Open Access Journal of Toxicology
ISSN 2474-7599

Research Article
Volume 6 Issue 4 - Septembe 2025
DOI: 10.19080/OAJT.2025.06.555693

Open Acc J of Toxicol

Evaluation of Water Quality and Pollution Levels of the Razzaza Lake Water in Terms of Heavy Metals

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Submission: September 03, 2025; **Published:** September 15, 2025

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Abstract

In this study, it is aimed to evaluate the water of Razzaza Lake in Iraq with water quality and pollution levels in terms of heavy metals. Razzaza Lake, the second largest lake in Iraq, is a lake 15 km west of Karbala, in the southwest of Baghdad, 1810 km2 in size and 40 meters in depth. There are many elements that pollute the waters. One of the most important of these pollutant sources is heavy metals, which have a toxic effect. Concentration in industrial and agricultural activities is one of the most important factors in the increase of heavy metal pollution. This situation threatens the life of living organisms in aquatic environments. Considering that heavy metals have carcinogenic, toxic and mutagenic effects even at low concentrations, it can be said that they are extremely important. In addition, heavy metals mixed with aquatic environments through inappropriate discharges and atmospheric transport routes tend to accumulate in living organisms because they are not biodegradable. Many indices have been developed to assess the environmental risks of toxic metals accumulating in waters. In this study, water quality index (WQI) was used to evaluate water quality, heavy metal pollution index (HPI), heavy metal assessment index (HEI) and pollution degree (DC) were used to determine pollution level. For this study, water samples taken from the Razzaza Lake were filtered through filter paper and placed in 500 ml-colored bottles. The medium was acidified by adding 5 ml of concentrated (65%, w/w) nitric acid. Cd, Al, As, Cu, Ni, Pb, Zn and Hg analyze in water samples were made in ICP-MS device. The average WQI, HPI, HEI and DC values of the lake water were determined as 3.71, 0.968, 0.25, -5.75, respectively. Since the WQI value of the lake water is <50, this water is defined as "excellent quality water" according to the water quality criteria. According to the Heavy Metal Pollution Index results of the lake water samples, Razzaza lake water samples are in the "excellent" class, and according to the Heavy Metal Evaluation Index and Pollution Degree results, it is included in the "low pollution" class. According to the results of this study, it was concluded that the Razzaza lake water is suitable for drinking.

Keywords: Razzaza Lake; Heavy Metal; Water Quality; Pollution Index

Abbreviations: : WQI: Water Quality Index, HPI: Heavy Metal Pollution Index, HEI: Heavy Metal Assessment Index, RW: Relative Weight, CD: pollution degree

Introduction

The Razzaza lake, the second largest lake in Iraq, is a lake 15 km west of Karbala (32° 41'N 43° 40'E), in the southwest of Baghdad, 1810 km2 in size, 40 meters in depth and containing 25,750 billion cubic meters of water. The Razzaza Lake is also known as the Salt Sea, Bahr al-Milh and Karbala Gap. The lake is listed as a wetland of international importance. The lake is quite shallow and the water levels change with the seasons. Due to salts and changing water levels, this largest freshwater lake in Iraq has lost a significant number of fish species. This Lake was built by a Spanish contractor in the 1970s downstream of Haur Al Habbaniya as a second storage reservoir to control floods on the Euphrates. The presence of the lake has an important place in the development of the local fish industry, tourism and economy in the region. The Razzaza lake is fed by the Euphrates River waters, the Habbaniye Lake located to the east of Ramadiye, the Al-Rashidiyya branch located to the north of Karbala, precipitation, groundwater, Ayn al-Tamr springs and seasonal flows that occur from time to time. The Razzaza lake is connected to Habbaniya lake by a narrow channel that runs through the semi-desert and is called the Sin-Al-Thibban Canal.

The Razzaza lake, formerly a deep lake, is characterized by very high salinity levels, which have increased over the last decade due to increased evaporation and water shortages during Iraq's very dry, hot summers. The geological formation in and around the lake consists of marls, siltstones, gypsum/anhydrite and limestone bands, but mostly silt. [1]. More than 60 metals, including Pb, Cd, Fe, Co, Cu, Ni, Hg and Zn, belong to heavy metal groups [2]. Some of these metals (iron, magnesium, zinc, copper, manganese) are essential metals required for the biochemical events in human metabolism. These enter our bodies in very small quantities through drinking water, food, and air. However, if these elements are taken into the body at high levels, they can cause acute or chronic poisoning. Hg, Cd, Pb and as are non-essential metals. These metals, which do not have any biological function, can cause toxic effects that end the life of organisms when they exceed certain limits in the aquatic environment [3].

