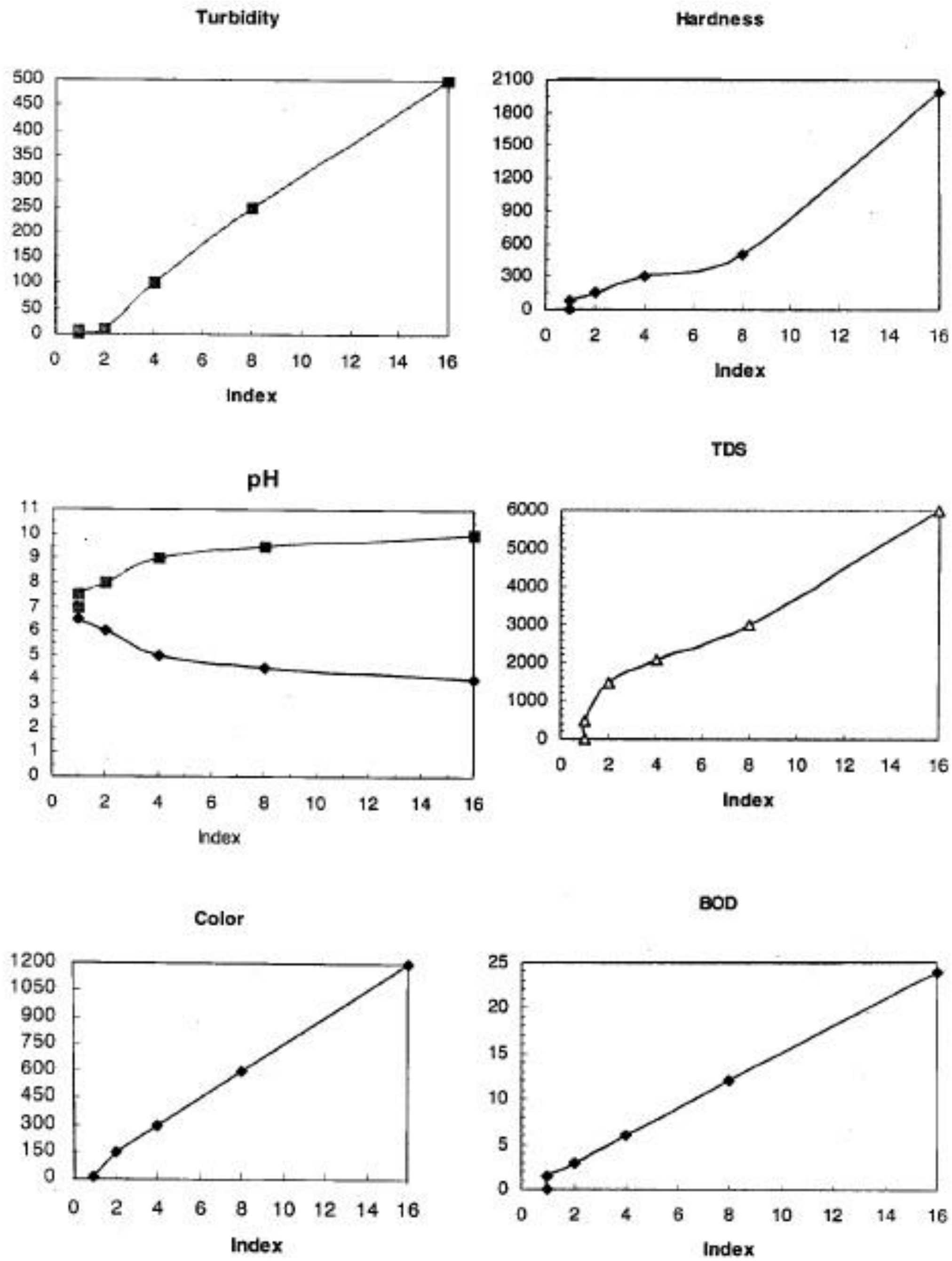

Figure (2) Value function curves for water quality parameters in the OIP.

