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RESEARCH ARTICLE

Environmental Assessment of Heavy Metal Distribution in Sediments of Tigris River within Baghdad City

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Abstract

This work contributes to the monitoring of Tigris river pollution by assessing the degree of heavy metals pollution in the sediment samples. The order of the mean concentrations of examined heavy metals: Cr>Zn>Ni >Pb>Cu>Cd. The results indicated that the entire tested heavy metal exhibit higher values than ISQG for fresh water sediments. Geo-accumulation Index (Igeo), Enrichment Factor (EF), Contamination Factor (CF), Degree of Contamination (C_d) and Pollution Load Index (PLI) were applied to evaluated heavy metals contamination in the sediment samples. Based on I-geo the sediment of Tigris river within the study area can be considered to be a strongly to extremely polluted with Cd, while the Igeo values of Pb show moderately polluted degree. With respect to specific sites, high EF values (e.g., 97.89 for Cd, 9.73 for Pb, 5.07 for Cr, 3.98 for Ni, 2.90 for Cu and 2.52 for Zn) are found at Site 3, which was located at the downstream and continuously receives a vast amount of wastewater and other wastes of the city. According to the calculated C_d values, the pollution levels for the sites in the following order: 3>1>2, suggesting that the site located in the downstream is more seriously polluted by heavy metals than other sites, attributed to the feeding river input. Furthermore, site 3 displayed the highest PLI value and reflects the highest presence of all the examined heavy metals; indicating that this site is considerably affected by different anthropogenic activities.

Introduction

Heavy metals pollution mostly from anthropogenic activities represents a serious problem for human health [1]. Nevertheless, the terrestrial and aquatic ecosystem received elevated inputs of heavy metals as a result of an increase in atmospheric deposition and anthropogenic activities. Furthermore, they reported that heavy metals contamination in aquatic ecosystem is of critical concern, as the effect of heavy metals toxicity and their accumulation in aquatic habitats [2].

In the aquatic ecosystem sediments have been commonly used as environmental indicators due to high physical-chemical stability and their chemical analysis can provide considerable information on the assessment of anthropogenic activities [3]. Sediments are essential and integral parts of water regime. They can provide the substrate for organisms and through interaction with the overlying waters play an important responsibility in the aquatic ecosystem [4]. They are gradually more considered as both a carrier and a probable source of contaminants in aquatic systems. However, the investigation of bottom sediments, which accumulate most of the heavy-metal pollutants, enable us to get an integrated picture of the metals contamination since the level of metals in bottom sediments is the result of expanded sedimentation processes and does not undergo rapid changes because of varying external conditions [5]. Furthermore, Sediments are combination materials, consisting of inorganic components, mineral particulates, and organic matter in various stages of decomposition. Thus, this investigation was conducted to assess the level of heavy metal concentrations and sediment quality in the Tigris River and to look at the natural and anthropogenic input of heavy metals and to draw attention to relationships among heavy metals pollution in the study area.

