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Evaluating Study of Tigris River Water Quality and Three Water Treatment Plants within Nineveh Governorate

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Abstract

Tigris River considers the main resource of water for Mosul city, therefore it is of great importance to evaluate its quality continuously. In this study, chemical and physical properties of Tigris River had been studied within Nineveh governorate during the year (2012) by using the average values for ten selected sites. Computing of Water Quality Index (WQI) was done by using Weight Average (WAV) method. In spite of the large amount of the wastewater disposed into the river, the results indicated that Water Quality (WQ) in all the studied sites was suitable for irrigation purposes. For drinking purposes, only the first northern four sites were in need to simple treatment, while the following remaining sites need conventional treatment. The efficiency of the three main Water Treatment Plants (WTPs) on Tigris River were computed according to a new (WQI) that include new additional parameters and different relative weights. These three plants are; Mosul new left side (WTP), Mosul right side monotheist (WTP), and Mosul old left side (WTP). The efficiency results were (70, 62, 55)% respectively. The Low efficiency of the old plant was due to the high effluent concentrations of turbidity, SO_4, total hardness, and TDS.

Keywords: Water Quality, Water Quality Index, Weighted average method, Water Treatment Plants.

دراسة تقيمية لنوعية مياه نهر دجلة وثلاث محطات إسالة رئيسية ضمن محافظة نينوى

الخلاصة

يعتبر نهر دجلة المورد الرئيسي للمياه في مدينة الموصل ، وان التقييم المستمر له أصبح من الحاجات الملحة خاصة بعد ازدياد الملوثات المطروحة نتيجة زيادة العدد السكاني. تم في هذا البحث دراسة الخصائص الكيمياوية والفيزياوية لنهر دجلة وذلك بأخذ معدل القيم الشهرية لعشرة مواقع متفرقة ضمن محافظة نينوى لعام (2012). تم اعتماد طريقة المعدل الوزني وذلك لإيجاد قيمة مؤشر نوعية المياه في كل موقع. وعلى الرغم من كثرة المطروحات على النهر فقد بينت النتائج أن نوعية مياه نهر دجلة في جميع المواقع المدروسة كانت ملائمة لأغراض الري، أما لأغراض الشرب فقد كانت المواقع الأربعة الأولى الشمالية تحتاج إلى معالجة بسيطة وتحتاج المواقع الأخرى التي تليها إلى معالجة تقليدية. كذلك تم تحديد كفاءة ثلاثة محطات تصفية رئيسية لمدينة الموصل استنادا لمؤشر نوعية مياه يضم معلمات جديدة للمياه الداخلة والخارجة منها. بينت النتائج أن كفاءة محطات تصفية المياه الرئيسية كانت (70،62،55)% لكل من محطة تصفية (ماء الأيسر الجديد، ماء الأيمن الموحد، ماء الأيسر القديم) على التوالي وأن الكفاءة المنخفضة للمحطة القديمة كانت بسبب التراكيز العالية من العكورة، الكبريتات، العسرة الكلية والمواد الصلبة المذابة الخارجة.

الكلمات الدالة: نوعية المياه، مؤشر نوعية المياه، طريقة المعدل الوزني، محطات تصفية المياه.

Introduction

Tigris River considers one of the main water resources in Iraq. It is important to evaluate its Water Quality (WQ) continuously since there are huge quantities of unwatched and unstudied spills on it. Water Quality Index (WQI) considers one of the most important assessment ways for surface and ground (WQ). This indicator has the ability to gather a huge data into a single number. (WQI) is defined as a technique of rating that provides the composite influence of individual (WQ) parameters on the overall quality of water for human consumption. One of the advantages of this indicator is, in addition to its ability to gather data in a single number, it can also shows the sanitary status for water resource[1].

There are different statistical methods in computing (WQI) like, weighted average, arithmetic weighted average, square rooted average, harmonic mean, ..etc). Most of these methods depend in their calculations on determining the divergence of the included parameters from their standard limits. Now a days there are several computer programs to determine this indicator for various purposes in a simple manner [2].

