Water quality assessment in terms of water quality index (WQI): A case study of the Tigris River, Baghdad, Iraq

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Abstract. This work deals with the monitoring and assessment of water quality of the Tigris River within Baghdad. Samples were taken monthly from September 2018 till August 2019 for a year, from eleven sites in Baghdad city. The National Sanitation Foundation Index (NSF-WQI) values of river water deteriorated from “medium” to “bad” to “very bad” in almost all the eleven sampling sites. The water quality is found to be most deteriorate during the summer season with an average NSF-WQI value of 34.9 as compared to spring, winter and autumn seasons, having an average NSF-WQI value of 40.8, 43.1 and 44, respectively. Out of the eleven sampling sites, Al-Wathba site (S7) and Al-Rasheed site (S11) is observed to be the most polluted sites. The metal pollution index (MI) model is categorized the water quality of the Tigris as seriously affected where the Iron (Fe) and Lead (Pb), are prominent parameters and most deteriorated in this model. Based on these indices, it is concluded that industrial facilities, city wastewater and intensive communities that living along the river bank are negatively affecting the water quality of the Tigris River.

Keywords: Water Quality Index, River Pollution, NSF-WQI, MI-WQI and Tigris River.

1. Introduction
The rapid increase in population density and industrial activities, urban activity in the basin of the river, discharge of rural, urban and industrial wastewater, excessive consumption of chemical fertilizers, solid wastes and pesticides has a continuously increasing trend is the main source of river pollution [1][2]. Surface water contamination is an obvious form of pollution. The trash from human consumption, such as plastics, water bottles and other waste products is often evident in water pollution that significantly degrades water quality [3].

The maintenance of safe and clean water sources will encourage the existence of an appropriate water body of living the organisms that required high-quality water quality. According to this concept, determining the factors through which water quality can be identified is important for diagnosing the quality, condition and level of water pollution, and because of the large number of factors and variables through which water quality can be recognized and overlapping among them, it has become necessary to find scientific methods to interpret the huge amount of data on water quality to be easy to understand and clear and give quick results without the need to go into the interpretation of factors and variables indicating water quality separately, so the simplest ways to assess the state of water quality are used water quality indices (WQIs),[4][5].

Alobaidy et al. [6] had used water quality index (WQI) and cluster analysis (CA) based on thirteen parameters to evaluate the Tigris river water quality at seven stations. Concluded in their study that there are the needs for intensive studies on WQI and also the needs more consideration of the water treatment plants along Tigris river for years to come. Hadi [7] applied the Canadian and Bhargava methods for calculating WQI in Tigris River. The study results revealed that water quality classification according to Bhargava is more appropriate than the water quality classification according to the Canadian method. Ismail [8] have studied the use of a overall index of pollution (OIP) for the prediction of water quality parameters in Tigris river. He selected seven sites along the river to
be used for samples collection within Baghdad city. OIP-WQI values of river water deteriorated from “acceptable” to “slightly polluted” to “heavily polluted” in almost all the seven sampling sites. However, it was noticed that the OIP is not quite applicable in assessment of Tigris river quality. Ewaid et al. [9] find the WQI for Tigris River water quality within Baghdad, for 10 different sites, and concluded that the water is unsuitable for drinking at almost all the sites of sampling. They proved WQI is an important tool for the assessment of water quality. Al-Mayah and Rabee [10] utilized the water quality index to evaluate the degree of pollution for Al-Gharrar Rivers, where revealed results that the river is not suitable for use as drinking water without elaborate treatment, poor for aquatic life protection and fair for irrigation. Banda and Kumarasamy [11] used various physical, chemical and biological parameters for developing a universal water quality model for South African river catchments. The study revealed that WQIs cannot evaluate the quality of water for all the applications but they are customarily developed to accommodate specific water quality parameters. According to Zotou et al. [12] WQIs are particularly useful tools, in the direction of the qualitative evaluate of aquatic systems, as they provide the opportunity to evaluate existing quality conditions by classifying water bodies into certain quality categories. Al-Mayah [13] found that NSF-WQI is an effective model to assessment drinking water quality and it presents an exact, rapid and modern method to evaluate and monitor the water quality in treatment plants.

In this study, two water quality indices (NSF-WQI & MI-WQI) were used along with the extent of the Tigris River in Baghdad city for evaluate the condition of water quality, based on the available physical, biological and chemical parameters for one year. And also, to generate pave ways for future management and action plans that can be used by the public and decision makers to protect the water resources.

