IASJ

المجلات الاكاديمية العراقية

**Tikrit Journal of Pure Science**

*ISSN: 1813 – 1662 (Print) --- E-ISSN: 2415 – 1726 (Online)*

**Journal Homepage:** http://tjps.tu.edu.iq/index.php/j

# Applying of pollution indices as a monitoring tool for assessment of water quality in Tigris River, Baiji district, Salah alden governorate

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https://doi.org/10.25130/tjps.v24i5.416

**ARTICLE INFO.**

**Article history:**

**-Received: 27 / 1 / 2019**

**-Accepted: 10 / 6 / 2019**

**-Available online: / / 2019**

**Keywords:** heavy metals, pollution indices, water quality.

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## ABSTRACT

This research has investigated the quality of surface water at Baiji district of Salah Alden governorate based on 5 sampling stations for two season (September 2012 and April 2013). Water evaluation indices (i.e. heavy metal pollution index (HPI), heavy metal evaluation index (HEI) and contamination degree index ($C_d$)) are utilized to characterize the quality of water in term of drinking purposes. All values of HPI were lower than (15), suggesting low heavy metal pollution. The values of HEI were also less than (10), indicating low heavy metal pollution, whereas $C_d$ values were much less than (1) for all stations, indicating low heavy metal pollution. Consequently, Tigris River water in the study area is suitable for drinking purposes in terms of heavy metal pollution.

## Introduction

Industrial expansion associated with increasing of population and consumption growth has led to heavy pollution loads [1]. The heavy metals are considered to be the most common contaminants because they are toxic, persistent and non-degradable in the environment [2], and their occurrence in water and organisms point to the existence of natural or human activities [3]. The exposure to heavy element lead to serious health problems, such as reducing in growth and development, nervous system damage, organ damage, cancer, and in extreme cases death [4]. The main source of metal pollution is industrial processes, domestic sewages and agricultural fertilizers [5]. The surface waters are among the most critical sources that are susceptible to influences from anthropogenic activities which can lead to the deterioration of resource in the future [1].

Because the water bodies are considered to be very important natural resources on the earth, their quality become a global concern. Therefore, the observation and the evaluation of the pollution of water are a crucial area of study [6]. Some numerical water quality indicators were recently developed to supply interpretative tools for estimating heavy metals contamination [7], [8]. The most used methods are HPI: heavy metals pollution index [9], [10], HEI: heavy metal evaluation index [11], and degree of contamination [12] to calculate the overall water pollution with trace elements.

Tigris River is the main source of water which satisfies the domestic and agricultural needs of Baiji city of Salahelden governorate, Iraq. The adjoining areas of the river are used as sink and repositories to discharge and dispose off industrial, agriculture and domestic waste, degrading the water quality and hence there is a need for a quality assessment of Tigris River. In the present study, water quality pollution indices have been evaluated to know the status of overall pollution level of Tigris river at Baiji city in 2012 and 2013 with respect to ten important heavy metals (Al, As, Ba , Cr, Cu, Fe, Mn, Ni, Pb, and Zn).

## Materials and Methods

### Study area

Five sampling sites of surface water have been fixed (table 1) at the stretch of 30 km along Tigris River within Baiji city of Salahelden governorate as given in Figure 1. Five villages are located on both side of river banks with thousands of people who depend on river water for their life and work.

**Table 1: Coordinate of Surface Water Samples Along Tigris River.**

| Sample no. | Location | Eastern | Northern |
|---|---|---|---|
| R1 | Breej village | 366574 | 3880875 |
| R2 | Al-Hinshi village | 369003 | 3877435 |
| R3 | Al-Laqlaq village | 369237 | 3873164 |
| R4 | Al-bojwari village | 365923 | 3869595 |
| R5 | Jedaida village | 363855 | 3867548 |