The most toxic heavy metals are Hg, Cu, Cd, Pb, Zn, Ni and Co, respectively. Toxicity depends on whether the metal is in compound or ionic form and to what extent the metal is absorbed by the organism [4]. Heavy metals can cause chronic health problems as they bioaccumulate when they enter the body through food, drinking water and air, even at low doses over long periods of time. Bioaccumulation is an increase in the level of a chemical in an organism above metabolizable or tolerable levels. Bioaccumulation is due to the rate of absorption of these compounds into the organism, which is higher than the rate of metabolism or excretion [5]. Pesticides, metal industry, thermal power plant, chemical industry, mining, glass industry, waste incinerators are the main sources of heavy metals. Metals are carried into the aquatic environment by rain and dust particles and liquid or solid waste. Especially in the second half of the twentieth century, heavy metal pollution, which emerged and intensified with the development of industry, posed a threat to organisms [6]. A simple comparison of heavy metal concentrations in water with acceptable limit values may be insufficient to accurately assess their negative effects on humans. Even if the concentrations of heavy metals in water meet international standards, they may still pose a significant health risk [7,8]. Therefore, in the last ten years, pollution indices have been used to evaluate surface water quality more effectively, sensitively and comprehensively [9,10]. These indices are used to evaluate water quality; They are simple, useful and easy to understand tools for water quality managers, environmental managers, decision makers and potential users. In this study, water quality index (WQI) was used in order to evaluate the water quality and heavy metal pollution index (HPI), heavy metal evaluation index (HEI) and pollution degree (DC) were used in order to determine the pollution level in terms of heavy metal results in the water samples taken from the Razzaza lake. Thus, the water quality and pollution level of the Razzaza lake were calculated and the usage area of the water was determined.

Materials and Method

Preparation of Water Samples for Heavy Metal Analysis

Water samples taken from the Razzaza lake were put into 500 ml-colored bottles that were previously washed with 4% HCl and rinsed with pure water. Water samples were brought to the laboratory by cold chain by placing in an ice pack and filtered through 0.45 µm filter paper. To prevent any subsequent contamination, 5 ml of the concentrate (65%, w/w) was added and stored at 4 °C until analysis [11].

Heavy Metal Analysis of Water Samples

Metal analyzes of water samples (Cd, Cu, Ni, Pb, Zn, As, Hg and Al) were performed with Thermo Scientific brand X series II model ICP-MS device in Van Yüzüncü Yıl University Central Laboratory. The element analyzes were recorded as means triplicate measurements [12].

Determination of Water Quality Index (WQI) Heavy Metal Pollution Index (HPI), Heavy Metal Evaluation Index (HEI) and Water Pollution Degree (DC)

Water Quality Index (WQI) Assessments: The Water Quality Index (WQI) is defined as a rating technique that provides the combined effect of each of the water quality parameters on the overall water quality for human consumption. The Water Quality Index is therefore an important parameter, especially for determining the quality of groundwater and its suitability for use as drinking water. WQI is also widely used to characterize the usefulness of water resources, especially for domestic purposes. The index used here reflects a weighted sum of water composition in line with specific defined targets. These targets are generally related to both national and WHO standards for each of the major parameters in drinking water [10].

The calculation and formulation of the WQI includes the following steps:

➢ In the first step, a weight (AWi) value ranging from 1 to 5 was assigned to each of the eight heavy metal parameters that are harmful to human health, depending on the collective expert opinions from different previous studies. Average values for the weights of each parameter with references used are shown in Table 1. However, “1” was accepted as the least significant value and “5” was accepted as the most significant value in terms of relative weight.

➢ In the second step, the relative weight (RW) is calculated using the following equation:

$$RW = \frac{AWi}{\sum AWi} \quad (1)$$

➢ In the third stage, after dividing heavy metal concentrations (Ci) by Si, which is the standard limit value for drinking water determined by [13], the quality grade, Qi, was found by multiplying by 100.

➢

$$Qi = \frac{Ci}{Si \times 100} \quad (2)$$

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- In the final step in the water quality index (WQI) analysis, after multiplying the relative weight (RW) with grade of quality (Qi), Sub-index for all metal values (SIi values) were calculated. As a result, the WQI value was calculated by summing all the SIi values.

$$SIi = RW \times Qi \quad (3)$$

$$WQI = \sum SIi \quad (4)$$

In Table 1, the weight values (AW) and relative weight (RW) values of the metal parameters evaluated in the study are indicated, and the Si values are given based on the WHO [13] limits. Only the Si value for Pb is taken from USEPA [14]. AW values were assigned by searching the relevant literature [15-17]. In this study, heavy metal pollution index (HPI) specified by Prasad and Bose [18], heavy metal evaluation index specified by Edet and Offiong [19], and pollution degree (CD) [20] specified by Brraich and Jangu [21] were used to investigate the pollution status of water. These indices are generally used to investigate the quality of drinking and irrigation water and to describe the overall water quality status in relation to heavy metals.