2. Materials and methods

2.1. Study area and Sampling analysis

This research is conducted in the Tigris River, which is the largest rivers in the Middle East, stretching for over 1900 km, of which 1415 km are within Iraq. Eleven sites were selected for this study namely Al-Karkh (Site.1), Sharq Dijla (Site.2), Al-Sader (Site.3), Al-Baldiat (Site.4), Al-Kadhimiya (Site.5), Al-Karama (Site.6), Al-Wathba (Site.7), Al-Qadisiya (Site.8), Al-Dora (Site.9), Al-Wahda (Site.10) and Al-Rasheed (Site.11), these sites were chosen to cover all the distance of Tigris River within Baghdad city is about 110 km, as presented in Figure (1). Monthly samples were collected from these sites from September, 2018 to August, 2019 for a year, by using clean polyethylene bottles and it was preserved in ice box and analyzed in the laboratory. Physical, chemical and biological properties were determined by Standard methods of American Public Health Association [14], in the central environmental laboratory within 24hrs with three replications per sample.

2.2. Calculate NSF-WQI.

NSF-WQI is a mathematical model used to determine of the water quality based on the results nine parameters such as: pH, DO, BOD5, NO3, PO4, TSS, turbidity, temperature and fecal coliform. The model’s value calculates manually by following equation that proposed by Abbasi and Abbasi [15]:

\[
WQI = \sum_{i=1}^{n} Qi.Wi
\]

Where: Qi= Quality parameters (value of 0 to 100), Wi= Unit weighting parameter (value 0 – 1); n=Number of parameters as presented Table 2. The values of Qi and Wi can be calculated from formula proposed by Al-Mayah [16].

Furthermore, can calculate the model’s value by following link online: http://www.water-research.net/watrqualindex/index.htm. Finally, the water quality of the Tigris River is classified according to USGS [17], as shown in Table 1.
2.3. Metal pollution Index (MI-WQI)

The MI-WQI model is intended to point out drinking water contamination level. Caeiro et al.[18] applied maximum allowed concentration (MAC) in assessing the value of MI-WQI model and expressed by following equation:

$$MI = \sum_{i=1}^{n} \frac{Ci}{(MAC)i}$$

Where, MI: Metal Pollution Index, Ci: Mean concentration of each metal, Table (8), and MACi: Maximum allowed concentration of each studied metals, as presented Table (8). Moreover, to assess the water quality of the Tigris River for drinking water, the value of MI model can be divided into six categories Table 2.

![Figure 1: All Sampling Sites in Tigris River in the Baghdad City.](image)

### Table 1: The illustrated the NSF-WQI categories.

| NSF-WQI values | Water quality | Class |
|----------------|---------------|-------|
| 0-25           | Very bad      | I     |
| 26-50          | Bad           | II    |
| 51-70          | Medium        | III   |
| 71-90          | Good          | IV    |
| 91-100         | Excellent     | V     |

### Table 2: MI-WQI Ranks Water Quality in 6 Categories.

| MI-WQI values | Rating               | Class |
|---------------|----------------------|-------|
| > 6.0         | Seriously Affected   | VI    |
| 4.0 - 6.0     | Strongly Affected    | V     |
| 2.0 - 4.0     | Moderately Affected  | IV    |
| 1.0 - 2.0     | Slightly Affected    | III   |
3. Results and Discussions

3.1. Estimating Water Quality Parameters

The examination of the water quality variables and their properties is an important part of the environmental monitoring and estimate the quality of the water. The annual mean values of various biological and physical-chemical variables for calculation of water quality index (WQI) and Iraqi international standards are presented in Table 3. All physical-chemical and biological parameters are exceeding allowable limit values recommended by the World Health Organization [19], and Iraqi drinking water standards [20], except for pH and NO3. The highest water temperature values recorded in July (30°C) and the lowest value recorded in January (15°C). Hydrogen ion concentration of study sites ranged between lowest value 6.83 in site1 at August and highest value 8.43 in site3 in September. Totally solid and turbidity levels showed differences between sites during the study period, it was ranged between 250 to 915 mg/L and 43 to 295 NTU respectively. The results were revealed that the DO in studying sites was ranged between 3.9 mg/L in site11 in August to 8.5 mg/L in site1 in January. While, BOD5 value ranged from 2.9 to 16.8 mg/L, in the same in studied sites and time of sampling. Data of nitrate level was ranged from 5.2 to 47 mg/L. Whereas, phosphate ranged between 0.11 to 3.9 mg/L. MPN of faecal coliform bacteria of study sites ranged between 2700 CFU/100 mL in site1 in October to 71000 CFU/100 mL in site11 in July. Moreover, statistical analysis that all water quality parameters except temperature showed that there were significant differences (p<0.05) were observed between studied sites and time of sampling. On the other hand, the main reason for the deterioration of water quality parameters (WQPs) and it exceed the Iraqi and international criteria in most sites and seasons are due to drainage the domestic and effluents of Baghdad city, also industrial and commercial companies which are increasing in trend from north to south. This agrees with studies of Banda and Kumarasamy [11] who referred to these factors as the main reasons for deteriorated water quality parameters.