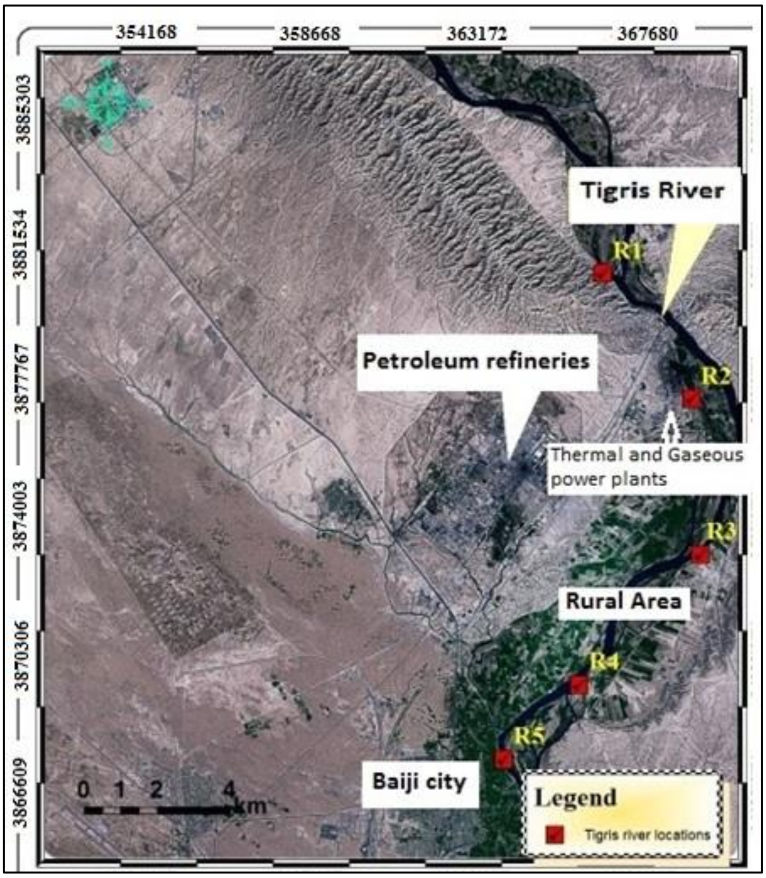



**Fig.1. Satellite Image of Surface Water Samples Locations**

**Geology and hydrology of study area**

The study area is located within Hemrin-Makhul Subzone or foothill zone which characterized by a thick cover of sediments [13]. The old rock exposed is back to Fatha formation (Middle Miocene) characterized by the prevailing evaporates facies which consist of anhydrite, gypsum and halite refer to shallow marine environment. The outcrops of Fatha formation be seen along Tigris River to the north of study area. Fatha formation is covered by Injana formation sediments (Upper Miocene) which consists of silty claystone, siltstone and sandstone with thin layers of gypsum nodules. This formation is exposed in some places along Tigris River and in Makhul Anticline [14].

Tigris River runs in the east part of study area. The long of Tigris River within the study is about 30 km. There are few meanders within river stream (Figure 1). These meanders are related with river velocity, discharge, and gradient, as well as differences in quantity and diversity in sediments, in addition to geological formations [15].

**Sampling and Sample Analysis**

For water pollution study, 5 samples of surface water along Tigris River were taken at low discharge period (Late September, 2012) and another 5 samples for high discharge period (April, 2013). Samples for trace elements analysis were taken using polyethylene containers (60 ml). First, the samples were filtered using 45μm membrane filter to get rid of colloids and then acidify them to a pH value less than two with high purity $HNO_3$ acid [16], [17].

**Water pollution indices**

For water pollution evaluation, three indicators were employed:

**Heavy Metal Pollution Index (HPI)**

This index was suggested by [9] and was applied for the assessment of the total quality of water on the basis of trace element concentrations. The HPI model is calculated according to following equation [9]:

$$HPI = \frac{\sum_{i=1}^{n} WiQi}{\sum_{i=1}^{n} Wi} \quad \text{……. (1)}$$

Where: Wi is the unit weightage factor of the $i^{th}$ parameter, Qi is the sub-index of the $i^{th}$ parameter and n is the number of parameters considered. The Wi which is inversely proportional to the maximum permissible concentration Si, can be calculated as:

$$Wi = 1/ Si \quad \text{……… (2)}$$

The proportionality constant is figured out as 1 for all the parameters [18].