2. Materials and Methods

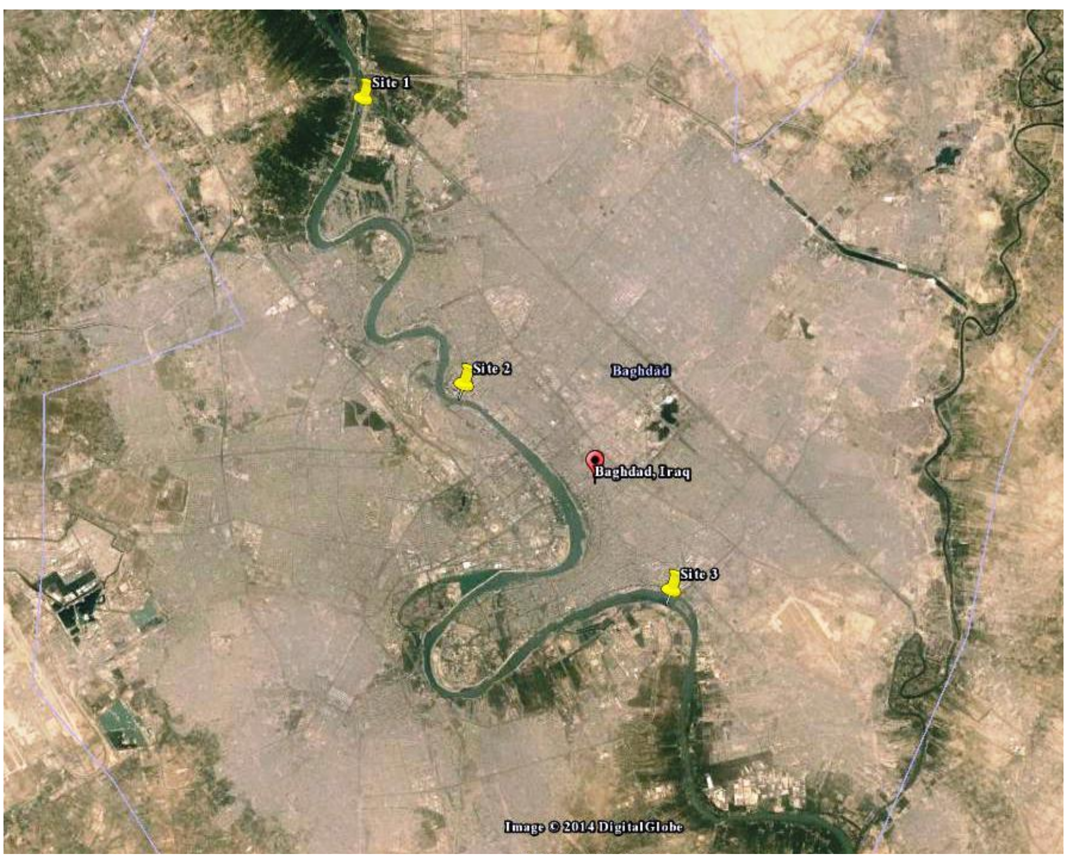
2.1 Study area

Tigris River is one of the major twin rivers in Iraq, sharing with Euphrates River as the main water resources for different uses, since they pass through the most important cities in the country [6]. Tigris River divides the Capital of Iraq Baghdad City (33°14′-33°25′ N, 44°31′-44°17′ E) into two sections (Karkh and Risafa) with a flow direction from north to south. In the current research three sites along Tigris River were chosen in order to estimate the heavy metals distribution (Figure 1). Site 1 was located upstream, while site 2 was situated in the midstream and the site 3 was located at the downstream.

2.2 Sample collection, preparation and analysis

Sediment samples were taken from the selected sites during November 2013 to May 2014. The samples were brought back to the laboratory of Environmental Research Center, University of Technology. These samples were air dried, homogenized and sieved through a 2-mm polyethylene sieve to remove large debris, stones and pebbles, after they were disaggregated with a porcelain pestle and mortar. Then sediment samples were stored in clean self-sealing plastic bags for further analysis. To estimate the total heavy metal content, sediment samples were wet-digested with aqua-regia (1:3 HNO_3+HCl). The digested samples are cooled and filtered through whatman No.42 filter paper and then the volumes were made up to 100 ml using volumetric flasks [7]. While for bio-available of heavy metal, sediment analysis was carried out with DTPA extraction method [8]. Analysis of the total and bio-available of heavy metal was performed with a flame atomic absorption spectrophotometer (AA6300, Shimadza, Japan).

3. Results and Discussion



3.1 Heavy metals content

Analysis values of heavy metals are given in Table 1. The mean value and the standard deviation are given. The order of the mean concentrations of examined heavy metals: Cr>Zn>Ni >Pb>Cu>Cd. The results indicated that the entire tested heavy metal exhibit higher values than the Interim sediment quality guideline (ISQG) for fresh water sediments, while Cd and Cr displayed higher values than the Probable effect level (PEL).