(WVA) method firstly adopted by (McDuffie and Haney, 1973) [3]. Then it had been adopted in a wide range in many national studies [4,5,6]. Each parameter given a relative weight (wi) according to its importance, but the sum of these relative weights mustn't exceed one. The quality rating scale (qi) was computed by using the following equation:

qi= (Ci/ Si) × 100 ………..……………………(1)

where (Ci) represents the concentration of its parameter, while the symbol (Si) represents the depended standards. Then the sub index (SIi) of ith parameter could be computed by multiplying the relative weight by quality rating using the equation:

SIi = wi × qi……………………………………(2)

Then (WQI) could be easily computed by summation of sub-index as in the equation:

WQI=∑SIi ……………………………………..(3)

Studied Area

The studied area included large sector of Tigris river, starting from the front of Mosul dam to Al-Qayarah town, with a length increase somewhat than (100) km. Ten sites with unequal distances were selected along this length. The distances between sites before and after Mosul city were longer than those located inside it,. These sites are named as follows: The front of Mosul dam, Badoosh, General hospital, Old Bridge, Hurriyah Bridge, Fourth Bridge, Yaremga, Al-Bouseif, Hammam Al-Aliel, and Al-Guyyara site, Figure (1).

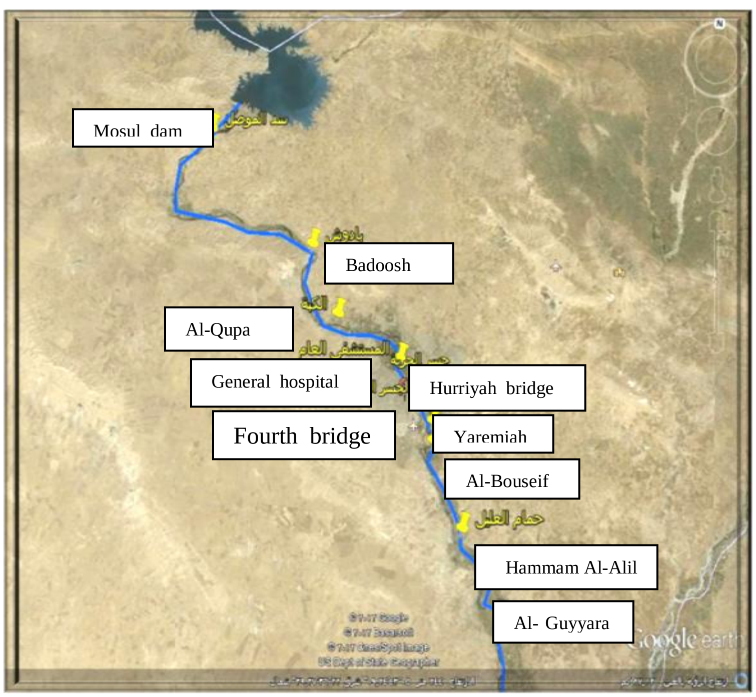

Fig. 1. The ten selective sites under study

Methodology

In this study, chemical and physical properties of the samples taken from ten selected sites along Tigris River within Nineveh governorate during one year (2012). The average monthly values of each parameter were adopted at each site, Table (1). In order to insure the pollution points doesn't affect the raw water samples and the dispersion takes somewhat its time, the selected samples were taken at sites far away from the pollution points in along distance.

The samples had been tested in the college of environmental sciences and technology laboratories according to standard methods (APAH, 1985) [7]. (WAV) method was adopted to compute (WQI).

Each parameter is given a relative value according to its impact to the river (WQ). The (Iraqi standards, 2001)[8], and the World Health Organization (WHO,2006)[9] standards were adopted for the parameters which aren't included in the local one. The relative weight of each parameter and its standard limits are listed in Table (2). (WQ) classification and the ranges of the computed (WQIs) are listed in Table (3). In order to indicate the Tigris (WQ) suitability for irrigation and drinking purposes, House classification (House, 1989) [10] were adopted, Table (4).