The (Qi) of each parameter is calculated as:

$$Qi = \sum \frac{(Mi-Li)}{(Si-Li)} \text{x } 100 \quad \text{…….. (3)}$$

Where: Mi is the measured value of trace element of the $i^{th}$ parameter, Li represents the ideal value of the $i^{th}$ parameter, and Si denote the standard value (Iraqi standards for drinking water) of $i^{th}$ parameter. In this study, the ideal values, Li, was taken as zero for all element [19]. This index model is purposed for the drinking water [20]. For the categorization of the heavy metal pollution index, a modified scale (Table 2) proposed by [21] has been applied in this study.

**Table 2 Categorization of heavy metal pollution index (HPI)**

| HPI | class |
|---|---|
| < 15 | Low |
| 15 – 30 | Medium |
| > 30 | High |

### Heavy Metal Evaluation Index (HEI)

It is a method of evaluating the quality of water by focusing on trace elements in surface water samples [21]. The suggested HEI criterion for the water samples are as follows: low when HEI is below 10, medium when HEI is between 10 and 20, and high when HEI is greater than 20 [22]. The index can be calculated from the following equation [23]:

$$HEI = \sum_{i=1}^{n} Hc/Hmac \quad \ldots\ldots\ldots (4)$$

Where, *Hc* is the measured value of the $i^{th}$ parameter and *Hmac* is the maximum permissible concentration of the $i^{th}$ parameter.

### Degree of contamination ($C_d$)

The index of contamination degree ($C_d$) outlines the combined impacts of some quality parameters that regarded as harmful to household water and is calculated as follows [12]:

$$Cd = \sum_{i=1}^{n} C_{fi} \ldots\ldots\ldots (5)$$

$$C_{fi} = (C_{Vi} / C_{Si}) - 1 \;\ldots..(6)$$

Where, $C_{fi}$, $C_{Vi}$ and $C_{Si}$ depict pollution factor, measured value and standard value concentration of the $i^{th}$ parameter, respectively. The degree of contamination is depicted with a three grade scale as follows: low when Cd is below 1, medium when $C_d$ is ranged from 1 to 3, and high when $C_d$ is greater than 3 [12].

## Results and Discussion

Table 3 lists concentrations of heavy metal for both season samples. The pollution indicators (i.e. HPI, HEI and $C_d$) have been calculated for the two seasons (i.e. September and April), apart from the sampling stations, utilizing the Iraqi standards for drinking water [24], and were listed in Table 4. Ten heavy metals namely Al, As, Ba, Cr, Cu, Fe, Mn, Ni, Pb, and Zn are taken into consideration for the assessment of Tigris river samples. The values of HPI for the water samples collected in September are ranged from (7.8 – 9.6) with an average of (8.6) and for the water samples collected in April are ranged from (5.9 – 7.6) with an average of (7.1). The HPI values showed that all sites of surface water for both seasons have low heavy metal pollution index according to table 2.

For a good perception of the load of pollution in the river, heavy metal evaluation index HEI has also been assessed. The values of HEI ranged from (0.7 to 1.1) with an average of (0.8) and (0.5 to 1.3) with an average of (0.8) in September and April respectively (table 4). The values of heavy metal evaluation index manifest that the water samples collected from all stations during September 2012 and April 2013 are much less than the criteria value proposed by [22], suggesting that the Tigris river within the study area is low influenced by heavy metal contamination and fit for domestic.