Table 1: Concentration of heavy metals (mg/Kg) for sediments of Tigris River

Sites	Cd	Cr	Cu	Ni	Pb	Zn
1	6.63±3.42	163.14±26.83	38.25±11.21	92.09±32.09	69.41±11.40	114.76±48.01
2	6.41±2.30	156.95±75.80	34.94±6.83	67.87±20.30	69.54±33.96	116.11±57.09
3	9.09±2.70	174.73±40.09	45.04±8.70	94.71±36.18	75.60±41.88	155.31±37.20
Mean value of all sites	7.38±0.57	164.94±24.67	39.41±2.20	84.89±8.24	71.52±15.82	128.73±9.96
Background [9]	0.20	71.00	32.00	49.00	16.00	127.00
ISQG (Fresh water sediment) [10]	0.6	37.30	35.70	----	35.00	123.00
PEL (Fresh water sediment) [10]	3.5	90.00	197.00	----	91.30	315.00

ISQG: Interim sediment quality guideline, PEL: Probable effect level

3.2. Indices

Several indices were used to assess the metal contamination levels in the sediment samples, namely Geo-accumulation index (I-geo), Pollution Load Index (PLI), Enrichment Factors (EF), Contamination Factor (CF) and Degree of Contamination (C_d). World surface rock average data of heavy metals which was used as background values were taken from Martin and Meybeck [9].

3.2.1 Geo-accumulation index

Geo-accumulation index (I-geo) was employed to evaluate the heavy metals pollution in the sediment of Tigris River. This method has been used by Müller since the late 1960s [11]. I-geo was calculated using the following equation:

$$\text{I-geo} = \log_{2\,/}\,(C_n / 1.5B_n)$$

Where C_n is the measured content of the examined metal in the sediment samples and B_n is the geochemical background content of the same metal. The constant 1.5 is introduced to minimize the effect of possible variations in the background values, which may be recognized to anthropogenic influences. The following classification is given for I-geo: <0 = practically unpolluted, 0-1 = unpolluted to moderately polluted, 1-2 = moderately polluted, 2-3 =

moderately to strongly polluted, 3-4 = strongly polluted, 4-5 = strongly to extremely polluted, and > 5 = extremely polluted [11].
The calculated results of I-geo (Table 2), indicate that Cd can be considered to be a strongly to extremely polluted, while the Igeo values of Pb show moderately polluted degree. With few exceptions Cr and Ni exhibit unpolluted to moderately polluted degree. Furthermore, Cu and Zn displayed practically unpolluted degree. On the basis of the mean values of I-geo, sediments in the Tigris river are enriched for metals in the following order: Cd> Pb>Cr>Ni>Cu>Zn, and the pollution levels for the sites in the following order: 3>1>2.

Table 2: I-geo values for sediments samples of the Tigris River

Sites	I geo					
	Cd	Cr	Cu	Ni	Pb	Zn
1	4.47	0.61	-0.32	0.32	1.53	-0.74
2	4.42	0.56	-0.45	-0.12	1.54	-0.71
3	4.92	0.71	-0.09	0.37	1.66	-0.29
All samples	4.62	0.63	-0.29	0.20	1.58	-0.56

3.2.2 Enrichment factor

Enrichment Factors (EF) were considered to estimate the abundance of metals in sediment samples. EF was calculated by a comparison of each tested metal concentration with that of a reference metal [12]. The normally used reference metals are Mn, Al and Fe [13]. In this study iron was used as a conservative tracer to differentiate natural from anthropogenic components, following the hypothesis that its content in the earth crust has not been troubled by anthropogenic activity and it has been chosen as the element of normalization because natural sources (98%) greatly dominate its contribution [14]. According to Rubio *et al.* [15], the EF is defined as follows:

$$\text{EF} = \frac{(M / Fe)sample}{(M / Fe)background}$$

Where EF is the enrichment factor, (M/Fe)sample is the ratio of metal and Fe concentration of the sample and (M/Fe)background is the ratio of metals and Fe concentration of a background. Five contamination categories are reported on the basis of the enrichment factor [16]. EF <2 deficiency to minimal enrichment, EF = 2-5 moderate enrichment, EF = 5-20 significant enrichment, EF = 20-40 very high enrichment, EF>40 extremely high enrichment.
As shown in Table 3, average EF values for heavy metals have an order Cd>Pb>Cr>Ni>Cu>Zn, suggesting that sediment samples was extremely high enrichment with Cd, while Pb exhibit significant enrichment. In contrast, the rest of the metals show moderate or minimal enrichment in the study area. With respect to specific sites, high EF values (e.g., 95.89 for Cd, 9.97 for Pb, 5.19 for Cr, 4.08 for Ni, 2.97 for Cu and 2.58 for Zn) are found at Site 3, which was located at the downstream and continuously receives a vast amount of wastewater and other wastes of the city.