Table 1. Data of the average monthly concentrations of parameters at ten sites

Parameter	Unit	1	2	3	4	5	6	7	8	9	10
PH	--	7.78	7.79	7.83	7.83	7.79	7.8	7.88	7.88	7.8	7.84
Total Hard..	mg/l as $CaCO_3$	231	239	236	234	246	240	247	247	238	248
Chloride	mg/l	30	32	31	32	33	33	34	34	34	33
Na	mg/l	11	9.5	8	8	8.5	8.9	11	11	11	9.7
SO_4	mg/l	61	57	60	60	108	66	67	67	63	66
TDS	mg/l	231	289	293	294	373	288	294	294	300	293
Ca	mg/l	53	51	49	51	58	49	47	47	50	52
Mg	mg/l	24	29	27	30	27	29	56	56	30	29
NO_3	mg/l	1.4	1.6	1.6	1.8	2.4	2.5	2.8	2.8	0.2	3.1
D.O	mg/l	8.54	8.26	7.9	8.1	8.28	8.08	8.08	8.08	7.7	7.8
PO_4	mg/l	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Total Alkalinity	mg/l as $CaCO_3$	155	157	153	158	157	158	159	159	161	160
EC.	µmos /cm	445	460	469	471	581	472	478	478	483	480
Turbidity	NTU	8	9	11	11	7.7	9	8	8	10	15
Temp.	^0C	16	18	16	16	17	16	18.4	18.4	18	18

Table 2. The relative weight of parameters and it's limits

No.	Parameter	Unit	Relative weight	Standard limits
1	pH	-------	0.08	6.5-8.5
2	Total Hardness	mg/l as $CaCO_3$	0.05	300
3	Chloride (CL)	mg/l	0.06	250
4	Na	mg/l	0.06	200
5	SO_4	mg/l	0.07	400
6	TDS	mg/l	0.09	1500
7	Ca	mg/l	0.05	200
8	Mg	mg/l	0.05	150
9	NO_3	mg/l	0.07	40
10	D.O	mg/l	0.08	5
11	PO_4	mg/l	0.05	0.4
12	Total Alkalinity	mg/l as $CaCO_3$	0.07	200
13	EC	µmos /cm	0.06	750
14	Turbidity	NTU	0.09	25
15	Temperature	^oC	0.07	25

Table 3. (WQI) Classes used by (WAV) method

WQ	Excellent	Good	Poor	Very Poor	Bad
WQI	0-25	26-50	51-75	76-100	>101

Table 4. House Classification of (WQ) for drinking and irrigation purposes

Class	Kind of needed treatment for drinking purpose	Kind of needed treatment for drinking purpose
I	Disinfection only	Suitable
II	Simple treatment	Suitable
III	Conventional treatment	Suitable
IV	Advanced treatment	Advanced treatment
v	Unsuitable	Unsuitable

The Efficiency Indicator

A new indicator named, the efficiency indicator, is used to compute the efficiency of three chief Water Treatment Plants (WTPs) located nearby (Al-Qupa site) in the north of Mosul city. They have different names and capacities, Table (5). The efficiency indicator has the same depended method in its calculating with the ordinary (WQI), but the only difference between them is that, the efficiency indicator has anew additional parameters with different relative weights. These inserted parameters have impacts on the human health such as (E.coli bacteria, residual chlorine, and aluminum ions). The above parameters are inserted since they have an adverse proportional with their disinfected efficiency [11].

These parameters, are given different relative weights proportional with their impacts to the public health, Table (6). The efficiency indicator can be easily computed as follows:

WTPs Efficiency Indicator = [(WQI raw–WQI treated) / WQI raw]×100……………………..(4)

Table 5. The effluent discharge capacity of the three chief (WTPs)

No.	WTP name	effluent capacity (m^3/day)
1	Mosul new left side	365000
2	Mosul right side Monotheist	228000
3	Mosul old left side	200000

Table 6. Parameters and its relative weights used in computing the efficiency indicator of the three (WTPs)