The contamination degree index ($C_d$) is also utilized so as to evaluate the range of heavy metal contamination. The range and average values for $C_d$ are (-9.3) to (-8.9) and (-9.2) in September, and in April it ranges from (-9.5) to (-8.7) with a mean of (-9.2) (table 4). The study of $C_d$ reveals that the metal concentrations in all the samples from both seasons tend to be very low according to the grade scale proposed by [12].

**Table 3 heavy and trace element concentrations in (ppb) for both season samples.**

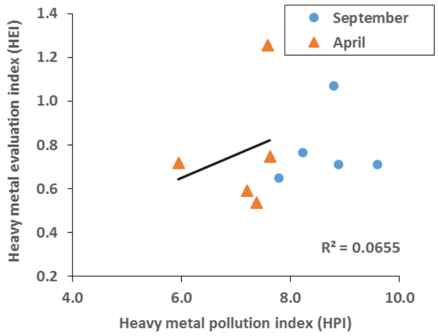
| September 2012 (low discharge) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling station | Al | As | Ba | Cr | Cu | Fe | Mn | Ni | Pb | Zn | |
| R1 | 21 | 1.3 | 48.06 | 1.2 | 2.5 | 11 | 10.45 | 0.6 | 1 | 13 | |
| R2 | 23 | 1.3 | 51.31 | 1 | 1.7 | 17 | 5.26 | 0.6 | 0.5 | 18.1 | |
| R3 | 49 | 1.3 | 47.04 | 0.7 | 1 | 63 | 7.98 | 0.5 | 0.5 | 9.6 | |
| R4 | 23 | 1.3 | 50.22 | 0.7 | 1.4 | 41 | 9.21 | 0.5 | 0.6 | 12.7 | |
| R5 | 21 | 1.4 | 48.54 | 0.7 | 1 | 33 | 6.74 | 0.3 | 0.8 | 10.3 | |
| Si* | 100 | 10 | 700 | 50 | 1000 | 300 | 100 | 20 | 10 | 3000 | |
| Wi | 0.01 | 0.1 | 0.0014 | 0.02 | 0.001 | 0.003 | 0.01 | 0.05 | 0.1 | 0.0003 | ∑Wi = 0.2957 |
| April 2013 (high discharge) | | | | | | | | | | | |
| Sampling station no. | Al | As | Ba | Cr | Cu | Fe | Mn | Ni | Pb | Zn | |
| R1 | 13 | 1.4 | 46.94 | 1 | 3.8 | 15 | 5.61 | 0.5 | 0.4 | 17.4 | |
| R2 | 21 | 1.1 | 42.83 | 0.8 | 3.1 | 19 | 3.04 | 0.5 | 0.6 | 34.2 | |
| R3 | 69 | 1 | 47.1 | 1 | 1.6 | 87 | 3.77 | 0.3 | 0.3 | 13.8 | |
| R4 | 23 | 1 | 51.3 | 0.9 | 2.5 | 61 | 4.16 | 0.3 | 0.3 | 15.9 | |
| R5 | 25 | 1.3 | 50.66 | 0.7 | 2.1 | 53 | 3.21 | 0.3 | 0.5 | 14.2 | |

* Iraqi standards for drinking water [24].

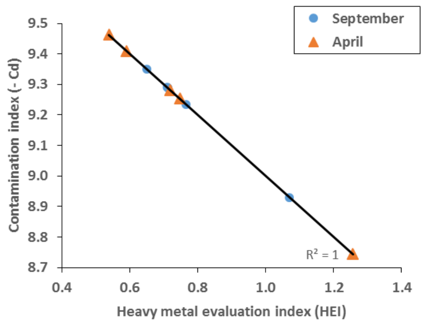
**Table 4 Water pollution indices for both season samples.**

