



Assessment of Heavy Metals Pollution in Sediment of Shatt Al-Hilla by Using Ecological Indices

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Abstract

Surficial sediment samples were collected from four stations at Shatt Al-Hilla from Western Zoer area to Almaimirh in Babylon province for the period from August 2016 to April 2017. The level of contamination in the sediments of Shatt Al-Hilla, by Lead (Pb), Copper (Cu), Nickel (Ni), Manganese (Mn), Zinc (Zn), Arsenic (As), and Cobalt (Co) has been evaluated using the index of Geo-accumulation (I-Geo), Contamination factor (CF), pollution load index (PLI) and Potential ecological risk index (E_r). In the present study the levels of heavy metals in sediment samples were found in the range of (10-15.22 ppm) for Pb, (25.6-46.09 ppm) for Cu, (144.9-413.7 ppm) for Ni, (666.1- 906.3 ppm) for Mn, (68.69- 119.2 ppm) for Zn, for As (5.22- 8.25 ppm) and for Co (10.3- 68.44 ppm). The values of the Pollution Load Index (PLI) were founded at station 1 unpolluted by whole studied heavy metals, while the (PLI) value at other stations 2, 3 and 4 were more than 1 which means that polluted by heavy metals. According to contamination factor (CF), station 1 considered as moderate contamination by Ni, while the station 2, 3 and 4 considered as considerable contamination by Ni, while all stations were low contamination by Zn and Co. Depending on the results of Geoaccumulation index (I-Geo) all stations considered slightly polluted by Ni, while station 1 and 2 considered slightly polluted by Co. The values of the Pollution Load Index (PLI) were varied between unpolluted in station 1 and polluted in other studied stations. The values of the Potential Ecological Risk (E_r^I) and (RI) for all heavy metals indicated that these metals do not pose a threat to the environment in the study area.

Keywords: Heavy Metals; Shatt Al-Hilla; River Sediments; Pollution; Iraq.

تقييم التلوث بالمعادن الثقيلة في رواسب شط الحلة بواسطة استخدام بعض الدلائل البيئية

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الخلاصة

جمعت عينات الرواسب السطحية من اربعة محطات على شط الحلة من منطقة زوير الغربي الى منطقة المعيميرة في محافظة بابل للفترة من آب 2016 ولغاية نيسان 2017 وتم تقييم درجة التلوث في رواسب شط الحلة للعناصر (الرصاص والنحاس والنيكل والمنغنيز والزنك والزرنيخ والكوبلت) بواسطة استخدام مؤشر حمل التلوث (PLI) ومؤشر التراكم الارضي (I-geo) ومؤشر عامل التلوث (CF) ومؤشر الخطر البيئي المحتمل (E_r^I). في هذه الدراسة وجدت مستويات العناصر الثقيلة في رواسب شط الحلة ضمن الحدود التالية (10-

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15.22 جزء من المليون) للرصاص و(46.09-25.6 جزء من المليون) للنحاس و(413.7-144.9 جزء من المليون) للنكل و(906.3-666.1 جزء من المليون) للمغنيز و(119.2-68.69 جزء من المليون) للزنك و(8.25-5.22 جزء من المليون) للزنيخ و(68.44-10.3 جزء من المليون) للكوبلت. قيم مؤشر حمل التلوث وجدت بان محطة رقم 1 غير ملوثة بأي من العناصر الثقيلة المدروسة بينما محطات 2 و3 و4 كانت قيمة (PLI) اكثر من 1 وهذا يدل على تلوث هذه المحطات بالعناصر الثقيلة. استنادا لعامل التلوث (FC) اعتبرت المحطة رقم 1 متوسطة التلوث بالنكل بينما محطات 2 و3 و4 كبيرة التلوث بهذا العنصر بينما اعتبرت جميع المحطات منخفضة التلوث بعنصري الزنك والكوبلت. واستنادا لمؤشر التراكم الارضي (I-geo) فان جميع المحطات ملوث بدرجة قليلة بعنصر النيكل بينما محطتي 1 و2 ملوثة بدرجة قليلة بعنصر الكوبلت. اشارت قيم الخطر البيئي المحتمل الى ان جميع المحطات ولكل العناصر الثقيلة في هذه الدراسة تشير الى ان التلوث منخفض.