Table 3: Enrichment factor for the sediments samples of the Tigris River

Sites	EF					
	Cd	Cr	Cu	Ni	Pb	Zn
1	64.42	4.47	2.32	3.65	8.43	1.76
2	58.40	4.03	1.99	2.52	7.92	1.67
3	95.89	5.19	2.97	4.08	9.97	2.58
All samples	71.93	4.53	2.40	3.38	8.71	1.98

3.2.3 Contamination factor and degree of contamination

Generally sediments have been used as environmental indicators, and this ability to identify heavy metal contamination sources and monitor contaminants is also well documented. Thus, the accumulation of metals in the sediments is strongly controlled by the nature of the substrate as well as the physicochemical conditions controlling dissolution and precipitation [17]. The level of metal contamination was expressed by the contamination factor [18]. Contamination Factor (CF) was used to determine the contamination status of sediment in the current study. CF was calculated according to the equation described below:

$$CF = \frac{M_C}{B_C}$$

Where M_c Measured concentration of the metal and B_c is the background concentration of the same metal. Four contamination categories are documented on the basis of the contamination factor [19]. CF<1 low contamination; $1 \leq CF \geq 3$ moderate contamination; $3 \leq CF < 6$ considerable contamination; CF>6 very high contamination, while the degree of contamination (C_d) was defined as the sum of all contamination factors. The following terms is adopted to illustrate the degree of contamination: $C_d<6$: low degree of contamination; $6 \leq C_d < 12$: moderate degree of contamination; $12 \leq C_d < 24$: considerable degree of contamination; $C_d>24$: very high degree of contamination indicating serious anthropogenic pollution.

The average CF values for different heavy metals in the sediments of Tigris river are Cd>Pb>Cr>Ni>Cu>Zn (Table 4). For all sites along the Tigris river, the CF value for Cd is >6, indicating that this environment are highly contaminated with Cd, while Pb displayed considerable contamination. In contrast, the rest of the heavy metals exhibit moderate contamination in general. Furthermore, very high degrees of contamination ($C_d>24$) were observed indicating serious anthropogenic pollution. However, on the basis of the mean values of C_d, the pollution levels for the sites in the following order: 3>1>2, suggesting that the site located in the downstream is more seriously polluted by heavy metals than other sites, attributed to the feeding river input.

3.2.4 Pollution Load Index

Pollution Load Index (PLI) was used to evaluate the extent of pollution by heavy metals in the environment. The range and class are same as Igeo. PLI for a particular site has been calculated following the method planned by Tomlinson et al. [20] as follows:

$$PLI = \left(CF_1 \times CF_2 \times CF_3 \times .... \times CF_n\right)^{1/n}$$

Where n is the number of metals and CF is the contamination factor.

The value of PLI ranges from 3.47 in the downstream site to 2.74 in midstream site (Table 4), indicated moderately to strongly polluted. However, site 3 displayed the highest PLI value and reflects the highest presence of all the examined heavy metals; indicating that this site is considerably affected by different anthropogenic activities, while site 2 exhibit the lowest contamination factors of all the studied heavy metals, except for Pb and Zn. Therefore, this site has the lowest PLI.

Table 4: Contamination factor values for sediments sample of Tigris River

Sites	Contamination Factor (CF)						Degree of contamination (C_d)	Pollution Load Index (PLI)
	Cd	Cr	Cu	Ni	Pb	Zn		
1	33.15	2.30	1.20	1.88	4.34	0.90	43.77	2.96
2	32.05	2.21	1.09	1.39	4.35	0.91	42	2.74
3	45.45	2.46	1.41	1.93	4.73	1.22	57.2	3.47
All samples	36.9	2.32	1.23	1.73	4.47	1.01	47.66	3.06

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