Table 3: Summary annual mean of the water quality data of Tigris River at different locations.

| ID | Name of station | WT°C | PH unit | TUR. NTU | TS mg/L | DO mg/L | BOD5 mg/L | NO3 mg/L | PO4 mg/L | FC CFU |
|----|-----------------|------|---------|-----------|---------|---------|-----------|----------|----------|-------|
| S1 | Al-Karkh        | 21.5 | 8.05    | 72.85     | 360     | 8.2     | 3.6       | 12.31    | 0.42     | 8587  |
| S2 | Sharq Dijla     | 21.5 | 7.8     | 112.5     | 473     | 7.6     | 5.12      | 21.56    | 0.55     | 11975 |
| S3 | Al-Sader        | 21   | 8.00    | 97.5      | 384.5   | 7.8     | 4.545     | 20.87    | 0.53     | 10525 |
| S4 | Al-Baldiat      | 21.5 | 7.91    | 101.3     | 428     | 7.6     | 5.12      | 21.56    | 0.55     | 11975 |
| S5 | Al-Kadhimiya    | 21.8 | 7.85    | 105.2     | 459     | 7.5     | 5.68      | 25.11    | 0.72     | 13625 |
| S6 | Al-Karama       | 21.5 | 7.79    | 117.8     | 499     | 7.3     | 5.63      | 28.18    | 0.78     | 15750 |
| S7 | Al-Wathba       | 21.7 | 7.09    | 216       | 639.5   | 5.8     | 8.89      | 36.42    | 1.8      | 28500 |
| S8 | Al-Qadisyia     | 21.3 | 7.68    | 138.8     | 507.3   | 6.9     | 6.03      | 27.78    | 0.77     | 18850 |
| S9 | Al-Dora         | 21   | 7.4     | 168       | 568     | 6.7     | 7.48      | 33.5     | 1.19     | 20800 |
| S10| Al-Wahda        | 21   | 7.78    | 151.5     | 462     | 7.0     | 5.6       | 28.9     | 0.70     | 16825 |
| S11| Al-Rasheed      | 22.5 | 7.04    | 235       | 696     | 5.2     | 11.43     | 44.8     | 2.34     | 43250 |
| WHO standard/2011 | 35 | 8.5-6.5 | 5 | 25 | >5 | <5 | 45 | 0.1 | 0 |
| Iraqi standard/2009 | 25 | 8.5-6.5 | <10 | 25 | - | 0-5 | 50 | 0.4 | 0 |

3.2. Calculation of NSF-WQI

NSF-WQIs is a method developed to evaluate surface water contamination in any water system based on major nine variables, such as WT, pH, NTU, TS, DO, BOD5, NO3, PO4, and FC [21]. The parameters are used to classify the Tigris river in Baghdad city. The calculated factors, resulting NSF-WQI of different stations and seasons are listed in Tables (4, 5, 6 & 7). The increase in NSF-WQI value in this site (Al-Karkh site) is due to decreasing of the values of turbidity (less than 75NTU),...
biological oxygen demand (less than 3.8 mg/L), nitrate (less than 12.5 mg/L), phosphate (less than 0.45 mg/L), and fecal coliform (less than 9000 CFU), as result decrease of anthropogenic activities such as untreated domestic sewage from city near the banks of the Tigris river. While the decrease in NSF-WQI value is a reflection of the shortage of water level of the river, as well as water contains high concentrations of the above water quality parameters (WQPs). A big change occurs in site Al-Wathba (S7) and Al-Rasheed (S11) during June, July, and August in year, 2019. The water quality classification changed from bad, NSF-WQI (26-50) during the autumn, 2018 winter, 2019 and spring, 2019 to very bad, NSF-WQI (0-25) during the summer 2019. The real reason for deterioration of these two sites result from intensive human activities such as sewage and industrial effluents of Baghdad city, subsequently increase concentrations of BOD5 (more than 11 mg/l), TS (more than 690 mg/l), NO3 (more than 40 mg/l), PO4 (more than 2 mg/l) and FC (more than 43000 CFU). For the same reasons that previously mentioned, it was noticed from Figure (2), that the NSF-WQI values of Tigris river water deteriorated from “medium” in site1 (Al-Karkh) at upstream, to “bad” in site2, site3, site4, site5, site6, site8, site9 and site10 respectively and to “very bad” in site7 and site11 (Al-Rasheed) at downstream for most seasons of year. This comes in accordance with the findings of [22] and [23].