Table 1: Weight values (AW), relative weight (RW) values and standard values (Si) in the drinking water category of the metal parameters evaluated in the study.

Heavy metal Parameter	AW	RW	Si, HMAC
Cd (µg/L)	5	0,172	5
Cu (µg/L)	2	0,069	2000
Ni (µg/L)	5	0,172	20
Pb (µg/L)	5	0,172	15
Zn (µg/L)	3	0,103	500
As (µg/L)	5	0,172	10
Hg (µg/L)	5	0,172	6
Al (µg/L)	4	0,138	200
Toplam	34	1.17	-

Table 2: Water Quality Rating as per Weight Arithmetic Water Quality Index Method (Sahu and Sikdar, 2008).

WQI Value	Rating of Water Quality	Usage Possibilities	Grading
< 50	Excellent water quality	Drinking, irrigation, industrial	A
50 – 100	Good water quality	Drinking, irrigation, industrial	B
100 – 200	Poor water quality	Irrigation, industrial	C
200 – 300	Very Poor water quality	Irrigation	D

Heavy Metal Pollution Index (HPI) Assessments: Calculation of heavy metal pollution index is necessary to evaluate the effect of metal parameters on water quality. Therefore, HPI values are a commonly used parameter to determine the effect of heavy metals on total water quality [16,21]. The heavy metal pollution index (HPI) is calculated as follows (1-3) [18];

$$HPI = \frac{\sum (Qi \times Wi)}{\sum Wi} \quad (1)$$

$$Qi = \frac{Ci}{Si \times 100} \quad (2)$$

$$Wi = \frac{k}{Si} \quad (3)$$

Qi: Sub-index of heavy metal parameters,

Ci: Concentration value of heavy metal parameters (µg/L),

Si: Standard values of heavy metal parameters in drinking water category [13],

Wi: unit weight of heavy metals,

k: Fixed value, 1

Heavy Metal Evaluation Index (HEI) Assessments: Heavy metal evaluation index refers to the evaluation of water depending on its quality related to heavy metal pollution [19]. Heavy metal evaluation index, HEI is calculated as in the formula below (4).

$$HEI = \frac{\sum HC}{HMAC} \quad (4)$$

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HC: Values determined for heavy metal parameters,

HMAC: Maximum allowable concentration value for heavy metal parameters (1) [13]

Pollution degree (DC) Assessments: The degree of pollution (DC) indicates the total effects of various heavy metals considered harmful to drinking water. The degree of pollution is calculated with the following equation [21,22].

$$DC = \sum Cfi$$

$$Cfi = \frac{Cai}{CNi - 1}$$

Cfi = contamination factor;

Cai = Analytical value determined for heavy metal parameters

CNi = Permissible upper concentration for heavy metal parameters

Statistical Analysis

Descriptive statistics for the featured features; expressed as mean, standard deviation, minimum and maximum value. One-way analysis of variance (One-way ANOVA) was performed to determine whether there was a difference between the groups in terms of these characteristics. Duncan's multiple comparison test was used to identify different groups following analysis of variance. In the calculations, the statistical significance level was taken as 5% and the SPSS (ver: 13) statistical package program was used for the calculations.

Results

Table 3: The classification based on HPI (Prasad and Bose, 2001), HEI (Edet and Offiong, 2002) and DC (Brraich and Jangu, 2015) values.

HPI Value	Classification	HEI Value	PollutionLevel	DC Value	PollutionLevel
0-25	Excellent	< 10	Low	< 1	Low
26-50	Good	10<HEI<20	Medium	1–3	Medium
51-75	Poor	> 20	High	> 3	High
76-100	Very poor				
100<	Inconsumable				

Cd and Hg were not detected in the lake water. The average concentrations of 8 heavy metals (Al, As, Cu, Ni, Pb, Cd, Hg and Zn) were used to determine the HPI values. Details on the calculation of HPI values are given in Table 3. According to Table 4, the metal with the highest average concentration is Al. According to the average concentration values, the heavy metal order is Al>Zn> Ni> Cu> As> Pb. When the calculations of the lake water are examined, it is seen that the average WOI value is well below 50, the average HPI value is well below 100, the average HEI value is well below 10 and the average DC value is well below 1.

Table 4: HPI, HEI, DC and WQI values of lake water samples.