No.	Parameter	Unit	Relative weight	limits
1	Turbidity	NTU	0.10	5
2	Temperature	ºC	0.07	25
3	pH	None	0.07	7.5
4	EC	µmos/cm	0.06	750
5	Total Alkalinity	mg/l as $CaCO_3$	0.07	200
6	Total Hardness	mg/l as $CaCO_3$	0.05	300
7	Ca	mg/l	0.05	200
8	Mg	mg/l	0.05	150
9	TDS	mg/l	0.08	500
10	Al	mg/l	0.07	0.2
11	Na	mg/l	0.05	200
12	E.coli	MPN/100ml	0.1	2
13	Residual Chlorine	mg/l	0.08	0.5- 4.0
14	SO_4	mg/l	0.04	400
15	NO_3	mg/l	0.06	20

The Previous Studies

Status of Tigris river had been covered by many researchers [12,13,14]**.** The studies of the other researches and the historical development of (WQIs) are explained with some details below. Most of the researchers explained the suitability of Tigris River at selected sites for different purposes by determining the changes of the effective parameters concentrations and comparing them with the nationally accepted limits, or by using deferent indicators developed by the time.

(Horton, 1965)[15] considers the first one who used (WQI), then (Brown *et. al.*, 1970) [16] developed the Horton's method by using sensitive scales. They canceled the trace elements from the parameters in computing (WQI) since they reduce the indicator to zero level.

(Naauum, 1985)**[**17] studied the specific characterizes of Tigris river within Mosul City, and he indicated how much the pollutants spills affects it's quality. He concluded that the Tigris river water was unsuitable for swimming at some of its sites since there are huge numbers of E.coil bacteria.

(Al-Ani,1988)[18] studied Tigris (WQ) within Baghdad City by using geometric mean method. He classified the quality of this river as a first class for agricultural purposes, and a third for both drinking and industrial purposes.

(Shihab and Al-Rawi,1994)[19] studied Tigris (WQ) within Mosul City for (20) km long. They concluded that the quality of this river classified within the excellent class for irrigation and within the first class for both aquatic life and industrial purposes.

(Al-Huseen, 1998)[20] studied Tigris (WQ) for (17) section, starting from the north of Mosul City until Hammam Al-Alil. She arranged (WQ) of Tigris River within Mosul City as an excellent order for irrigation, and good for industrial, but in the last for human uses.

One of the studies about the assessment the efficiencies of (WTPs) within Mosul city, is the study covered by (Matee and Hekmat, 2007)[21] . They studied the efficiency of Sallammeia (WTP). The assessment of the efficiency done by the comparing the outer and inner (WQ) of this plant during one year (2004). They concluded that, the efficiency of the plant ranged between (42-62)%. The reasons which they gave about this reduction in the efficiency belongs to the increasing of turbidity in the rainy season, and such small plant has not the ability to deal with high turbidity.

Results and Discussion

Figure (2) show the computed (WQI) at sites which selected in this study. The relative decreases in (WQ) were detailed in Table (7). (WQ) in the front of the dam assumed to be the base which assumed it's (WQ) is (100)%. From this assumption, each site comes later has relative reduction or increase in quality according to this base. (WQ) at each site which listed in Table (7) shows the following:

It is clear that (WQ) in the front of Mosul dam site is considered good, but its quality doesn't reach the optimum value. This was due to the large number of the non-point agricultural disposed into the dam lake producing a high Turbidity. Figure (3) shows the yearly average turbidity values at four sites reaches twice the standard value of (5) NTU.

There is a slight relative decrease of about (1.2) % in the (WQ) at Badoosh site comparing with the front of the dam site. This is due to the discharges of Badoosh cement factory which causes high concentration of (TDS) and Turbidity.

There is a relative decrease in (WQ) of about (2.4)% (before the general hospital site) comparing with the site at the front of the dam. This is due to the high concentrations of SO_4, TDS, and the reduction in Dissolved Oxygen (D.O) concentration. The high concentration of these parameters is probably due to the high number of the buffaloes which they distributed at many fore sites.