Table 4: The calculate NSF-WQI of Tigris River during Autumn (September, October, November, 2018).

| ID | Name of station | WT C° | PH unit | TUR. NTU | TS mg/L | DO% mg/L | BOD5 mg/L | NO3 mg/L | PO4 mg/L | FC CFU | NSF-WQI value | NSF-WQI scale | Water Quality Rating |
|----|-----------------|-------|---------|----------|---------|-----------|-----------|----------|----------|--------|----------------|------------------|---------------------|
| S1 | Al-Karkh        | 18    | 84      | 39       | 20      | 78        | 69        | 49       | 71       | 17     | 51             | 51-70            | Medium              |
| S2 | Sharq Dijla     | 19    | 80      | 32       | 20      | 66        | 49        | 51       | 63       | 10     | 44             | 26-50            | Bad                 |
| S3 | Al-Sader        | 19    | 82      | 36       | 34       | 70        | 57        | 62       | 57       | 11     | 49             | 26-50            | Bad                 |
| S4 | Al-Kadhimiya    | 18    | 90      | 31       | 20      | 68        | 56        | 49       | 55       | 10     | 45             | 26-50            | Bad                 |
| S5 | Al-Baldiat      | 20    | 61      | 43       | 40       | 68        | 55        | 64       | 64       | 11     | 48             | 26-50            | Bad                 |
| S6 | Al-Karama       | 19    | 80      | 39       | 20      | 72        | 60        | 55       | 60       | 9      | 47             | 26-50            | Bad                 |
| S7 | Al-Wathba       | 18    | 89      | 5        | 20      | 53        | 41        | 37       | 35       | 7      | 35             | 26-50            | Bad                 |
| S8 | Al-Qadisiya     | 19    | 87      | 19       | 20      | 72        | 48        | 53       | 51       | 8      | 44             | 26-50            | Bad                 |
| S9 | Al-Dora         | 22    | 92      | 5        | 20      | 56        | 46        | 44       | 45       | 8      | 39             | 26-50            | Bad                 |
| S10| Al-Wahda        | 19    | 91      | 17       | 20      | 70        | 56        | 53       | 63       | 9      | 46             | 26-50            | Bad                 |
| S11| Al-Rasheed      | 18    | 89      | 5        | 20      | 52        | 34        | 26       | 27       | 7      | 32             | 26-50            | Bad                 |

Wi = 0.10 0.11 0.08 0.07 0.17 0.11 0.10 0.10 0.16 \[\sum Wi = 1\]

Table 5: The calculate NSF-WQI of Tigris River during Winter (December, January, February, 2019).

| ID | Name of station | WT C° | PH unit | TUR. NTU | TS mg/L | DO% mg/L | BOD5 mg/L | NO3 mg/L | PO4 mg/L | FC CFU | NSF-WQI value | NSF-WQI scale | Water Quality Rating |
|----|-----------------|-------|---------|----------|---------|-----------|-----------|----------|----------|--------|----------------|------------------|---------------------|
| S1 | Al-Karkh        | 31    | 84      | 17       | 47      | 81        | 63        | 59       | 77       | 15     | 54             | 51-70            | Medium              |
| S2 | Sharq Dijla     | 29    | 89      | 5        | 20      | 73        | 64        | 24       | 54       | 14     | 44             | 26-50            | Bad                 |
| S3 | Al-Sader        | 31    | 83      | 5        | 20      | 75        | 73        | 26       | 79       | 18     | 48             | 26-50            | Bad                 |
| S4 | Al-Kadhimiya    | 29    | 84      | 5        | 20      | 68        | 60        | 19       | 46       | 15     | 41             | 26-50            | Bad                 |
| S5 | Al-Baldiat      | 29    | 82      | 5        | 20      | 75        | 61        | 26       | 59       | 17     | 44             | 26-50            | Bad                 |
| S6 | Al-Karama       | 26    | 87      | 5        | 20      | 72        | 61        | 13       | 52       | 13     | 42             | 26-50            | Bad                 |
| S7 | Al-Wathba       | 27    | 92      | 5        | 20      | 64        | 61        | 21       | 34       | 10     | 38             | 26-50            | Bad                 |
| S8 | Al-Qadisiya     | 29    | 91      | 5        | 20      | 70        | 60        | 22       | 58       | 12     | 43             | 26-50            | Bad                 |
| S9 | Al-Dora         | 29    | 93      | 5        | 20      | 68        | 57        | 15       | 41       | 13     | 40             | 26-50            | Bad                 |
| S10| Al-Wahda        | 31    | 85      | 5        | 20      | 73        | 64        | 18       | 69       | 15     | 45             | 26-50            | Bad                 |
| S11| Al-Rasheed      | 26    | 92      | 5        | 20      | 59        | 40        | 12       | 31       | 9      | 35             | 26-50            | Bad                 |