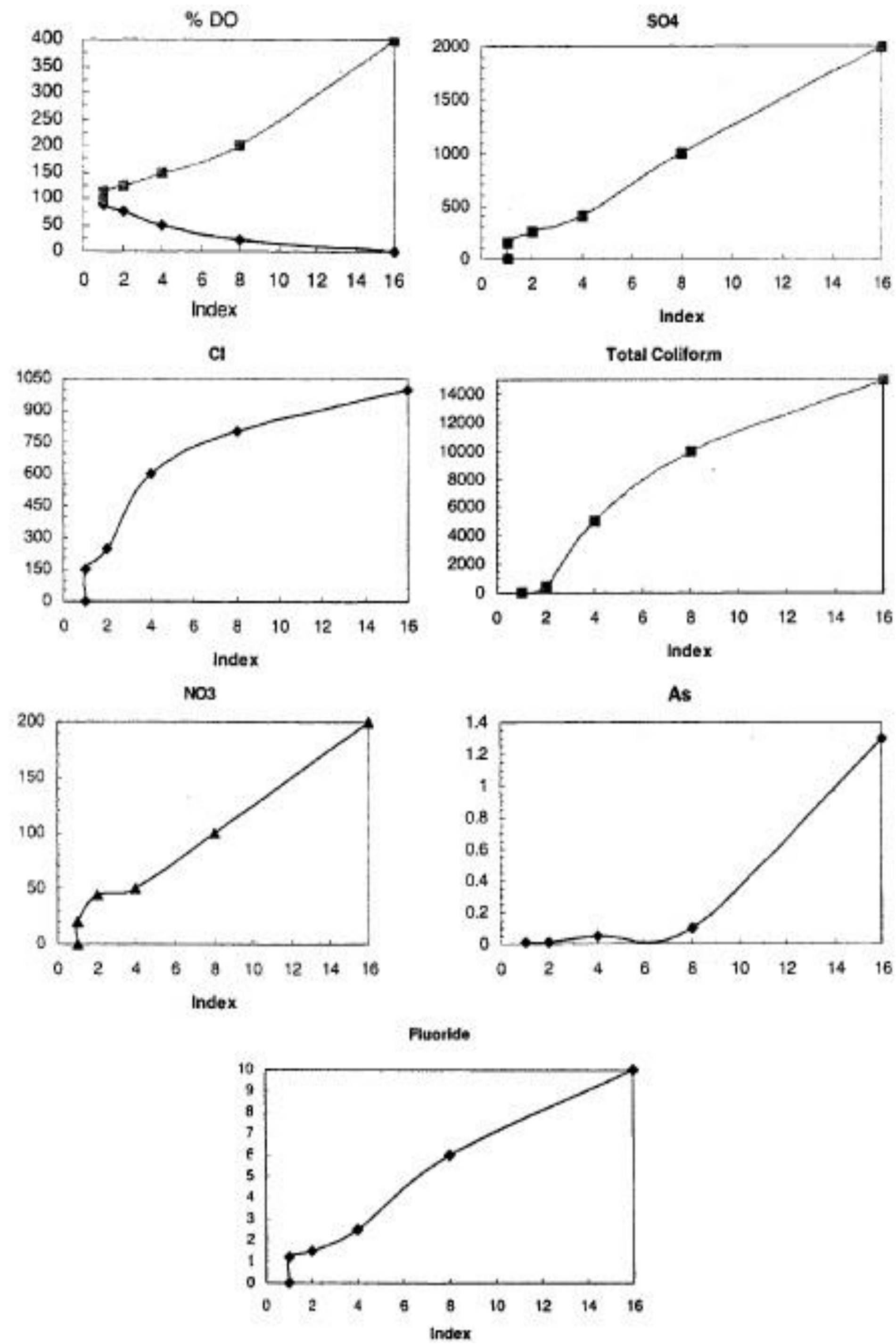

Figure (2) (Continued).