The relative decreases in (WQ) is about (3.9)% at the fourth site (before the old bridge) due to the hospitals spills, and the municipal waste water point spills. These sources contain high quantities of organic matter which responsible for the depletion of (D.O).

There is a relative decrease in (WQ) at the fifth site comparing with the site just before it. This decline in (WQ) is belong to the presence of high concentration of (Total Hardness, TDS, SO_4, NO_3 and a considerable decrease in D.O). Mixing of Al- Koser stream with the main river before this site in a distance not far away was the main reason of these high concentrations. Moreover, the presences of several other municipal spills before this site cause more reduction in quality. The short distance between this site and the previous one, however, didn't give enough time to the river to be recovered.

At the sixth site (before the Al- Hurriyah bridge), no changes in quality had been seen since there is no pollution spills on it.

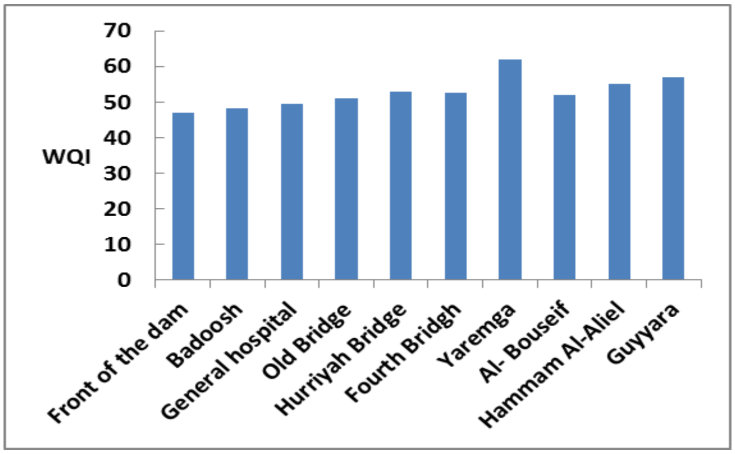

Fig. 2. The computed (WQI) at each site

Table 7. Results of the computed (WQI) and (WQ) of the river at each site

No.	Site	WQI	WQ	Relative Reduction in WQ (%)
1	Front of Mosul dam	47.0	Good	0
2	Badoosh	48.2	Good	1.2
3	General hospital	49.4	Good	2.4
4	Old Bridge	50.9	Good	3.9
5	Hurriyah bridge	52.8	Poor	5.8
6	Fourth bridge	52.5	Poor	5.5
7	Yaremga	60.0	Poor	13
8	Al-Bouseif	52.0	Poor	5.0
9	Hammam Al-Alil	55.0	Poor	8.0
10	Al-Guyyara	57.0	Poor	10

The results indicated that there is a sudden decrease (about 13%) at Yaremjah site. This is because of being this site is not far away from pollutant discharges of Al-Danafelly valley wastewater. Another reason for this deterioration at this site could be due to the water erosion to the low level organic clayey river banks that is rich in phosphate concentration which always releases from the clay sedimentation layers as shown in Figures (3, 4, 5).

The eighth site (Al-Bouseif), gave a relative improvement in (WQ) since there is a long distance between this site and the previous one which consequently gave enough time for the aeration and self-purification of the river.

Hammam Al-Alil site gave relative decrease in the (WQ) (about 1%) comparing with (Al-Bouseif) site. This is because of the wastes coming from Hammam Al-Alil cement Factory, Table 1.

There is a relative decrease in (WQ) about (10%) at Al-Guyyara site comparing with the first one (the front of the dam) is due to the huge pollutant components coming from Al-Guyyara refractory including SO_4, EC, TDS and Turbidity, Figures (3) and (4).