Heavy metals(μg/L)	Average concentration (Mi)	Maximum allowed value(-Si)*, Hmac	Unit weight (Wi= 1/Si)	Sub-index (Qi)	Wi×Qi
Al	34.92	200	0.005	17.46	0.0873
Ni	0.88	20	0.05	4.4	0.22
Cu	0.69	2000	0.0005	0.035	0.00002
Zn	1.98	500[a]	0.002	0.396	0.00079
As	0.16	10	0.1	1.6	0.16
Pb	0.13	10[b]	0.1	1.3	0.13
Cd	0.0	5	0.2	0.0	0.0
Hg	0.0	6	0.16	0.0	0.0
ΣWi = 0.6175, ΣQiWi = 0.598, ortalama HPI = 0.968					
ortalama HEI = 0.25, DC=-5.75, WQI=3.71					

*All limit values except lead and zinc are taken from USEPA (2009).

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Discussion and Conclusion

Due to the rapid increase in the world population and the increase in living standards, the pollution of industrial and industrial wastes reaching receiving environments such as lakes and rivers, decreases in the amount of drinkable and usable water and deterioration in water quality [23]. In this study, Cd and Hg were not detected in the lake water. The metal found in the highest average concentration in the water samples of the Razzaza lake is Al. The geological formation in and around the lake is mostly silt [1,24]. Silt is the name given to the material from sand to small clay to large grained material. It generally consists of aluminum silicates between 0.002 millimeters and 0.1 millimeters. Therefore, depending on the site in the lake, it is possible that the most abundant metal in the water of the lake is Al. The average WQI, HPI, HEI and DC values of the lake water were determined as 3.71, 0.968, 0.25, -5.75, respectively. Since the WQI value of the lake water is <50, this water is defined as "excellent quality water" according to Table 2. In Table 3, According to the HPI quality classes, the Razzaza lake water samples are in the "excellent" class, and according to the Heavy Metal Evaluation Index and Pollution Degree results, the Razzaza lake water samples are included in the "low pollution" class.

Atici et al. [25], in their study, determined that the brines of the Van Lake Basin are in the "unusable water" class according to HPI quality classes, and only one sampling point is in the "good" class. In similar heavy metal pollution index studies, Milivojević et al. [26] The average HPI in the Uglješnica River was calculated as 67.5 for the summer season and 80.7 for the autumn season. [27] calculated the average HPI value for Yamuna Water to be 261 in the summer season and 92.5 at the end of the rainy season. According to Leventeli et al. [28] determined the mean HPI values for the Düden and Göksu rivers to be 80.4 and 60.2, respectively. Ustaoglu [29] calculated the water quality index (WQI), heavy metal pollution index (HPI) and heavy metal evaluation index (HEI) values of the Değirmendere dam (Amasya, Turkey) to be 16.63-17.54-1.00, respectively. According to this result, Değirmendere Dam water is of "perfect water" (WQI=0-25) quality. Since the calculated HPI value (17.54) is <100, it indicates the presence of a low degree of metal contamination, but no adverse health effects. Similarly, since the HEI value (1.00) is <10, the water quality is included in the "low pollution" class. Kukrer and Mutlu [30] reported that the dam water is of excellent quality according to WQI values (17.62-29.88), in their study on Saraydüzü Dam, which is not affected much by anthropogenic sources. In the study conducted in Gala and Sığırcı lakes, which are heavily affected by industrial and agricultural activities, the WQI values were determined as 253 and 159, respectively. According to these results, it has been reported that both lakes are not of suitable quality for drinking water [31]. In the same study, it was evaluated that Gala and Sığırcı lakes were exposed to metal pollution according to the calculated HPI and HEI values, and therefore they were not suitable for drinking water. WQI, HPI and HEI values determined for Razzaza lake in this study are considerably lower than the values determined for lake and river waters in other studies. Most metal pollution accumulates in water. This accumulation in water may be in the form of dissolution, or it may be in the form of precipitation at the bottom of the waters without dissolving [32]. For this reason, the very low heavy metal level in the Razzaza lake water may be the result of heavy metals in the water sinking to the bottom, that is, accumulation in the lake sediment. According to the results of this study, it was concluded that the Razzaza lake water is suitable for drinking and other purposes [33]. However, aquatic environments such as lake water do not consist of only water, there are many animal and plant origin floating organisms or living in the sediment layer at the bottom. Water-soluble pollutants pass into the organism depending on the environmental conditions, accumulate in the food chain or settle to the bottom. For this reason, a pollutant should be examined not only in water, but also in sediment and the creatures living in that lake water.

Funding

No funding was received for this work.

Conflict of interests

No conflict of interest.

Acknowledgment

The author is thankful to Adel Abbas Safar Al-jobory for her participation in the sample collection process and analyzing some parameters.

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