Table (3) the summary of the water quality data of Tigris River over one year (2004).

Parameters		Sampling locations						
		Al-Karkh WTP	East Dijlah WTP	Al-Karama WTP	Al-Wathba WTP	Al-Qadisiya WTP	Al-Doura WTP	Al-Rasheed WTP
Color	Min	<5	<5	<5	<5	<5	<5	<5
	Max	<5	<5	<5	<5	<5	<5	<5
	Mean	<5	<5	<5	<5	<5	<5	<5
pH	Min	7.7	7.8	7	7.7	7.9	7.5	7.6
	Max	7.9	8.1	8.1	8.1	8.1	8.2	8.2
	Mean	7.8	7.95	7.55	7.9	8	7.85	7.9
Total Hardness	Min	216	232	268	252	259	262	250
	Max	562	710	895	871	873	869	965
	Mean	389	471	581.5	561.5	566	565.5	607.5
Turbidity	Min	47.5	28	26.5	20	39	43	34
	Max	345	118	109	118	161	293	250
	Mean	196.25	73	67.75	69	94	168	142
TDS	Min	251.52	332.8	416.64	372.48	386.56	368.64	380.16
	Max	378.88	570.3	641.92	572.16	663.04	638.08	629.76
	Mean	315.2	451.5	529.28	472.32	524.8	503.36	504.96
Cl	Min	26	42	55	44	47	51	44
	Max	47	75	86	83	93	88	88
	Mean	36.5	58.5	70.5	63.5	70	69.5	66
DO (%)*	Min	60	70	72	65	72	69	77
	Max	115	110	108	98	105	109	100
	Mean	83.5	85	83.5	78	93	82	82
BOD_5*	Min	0.8	1	0.9	2.3	2.1	1.9	2.0
	Max	2.5	1.5	2.1	7.4	6.5	5.1	6.3
	Mean	1.5	1.3	1.4	4.2	4.6	3.4	4.2
SO_4	Min	69	139	157	155	141	168	148
	Max	140	210	260	275	309	292	258
	Mean	104.5	174.5	208.5	215	225	230	203
Total coliform (MPN)	Min	100	1700	1000	1000	2300	10000	2000
	Max	300	3000	13000	13000	22000	95000	130000
	Mean	200	2350	7000	7000	12150	52500	66000
NO_3	Min	0.223	0.223	0.822	0.44	0.562	0.443	0.7
	Max	0.526	0.526	1.16	3.7	0.187	0.447	0.7
	Mean	0.375	0.375	0.991	2.07	0.357	0.445	0.7
F	Min	0.09	0.1	0.14	0.09	0.08	0.08	0.1
	Max	0.14	0.22	0.25	0.24	0.16	0.15	6
	Mean	0.115	0.16	0.195	0.165	0.12	0.11	3.05

All values in mg/L except color, pH, TC (MPN) and turbidity (NTU)

* Data for BOD and DO were extracted from [18] and [6].

RESULTS AND DISCUSSIONS

Overall Index of Pollution (OIP) Output

In the present study, twelve parameters were considered for estimation of OIP in Tigris River. One parameter is missing (As), and then was neglected. The OIP is simple to estimate and flexible to the addition or deletion of parameters [10]. The results of OIP are shown in Table (4). It was noticed that mathematical equations given by [10] Table (2) does not give a precise calculations, therefor, Microsoft excel (2010) for windows was used to extract value function curves for the individual parameter and then calculate the value of OIP using equation 1.

The results revealed that the Tigris river quality deteriorate downstream of Al-Qadisiya WTP. At Al-Karkh WTP, East Dijlah WTP, Al-Karama WTP and Al-Wathba WTP stations, it can be seen Figure (3) that Tigris river water falls between (Excellent C1 to acceptable water quality C2). These water treatment plants have to give only disinfection in their treatment processes. At Al-Qadisiya WTP station, the minimum and mean values were falls between (Excellent C1 to acceptable water quality C2), while maximum values were falls in (Slightly polluted C3). Al-Qadisiya WTP needs to give filtration and disinfection in their treatment processes.