Wi = 0.10 0.11 0.08 0.07 0.17 0.11 0.10 0.10 0.16 \[\sum Wi = 1\]

Table 6: The calculate NSF-WQI of Tigris River during Spring (March, April, May, 2019).

| ID | Name of station | WT C° | PH unit | TUR. NTU | TS mg/L | DO% mg/L | BOD5 mg/L | NO3 mg/L | PO4 mg/L | FC CFU | NSF-WQI value | NSF-WQI scale | Water Quality Rating |
|----|-----------------|-------|---------|----------|---------|-----------|-----------|----------|----------|--------|----------------|------------------|---------------------|
| S1 | Al-Karkh        | 24    | 84      | 18       | 63      | 68        | 67        | 35       | 95       | 17     | 54             | 51-70            | Medium              |
| S2 | Sharq Dijla     | 26    | 92      | 5        | 44      | 55        | 52        | 22       | 67       | 13     | 42             | 26-50            | Bad                 |
| S3 | Al-Sader        | 26    | 82      | 5        | 58      | 62        | 62        | 25       | 86       | 17     | 47             | 26-50            | Bad                 |
The site was obtained as presented in Table (9). It was noticed from MI-WQI values that highest value was found in site7 (MI=13.34), site9 (MI=12.24) and site11 (MI=15.59), as a result to intensives discharges of municipal sewage, industrial wastes at this site, this results coincided with Al-Mayah and Al-Azzawi [24] and Matta et al. [25]. While the lower MI-WQI values were found in site1 (MI=6.073), site3 (MI=6.315), site4 (MI=6.679) and site5 (MI=7.082), this may refer to the dilution factors due to reducing the discharges of city wastewater and other forms of anthropogenic activities. Moreover, the results revealed that the Tigris river quality deteriorate in in trend from north to south this is due to the same reasons that were mentioned previously, it can be noticed in Figure 3.

| ID | Name of station | WT | PH unit | TUR. | TS | BOD5 | DO% | NO3 | PO4 | FCU | NSF-WQI value | NSF-WQI scale | Water Quality Rating |
|----|-----------------|----|---------|------|----|------|------|-----|------|-----|----------------|----------------|---------------------|
| S1 | Al-Karkh        | 11 | 77      | 43   | 66 | 56   | 37   | 48  | 46   | 8   | 44             | 26-50          | Bad                 |
| S2 | Sharq Djila     | 10 | 93      | 30   | 55 | 40   | 42   | 33  | 30   | 7   | 36             | 26-50          | Bad                 |
| S3 | Al-Sader        | 11 | 88      | 36   | 71 | 46   | 51   | 43  | 41   | 7   | 42             | 26-50          | Bad                 |
| S4 | Al-Kadhimia     | 11 | 90      | 33   | 57 | 39   | 44   | 40  | 40   | 7   | 39             | 26-50          | Bad                 |
| S5 | Al-Baldiat      | 10 | 92      | 35   | 44 | 48   | 41   | 41  | 41   | 7   | 40             | 26-50          | Bad                 |
| S6 | Al-Karama       | 11 | 93      | 29   | 52 | 41   | 45   | 30  | 31   | 6   | 37             | 26-50          | Bad                 |
| S7 | Al-Wathba       | 10 | 80      | 5    | 43 | 24   | 20   | 17  | 22   | 5   | 24             | 0-25           | Very Bad            |
| S8 | Al-Qadisyaya    | 10 | 93      | 23   | 50 | 37   | 37   | 29  | 31   | 6   | 34             | 26-50          | Bad                 |
| S9 | Al-Dora         | 10 | 92      | 21   | 48 | 31   | 29   | 26  | 30   | 6   | 31             | 26-50          | Bad                 |
| S10| Al-Wahda        | 11 | 92      | 27   | 55 | 39   | 36   | 31  | 32   | 6   | 35             | 26-50          | Bad                 |
| S11| Al-Rasheed      | 10 | 84      | 5    | 35 | 16   | 19   | 12  | 17   | 5   | 22             | 0-25           | Very Bad            |

Figure 2: NSF-WQI values at values at study area.