Introduction

Heavy metal contamination is diffuse in diverse Iraqi water body [1, 2]. The worry for water resources containing contaminants, such as heavy metals, anions and cations that pose a hazard to health, has increased worldwide [3]. Heavy metals in water body are removed from the water column by interacting with particulate and are deposited as sediments [4, 5]. Sediment establishes the most essential sink of metals and other pollutants, it can act as a nonpoint source and have the potential to release the sediment-bound metals and other pollutants to covering waters, and in turn harmfully affects aquatic organisms [6]. A continuous monitoring of water quality is very essential to determine the state of pollution in our rivers. This information is important to be transferred to the community and the government in order to develop plans for the security of the expensive freshwater resources [7].

Heavy metals and most of the ions are natural constituents of natural waters; some represent at low concentrations and are biologically important in an aquatic environment, but some are toxic. The heavy metal toxicity has long been anxious since it is very important to the health of human health ecology [8, 9].

The assessment of sediment enrichment with elements can be approved in many ways. The most utilized ones are the index of Geo-accumulation (I-Geo) and pollution load index (PLI). The I-geo has been commonly used as a measure of pollution in freshwater sediment [10]. While the pollution load index (PLI) represents the number of times by which the heavy metal concentrations in the sediment exceeds the background concentration, and gives a total indication of the overall level of heavy metal toxicity in a particular sample [11]. The aim of the present study to evaluate the sediment pollution by heavy metals using recent ecological indices

Study Area

The Euphrates River is one of the most important rivers in the Iraq. Along with the Tigris River, it provided much of the water that supported the development of ancient Mesopotamian culture. The main water resources in Iraq to the Euphrates and Tigris Rivers [12]. The Euphrates River is divergent into two rivers namely Hindia and Shatt Al Hilla at its middle area. Shatt Al- Hilla is passing through several towns and villages, and receiving the liquid wastes from domestics, agriculture and industry wastewater [13]. Shatt AL-Hilla is considered the main source for all drinking and treatment plants in Babylon province in the middle of Iraq which including the large treatment units. Shatt Al-Hilla is used as a disposal site for a portion of untreated sanitary sewage which is discharged into it through the highly polluted lateral creeks. Therefore, the water of this river is of variable quality due to natural and man-made reasons and, subsequently, needs to be assessed as a source of domestic water supply [14].

In the present study four stations were chosen from the Shatt al-Hilla at Babylon province were selected for sample station 1 the located in the north of the city and called (Western Zoer) in the north latitude ($32^{\circ}31'05.75''$) and east longitude ($44^{\circ}25'04.67''$) the river characterized by high growth of plants and surrounded by farmland was low population density and spread with fish ponds. Station 2 located from the city center and called (health district) in the north latitude ($32^{\circ}29'36.00''$) and east longitude ($44^{\circ}25'59.00''$) and away from the first location about 4 km. Spread in this area car wash station as well as cafeterias and restaurants on the banks of the river. River bed in this area becomes narrow because buried parts of it for the purpose of establishing restaurants and theatres.

Station 3 located in the city center called (Alfaresi) in the north latitude (32°27'58.00") and east longitude (44°26'24.54") and away from the second location is about 3.2km. This region is characterized by high population density as well as the presence of sewage pipes and the large riverside waste. Station 4 was located down the city and called (Almaimirh) at north latitude (32°26'32.69") and east longitude (44°28'00.75") and away from the third location about 4.3km. This station is characterized by being a rural area and low population density with low waste and residues

Materials and methods

Sample collection

Samples of sediments were taken from four stations (covering the Shatt Al-Hilla in Hilla City) for the period during August 2016 to April 2017 which corresponds to the low and high level of water discharge seasons. The river sediment samples were collected by using the clean plastic scoop and stored in polyethylene bags. After collection of the samples dried in an oven at 110° C for 5 to 6 hours and crushed by glass mortar to 2µm [15]. For X-ray fluorescence measurements a sample has to be additionally pulverized, homogenized and pressed into a pellet with or without a binder. Five gm of powder was taken and compressed under the pressure of 5 tons to a pellet then left one day then tested by X-ray fluorescence analysis.