The results of OIP were much higher at Al-Doura WTP and Al-Rasheed WTP, in which the maximum and mean values falls in (heavily polluted C5). This indicates that the river water is highly polluted. According to OIP, river water at these stations cannot be used for any purpose. However, from Table 4, it can be seen that total coliform bacteria have the major impact on the quality of the river especially at Al-Doura WTP and Al-Rasheed WTP stations which makes the values of OIP higher. It may conclude that Al-Doura WTP and Al-Rasheed WTP stations require special treatment and disinfection for supplying safe water to people. Same trend were observed by [19] which concluded that the river tend to be very hard and turbid at Al-Rasheed and Al-Dora water treatment plants.

Comparison of OIP results with previous studies

As mentioned above, the OIP was developed for surface water quality based on Indian standards and other accepted guidelines and standards such as World Health Organization, European Community Standards and Criteria by [17] and was applied to Yamuna river at Delhi, India. In order to find the applicability of OIP, the results of OIP were compared with previous studies that used different water quality indices.

Alobaidy et al. 2010 [2] results have been shown in Figure 4. The scale of water quality index used is, water is excellent if the range of WQI between (0-25), good (26-50), poor (51-75), very poor (76-100) and unsuitable if WQI > 100. Alobaidy did not considered the total coliform bacteria, BOD, NO_3 and color in their index (these parameters included in OIP) and OIP does not take into account the calcium, magnesium, Iron, Aluminum and ammonia which has been considered in Alobaidy study, therefor comparison will be questionable. In general, the results of WQI of Alobaidy for the year 2004 were range from (Poor to Very Poor). Very poor class noticed at Al-Karama WTP, Al-Wathba WTP, Al-Qadisiya WTP, Al-Doura WTP and Al-Rasheed WTP.

Table (4) Individual parameter indices and OIP at seven sampling stations on Tigris river.

Parameters		Sampling locations						
		Al-Karkh WTP	East Dijlah WTP	Al-Karama WTP	Al-Wathba WTP	Al-Qadisiya WTP	Al-Doura WTP	Al-Rasheed WTP
Color	Min	1	1	1	1	1	1	1
	Max	1	1	1	1	1	1	1
	Mean	1	1	1	1	1	1	1
pH	Min	1.4	1.6	1	1.4	1.8	1	1.2
	Max	1.8	2.2	2.2	2.2	2.2	2.4	2.4
	Mean	1.6	1.9	1.1	1.8	2	1.7	1.8
Total Hardness	Min	2.89	3.05	3.58	3.36	3.45	3.49	3.34
	Max	8.55	9.68	11.17	10.97	10.98	10.95	11.72
	Mean	5.7	7.42	8.65	8.49	8.53	8.52	8.86
Turbidity	Min	2.83	2.4	2.37	2.23	2.65	2.73	2.53
	Max	10.6	4.48	4.24	4.48	5.63	9.2	8
	Mean	6.57	3.4	3.28	3.31	3.87	5.82	5.12
TDS	Min	1	1	1	1	1	1	1
	Max	1	1.07	1.14	1.07	1.16	1.14	1.13
	Mean	1	1	1.03	1	1.02	1.01	1.01
Cl	Min	1	1	1	1	1	1	1
	Max	1	1	1	1	1	1	1
	Mean	1	1	1	1	1	1	1
DO (%)	Min	2	2	2	2	2	2	2
	Max	1	1	1	1	1	1	1
	Mean	1.5	1.5	1.5	1.5	1	1.5	1.5
BOD_5	Min	1	1	1	1.55	1.4	1.25	1.35
	Max	1.7	1	1.4	4.95	4.35	3.4	4.2
	Mean	1	1	1	2.8	3.05	2.25	2.8
SO_4	Min	1	1	1.07	1.05	1	1.18	1
	Max	1	1.6	2.13	2.33	2.79	2.56	2.11
	Mean	1	1.25	1.59	1.65	1.75	1.8	1.53
Total coliform	Min	1.11	2.45	2.22	2.22	2.8	8	2.67
	Max	1.56	3.11	12.8	12.8	27.2	144	200
	Mean	1.33	2.82	5.6	5.6	11.4	76	97.6
NO_3	Min	1	1	1	1	1	1	1
	Max	1	1	1	1	1	1	1
	Mean	1	1	1	1	1	1	1
F	Min	1	1	1	1	1	1	1
	Max	1	1	1	1	1	1	8
	Mean	1	1	1	1	1	1	4.6
OIP	Min	1.44	1.54	1.52	1.568	1.675	2.04	1.59
	Max	2.6	2.345	3.34	3.65	4.943	14.888	20.13
	Mean	1.975	2.02	2.313	2.513	3.05	8.55	10.65