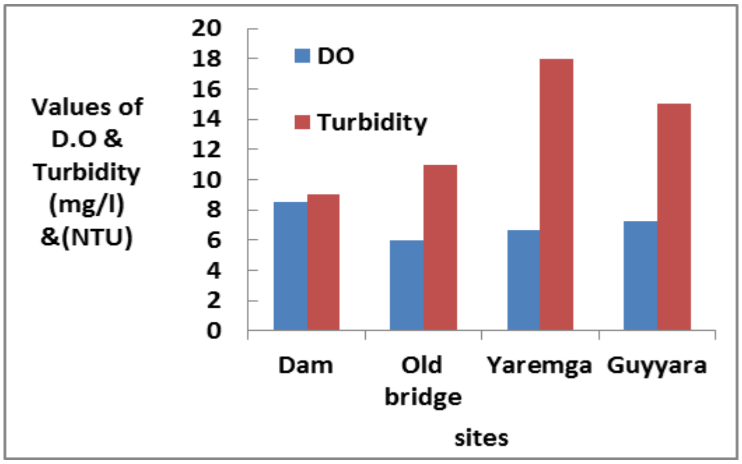

Fig. 3. Concentrations of Turbidity and (D.O) at four affected sites

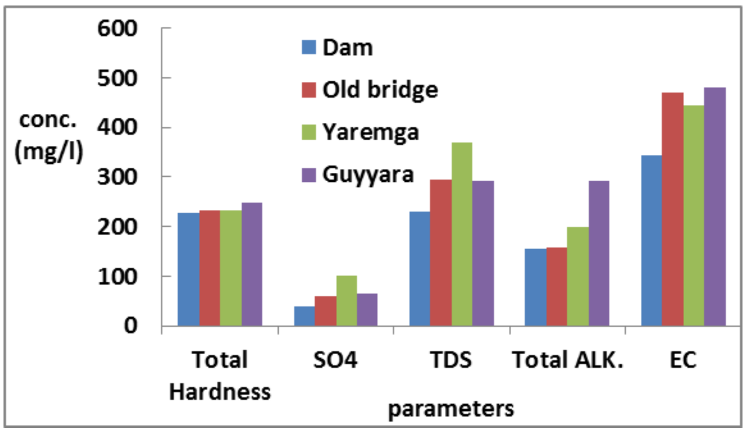

Fig. 4. Concentrations of some effective parameters at four affected sites

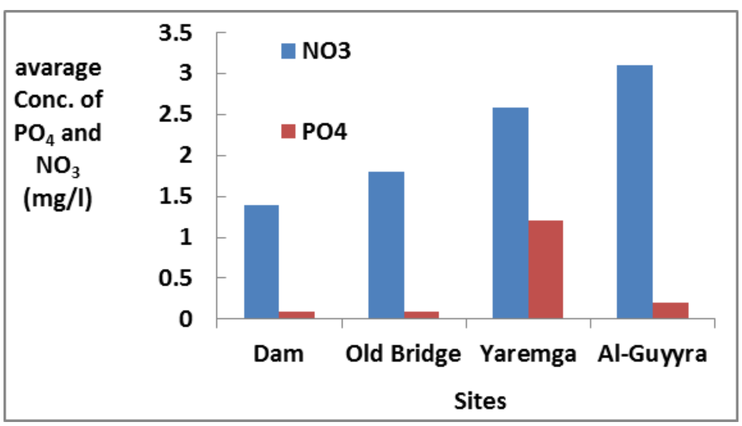

Fig. 5. Concentrations of the NO_3 and PO_4 at four different affected sites

From Figure (3), there is an inverse relationship between turbidity and (D.O) at all sites, since the viscosity of turbid water is more than the fresh, so the aeration has less chance to solute more oxygen such as this water.

Two observations were noticed in analyzing the data listed in Table (8), the first notice, the effluent water from Mosul old left side (WTP) has somewhat low pH values. This is due to the high addition of alum and chlorine to decrease the relatively high value of turbidity. Values of pH and turbidity at the three (WTPs) were shown in Figure (6). The addition of these components causes an acidic impact. The 2nd one, the efficiency indicator results show that Mosul old left side (WTP) gives water with bad quality since there are high concentrations of TDS, SO_4, and Total Hardness from its effluent as shown in Figure (7). This is because of the old filters in this plant.

An important notice could be shown from the data Table (1), there are an inverse relationship between DO and PO_4 ions concentration, especially at the lasts two site. That is belonging to the increase of soluble form of PO_4 ions as long as the DO is depleted. This is accepted with the study of (safawe *et. al*, 2008) [22].