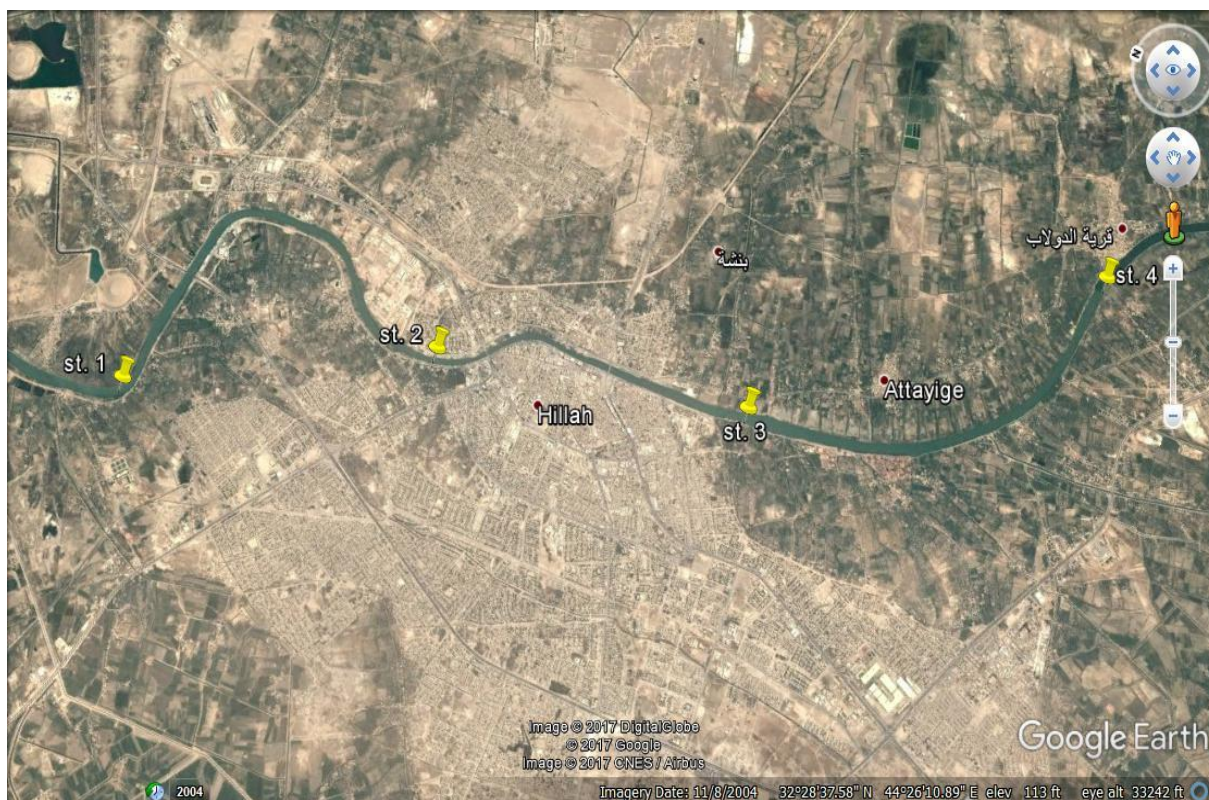


Figure 1- Showing the study station in the Shatt Al-Hilla in Babylon Province.

Sediment pollution indices

The Geo-accumulation index (I-Geo) and pollution load index (PLI) were employed to assess the pollution of metals in the sediment of Shatt Al-Hilla.

Geo-accumulation index (I-Geo)

According to [16] Geo-accumulation index was determined by the following equation according to which was described by Boszke [17]

$I\text{-Geo} = \log_2 (C_n / 1.5 B_n)$, where

C_n = Measured concentration of heavy metal in the river sediment.

B_n = Geochemical background value in average shale (Table- 1) of element n.