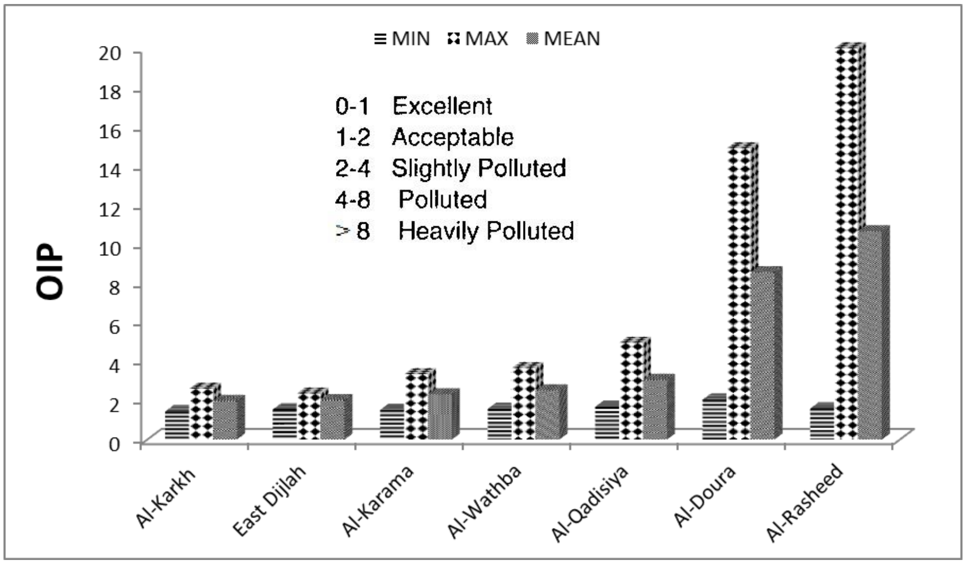

Figure (3) OIP at seven sampling stations on Tigris river.