Table 8. Average monthly concentration of some effective parameters from the effluents of the three WTPs

WTP name	pH	Turbidity NTU	SO_4 mg/l	TDS mg/l	Total Hardness mg/l as $CaCO_3$	Efficiency Indicator (%)
Mosul new left side	8.2	3	15	250	214	70
Mosul right side monotheist	7.7	3.5	22	300	300	62
Mosul old left side	6.9	5	26	390	390	55

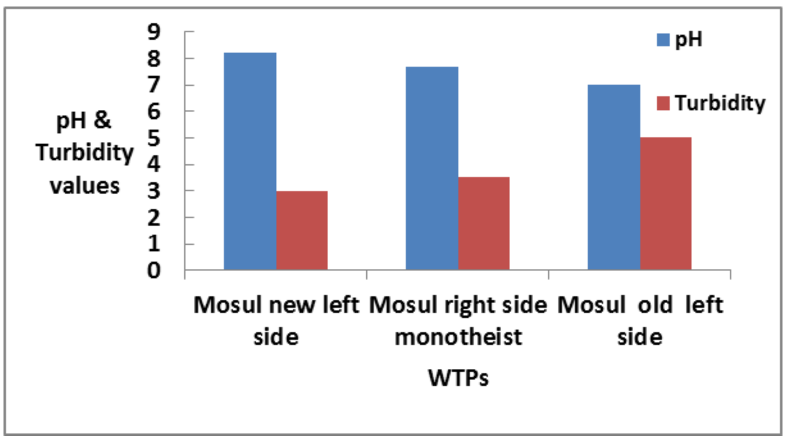

Fig. 6. Turbidity and pH values at the effluent of the three (WTPs)

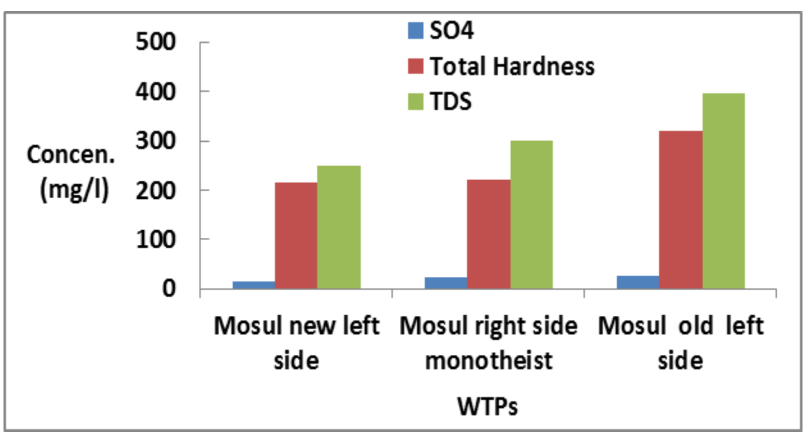

Fig. 7. Conc. of some effective parameters at the effluent of the three (WTPs)

Conclusions

According to the comparison between the results of (WQIs) at each site with House classification, which listed in Table (4), the following observation could be pointed:

1. (WQ) at all studied sites were suitable for irrigation purpose without need to any treatment.
2. The first four sites need simple treatment in case drinking purpose, in the other hand, the remaining sites needs for conventional purposes for this purpose.
3. For a general look on the selected parameters, one can sort the main responsible parameters which reduce the quality. They are: TDS, SO_4, Tur., Total hardness, EC, PO_4, and (D.O).
4. In spite of, the large disposal of pollutant along the river, the computed difference in (WQ) between the first site and the last one was not more than (10)%.
5. Mosul new left side (WTP) efficiency was the best (70)%. Mosul right side Monotheist (WTP) efficiency comes in the second (62)%, while Mosul old left side (WTP) was the worst one (55)%.
6. The high concentrations of TDS, SO_4, and Turbidity were the main important responsible parameters reducing the efficiency indicator in the third (WTP).

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