Factor 1.5 is used for the possible variations of the background data due to lithological variations.

According to [16] I-Geo was classified into seven levels: $I\text{-Geo} \leq 0$ (grade 0), unpolluted; $0 < I\text{-Geo} \leq 1$

(grade 1), slightly polluted; $1 < I\text{-Geo} \leq 2$ (grade 2), moderately polluted; $2 < I\text{-Geo} \leq 3$ (grade 3), moderately severely polluted; $3 < I\text{-Geo} \leq 4$ (grade 4), severely polluted; $4 < I\text{-Geo} \leq 5$ (grade 5), severely extremely polluted; $I\text{-Geo} > 5$ (grade 6), extremely polluted .

Contamination Factor (CF)

The level of contamination of sediment by metal is expressed in terms of a contamination factor (CF) calculated as:

$$CF = C_{\text{metal}} / C_{\text{background value}}$$

where, C_m Sample is the concentration of a given metal in river sediment, and C_m Background is a value (Table- 1). CF values for describing the contamination level as:

- CF < 1 Low contamination
- $1 \leq CF < 3$ Moderate contamination
- $3 \leq CF < 6$ Considerable contamination
- CF > 6 Very high contamination [18].

The Pollution Load Index (PLI)

The Pollution Load Index (PLI) is obtained as concentration Factors (CF). The PLI of the place is calculated by obtaining the n-root from the nCFs that were obtained for all the metals. With the PLI obtained from each place [19]. Commonly pollution load index (PLI) as developed by Tomlinson [20] which is as follows:

$$CF = C_{\text{metal}} / C_{\text{background value}} \text{ (Table- 1)}$$

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \times \dots \times CF_n}$$

Where, CF = contamination factor, n = number of metals. The PLI value of > 1 is polluted, whereas <1 indicates no pollution [21].

Potential Ecological Risk Index (E_r^i)

According to Hakanson [18] the potential ecological risk index (RI) was introduced to assess the degree of heavy metal pollution in sediments, according to the toxicity of heavy metals and the response of the environment where RI is calculated as the sum of all risk factors for heavy metals in sediments, E_r^i is the minimal potential ecological risk factor, C_f is the contamination factor, and is the toxic response factor, representing the potential hazard of heavy metal contamination by indicating the toxicity of particular heavy metals and the environmental sensitivity to contamination.

The potential ecological risk of a given contamination was calculated according to [18].

$$E_r^i = T_r^i \times C_f^i \text{ were } \dots \dots \dots (1)$$

T_r^i is the toxic response factor for a given heavy metal,

C_f^i is the contamination factor.

The potential ecological risk of heavy metals is classified into five levels according to the values of E_r^i :

- <40low.
- 40-80..... moderate.
- 80-160moderate to high.
- 160-320..... high.
- ≥ 320very high.

$$RI = \sum_{i=1}^n E_r^i \dots \dots \dots (2)$$

RI is the sum of all risk factors for heavy metals in sediments.

- < 150 Low.
- 150- 300 Moderate.
- 300- 600 High.
- ≥ 600 Very high.

According to the standardized toxic response factor proposed by Hakanson [18] Pb, Cu, Ni, Mn, Zn, As and Co have toxic response factor of 5,5,5,1,1,10 and 5 respectively.

Table 1-The world average concentration of heavy metals was considered as the background value

Elements	Pb	Cu	Ni	Mn	Co	As	Zn
Background value	20	45	68	900	20	13	74.2
Refernces	22	22	22	22	23	23	24

Results and Discussion

The concentration of heavy metals

The total metal concentrations for each sampling site found in sediments in this study are shown in (Table- 2). The concentration of Pb, Cu, Ni, Mn, Zn, As and Co in Shatt Al-Hilla sediments observed in this study ranging from 10-15.22, 25.6-46.09, 144.9-413.7, 666.1- 906.3, 68.69- 119.2, 5.22- 8.25, 10.3- 68.44 ppm respectively.