| Sampling station no. | ∑QiWi | HPI | HEI | $C_d$ |
|---|---|---|---|---|
| September 2012 (low discharge) | | | | |
| R1 | 2.8 | 9.6 | 0.7 | -9.3 |
| R2 | 2.3 | 7.8 | 0.7 | -9.3 |
| R3 | 2.6 | 8.8 | 1.1 | -8.9 |
| R4 | 2.4 | 8.2 | 0.8 | -9.2 |
| R5 | 2.6 | 8.9 | 0.7 | -9.3 |
| average | | 8.6 | 0.8 | -9.2 |
| April 2013 (high discharge) | | | | |
| Sampling station no. | ∑QiWi | HPI | HEI | $C_d$ |
| R1 | 2.2 | 7.4 | 0.5 | -9.5 |
| R2 | 2.1 | 7.2 | 0.6 | -9.4 |
| R3 | 2.2 | 7.6 | 1.3 | -8.7 |
| R4 | 1.8 | 5.9 | 0.7 | -9.3 |
| R5 | 2.2 | 7.6 | 0.7 | -9.3 |
| average | | 7.1 | 0.8 | -9.2 |

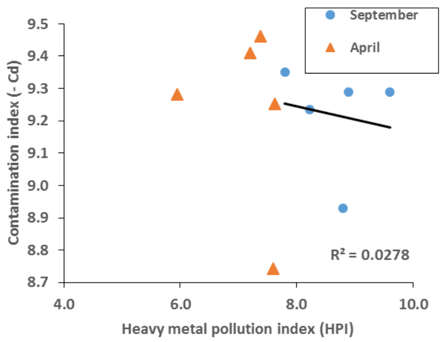
Different indices represent different categories of hazard levels. Thus, for further investigate, a scatter plot of Heavy metal pollution index and Heavy metal evaluation index and degree of contamination against each other have been constructed and are displayed in Fig. 2i, ii and iii. It is obvious from Figure below that there is a strong correlation between Heavy metal evaluation index and degree of contamination with correlation coefficient ($R^2$ = 1), while there are poor correlations between Heavy metal pollution index and Heavy metal evaluation index with correlation coefficient ($R^2$ =0.0655), and degree of contamination and heavy metal pollution index with correlation coefficient ($R^2$ = 0.0278). Consequently, the choice of heavy metal evaluation index or degree of contamination or both could be a better selection for the classification of water samples [25].




(i)




(ii)




(iii)

**Figure 2: Scatter plot of (i) HPI versus HEI (ii) HEI versus $C_d$ (iii) HPI against Cd indicators with their correlation coefficient values.**

## Conclusion

The HPI values fall within class low (<15) for both season, suggesting that Tigris river water within study area is suitable for drinking. The HEI and $C_d$ values are also within class low. Thus, the results of pollution indices (i.e. HPI, HEI and $C_d$) show a negligible effect of anthropogenic activities on the water environment of Tigris river in terms of heavy metals.

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# تطبيق مؤشرات التلوث كأداة رصد لتقييم جودة المياه في نهر دجلة، قضاء بيجي، محافظة صلاح الدين

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**الملخص**

تتحرى هذه الدراسة عن نوعية المياه السطحية في منطقة بيجي في محافظة صلاح الدين بالاعتماد على 5 محطات نمذجة لموسمين (أيلول 2012 ونيسان 2013). تم تطبيق مؤشرات تقييم التلوث (مؤشر تلوث العناصر الثقيلة، مؤشر تقييم العناصر الثقيلة ومؤشر درجة التلوث) لوصف نوعية المياه لأغراض الشرب. جميع قيم مؤشر تلوث العناصر الثقيلة كانت أقل من (15)، مما يشير إلى تلوث واطئ بالعناصر الثقيلة. إن قيم مؤشر تقييم العناصر الثقيلة كانت أيضا أقل من (10)، مما يقترح تلوث منخفض بالعناصر الثقيلة، في حين كانت قيم مؤشر درجة التلوث أقل بكثيرمن (1) ولجميع المحطات، مما يشير إلى تلوث منخفض بالعناصر الثقيلة. وبالنتيجة تعد مياه نهر دجلة في منطقة الدراسة مناسبة لأغراض الشرب من حيث التلوث بالعناصر الثقيلة.