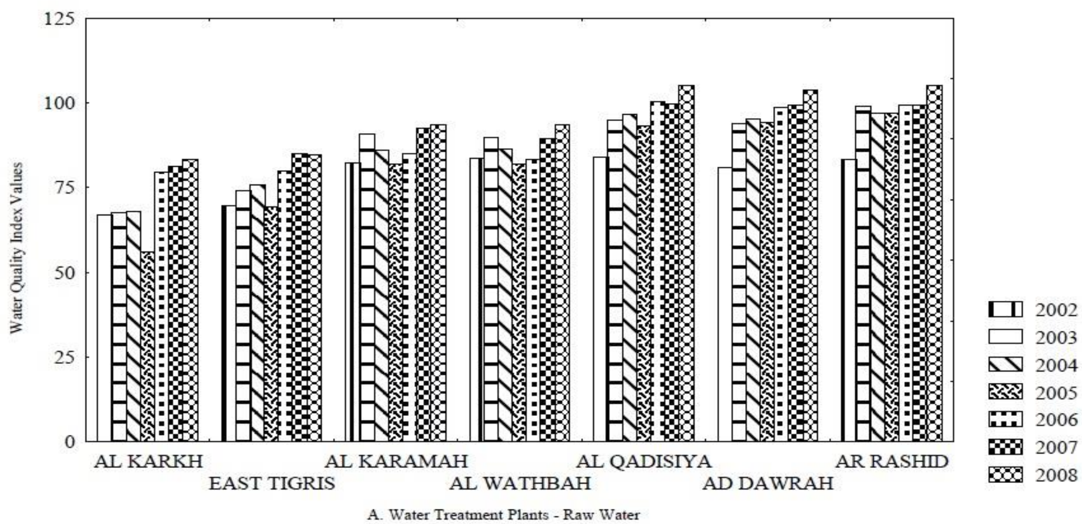

Figure (4) WQI of (Alobaidy et al. 2010) in Tigris river.

Al-Janabi et al. 2012 [4] had used Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) based on eleven parameters to assess the river water quality at three stations; Sader Al-Qanat, Al-Aoadia, Al-Zafrania see Figure (1). The CCME WQI categorization scheme is excellent if the range of WQI range between (95-100), good (80-94), fair (65-79), marginal (45-64) and poor (0-44).

Al-Janabi results have been shown in Figure (5), it can be noticed that all the stations falls under poor class. Al-Janabi did not considered parameters like DO, BOD, total coliform bacteria, color, total hardness, SO_4, chloride, fluoride. They had taken into account the heavy metals such as iron, lead, chromium.

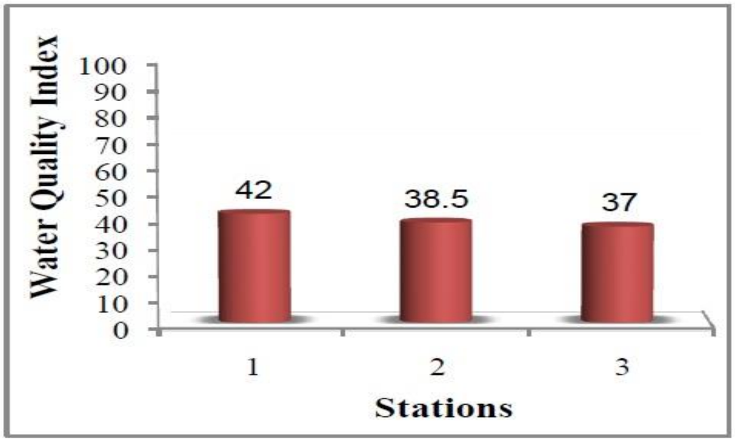

Figure (5) Average values of CCME WQI of (Al-Janabi et al. 2012) in Tigris river. Station 1: Sader Al-Qanat, Station 2: Al-Aoadia, Station 3: Al-Zafrania.

The water quality index classification of Rabee et al. 2011 [6] study is excellent (90-100), good (70-90), medium (50-70), bad (25-50) and very bad (0-24). Parameters included in this index are pH, turbidity, dissolved oxygen, BOD, total solids, total coliforms, total phosphates, nitrate, and temperature. Rabee does not calculate the WQI at each station. Their results demonstrated the calculation of overall WQI in a whole river and it was fallen under Medium class in all seasons. They concluded that the Tigris River was in class medium and the Tigris River water is relatively not suitable for direct public usage in all seasons. Nearly, all the parameters of OIP are included in Rabee index and the results might be close to OIP results.

AL Suhaili and Nasser, 2008 [9] had considered 22 parameters to calculate their WQI for Tigris river within Baghdad at three stations, namely Alkarkh WTP, Alwathba WTP and Alrasheed WTP. The overall WQI for five successive years are shown in Figure 6. All the parameters of OIP are included in Suhaili and Nasser index. By comparison the results in the year 2004, it can be found that results of OIP has similar trends in which the Tigris river is highly affected at Alrasheed WTP station other than at Alkarkh WTP, Alwathba WTP with some exception.