3.3. Calculate of MI-WQIs

Metal pollution Index (MI-WQI) can give suggestion assessing the water quality based on concentration of heavy metals and therefore can be taken action to improve water quality. Based on the MI-WQI analysis, classification of the Tigris river at each site was obtained as presented in Table (9).
Table 8: Mean MI-WQI of Tigris River during four seasons.

| Heavy metals (ppm) | Mean Concentrations (Ci) | Highest permitted value (MAC)i | MI |
|--------------------|--------------------------|-------------------------------|-----|
| Cd                 | 0.00426                  | 0.003                         | 1.42|
| Ni                 | 0.0395                   | 0.02                          | 1.975|
| Fe                 | 0.7640                   | 0.3                           | 2.546|
| Pb                 | 0.0592                   | 0.01                          | 5.92 |
| Zn                 | 0.658                    | 3                             | 0.219|
| Cu                 | 0.859                    | 1                             | 0.859|

\[ \Sigma \text{MI} = 12.94 \]

Table 9: The MI-WQI recorded at different sampling stations.

| ID | Name of station | Cd ppm | Ni ppm | Fe ppm | Pb ppm | Zn ppm | Cu ppm | \( \Sigma \text{MI-WQI} \) | MI-WQI scale | Water Quality Rating |
|----|----------------|--------|--------|--------|--------|--------|--------|--------------------------|----------------|----------------------|
| S1 | Al-Karkh       | 0.934  | 1.05   | 1.096  | 2.28   | 0.159  | 0.554  | 6.073                    | > 6.0          | Seriously affected    |
| S2 | Sharq Dijla    | 1.13   | 1.42   | 1.38   | 4.42   | 0.218  | 0.771  | 9.339                    | > 6.0          | Seriously affected    |
| S3 | Al-Sader       | 1.034  | 1.15   | 1.13   | 2.46   | 0.114  | 0.427  | 6.315                    | > 6.0          | Seriously affected    |
| S4 | Al-Baladiat    | 1.066  | 1.19   | 1.15   | 2.55   | 0.165  | 0.558  | 6.679                    | > 6.0          | Seriously affected    |
| S5 | Al-Kadhimiya   | 1.1    | 1.12   | 1.22   | 2.85   | 0.163  | 0.629  | 7.082                    | > 6.0          | Seriously affected    |
| S6 | Al-Karama      | 1.233  | 1.84   | 1.58   | 4.75   | 0.278  | 0.622  | 10.30                    | > 6.0          | Seriously affected    |
| S7 | Al-Wathba      | 1.62   | 2.06   | 2.195  | 6.24   | 0.311  | 0.916  | 13.34                    | > 6.0          | Seriously affected    |
| S8 | Al-Qadiya      | 1.27   | 1.57   | 1.79   | 5.24   | 0.244  | 0.783  | 10.89                    | > 6.0          | Seriously affected    |
| S9 | Al-Dora        | 1.4    | 1.78   | 1.96   | 5.93   | 0.296  | 0.871  | 12.24                    | > 6.0          | Seriously affected    |
| S10| Al-Wahda       | 1.3    | 1.53   | 1.76   | 4.31   | 0.237  | 0.755  | 9.892                    | > 6.0          | Seriously affected    |
| S11| Al-Rasheed     | 1.7    | 2.1    | 2.39   | 8.1    | 0.318  | 0.984  | 15.59                    | > 6.0          | Seriously affected    |

Total MI value = 107.74

Figure 3: MI-WQI values at various sampling points.

4. Conclusions
In this research, NSF-WQI provided realistic results in comparison to the raw data, they are useful models in evaluating surface water quality based on water quality parameters. Quality of water has decreased along the river from Al-Karkh station (S1) to Al-Rasheed station (S11) due to the discharge of the city wastewater and industrial wastes on both sides of the river, as well as other forms of the anthropogenic activities which are increasing in trend from north to south. On other hand, the results
of MI-WQIs indicates that the selected water samples from the Tigris river are seriously contaminated with respect to heavy metals.

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