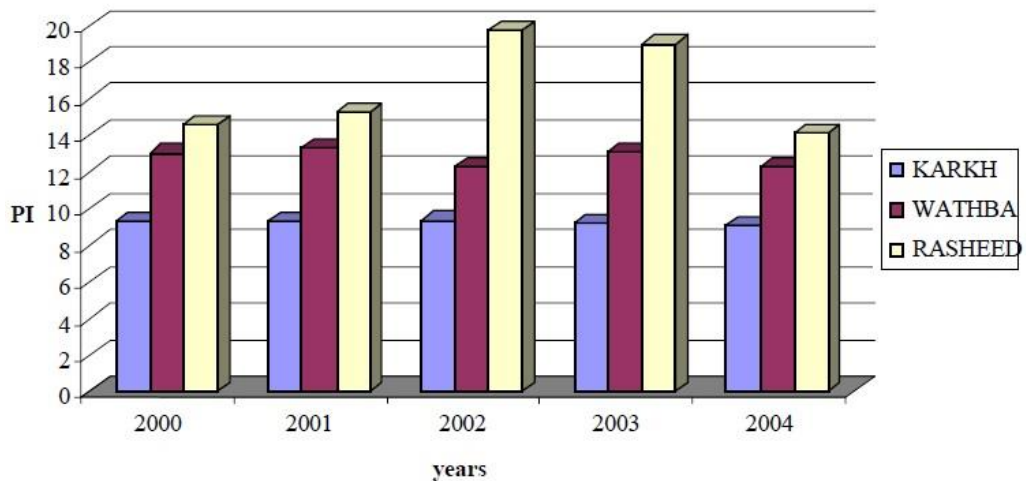

Figure (6) the overall water quality indices for the three WTPs.

The study of Suhaili and Nasser, 2008 [9] gave the best results and that is mainly due to large number of parameters included for estimation the water quality indices. Although, the result of OIP is similar to some previous studies conducted on Tigris river with some exception, it could be said that the OIP is not quite applicable in assessment of Tigris river quality. OIP need further development by considering the Iraqi standard/limits for surface water with other accepted guidelines and standards such as World Health Organization and European Community Standards. In addition to include and add more parameters responsible for deteriorate the quality of Iraqi water bodies.

It was also noticed that some contrarieties and variation in the results of previous studies which were conducted for the same river when compared between each other. Therefore, develop a unique water quality index applicable to Iraqi water bodies is of a prime importance.

CONCLUSIONS

In this study, applicability of Overall Index of Pollution (OIP) for surface water in assessment of Tigris river quality within Baghdad has been evaluated. The conclusion drawn of this study as follows:

1. According to OIP results, the Tigris river water At Al-Karkh WTP, East Dijlah WTP, Al-Karama WTP and Al-Wathba WTP stations was acceptable. These water treatment plants have to give only disinfection in their treatment processes. While at Qadisiya WTP station the river water was slightly polluted and the plant needs to give filtration and disinfection in their treatment processes. Ultimately, the river water at Al-Doura WTP and Al-Rasheed WTP stations were heavily polluted and the total coliform bacteria have the major impact on the quality of the river. These plants require special treatment and disinfection for supplying safe water to people.

2. By comparison with previous studies, it could be concluded that the OIP is not quite applicable in assessment of Tigris river quality in which OIP need further development by considering the Iraqi standard/limits for surface water with other accepted guidelines and standards. In addition, OIP also need to include and add more parameters responsible for deteriorating the quality of water.
3. Even the previous studies which were conducted for the same river, it was found that some contrarieties and variations in the results of these studies when compared between each other. Therefore, developing a unique water quality index applicable to Iraqi water bodies is of a prime importance.

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