These results were similar to that reported in previous study Tigris and Euphrates Rivers [1, 25 26], except for Mn and Ni. The concentration of Mn and Ni was the highest among the studied metals at Summer and Autumn seasons, and this may be due to the high concentration of metal in suspended solids [27], also that heavy metals react with suspended particulate matters and through sedimentation processes, accumulate in bottom deposits. Similar results have been reported from several global locations [17, 28]. The results of the statistical analysis showed significant differences for Cu, Ni, Mn, Zn, and Co in the study stations.

Table 2- Minimum and Maximum (first line), Mean and standard deviation (second line), for the studied metals in the sediment of Shatt Al-Hilla.

Stations	Pb	Cu	Ni	Mn	Zn	Co	As
1	10.9 - 11.6	26.3 - 33.8	144.9-303.5	666.1-797.1	71.17-84.5	22.5- 47.67	5.22-7.34
	11.2 ± 0.294	29.28 ± 3.422	197.9 ± 71.53	745 ± 56.17	77.37 ± 5.478	38.24 ± 9.945	6.3 ± 0.909
	a	a	a	a	a	a	a
2	10.8 - 15.22	25.99 - 47.64	175.8-413.6	743.1-866	72.3-98.46	25.7-68.44	6.5-7.8
	12.36 ± 2.038	36.53 ± 11.95	237.8 ± 117.3	787.3 ± 55.17	92.7 ± 20.73	38.31 ± 20.28	7.125 ± 0.538
	a	b	b	b	b	a	a
3	10 - 14.7	27.43 - 43.41	150.2-385.4	741.3-888.5	75.67-102.5	10.3-49.3	5.6-7.87
	12.81 ± 2.057	33.48 ± 7.096	223.7 ± 108.7	789.9 ± 69.26	85.58 ± 11.67	28.43 ± 16.44	6.663 ± 1.271
	a	a	c	b	ab	b	a
4	10.6 - 13.3	25.6 - 38.95	180.6-385.3	758.2-906.3	68.69-92.6	18.1-49.23	5.58-8.25
	11.83 ± 1.295	32.83 ± 8.29	238.1 ± 71.91	833 ± 79.12	80.25 ± 13.08	26.66 ± 6.544	7.055 ± 1.364
	a	a	b	c	a	b	a

Different superscript letters (a, b, and c) in a column show significant differences ($p \leq 0.05$); SD, standard deviation.

Geo-accumulation index

The geo-accumulation index is a quantitative measure of the degree of pollution in aquatic sediments [10]. Table-3 presents the geo-accumulation index for the quantification of heavy metal accumulation in the study area. The I-geo grades for the study area sediments varies from metal to other and between stations. Lead, Copper, Manganese, Zinc, and Arsenic remain in grade 0 (unpolluted) at all stations which suggesting that the study area sediments are in background value with respect to this metal. The I-Geo for Cobalt reaches grade 0 at stations 3 and 4 (unpolluted), while reach grade 1 at stations 1 and 2 (slightly polluted). The I-Geo for Nickel reaches grade at in all stations which indicate that sediments of these stations were slightly polluted by Ni. This may be due to the discharge of sewage and the dumping of industrial and agricultural waste along the river.

Table3- Geo-accumulation index for studying heavy metals in sediment of Satt Al- Hilla.

Station	I-Geo Pb	I-Geo Cu	I-Geo Ni	I-Geo Mn	I-Geo Zn	I-Geo Co	I-Geo As
1	-0.98	-0.82	0.66	-0.59	-0.36	0.24	-1.129
2	-0.88	-0.61	0.84	-0.53	-0.18	0.25	-1.009
3	-0.85	-0.7	0.78	-0.53	-0.26	-0.05	-1.07
4	-0.93	-0.72	0.84	-0.48	-0.32	-0.11	-1.01

Contamination factor (FC)

The contamination factor used to determine the contamination status of the sediment in the present study. The calculated CF values and PLI are given in Table-4. The results of the present study shown that the CF values of metals such as Pb, Cu, Mn, and As in the study area are low (< 1) which indicates that the sediments of the present study are not polluted by these metals. The CF value of Zn and Co in all locations shows the sediments were moderately contaminated by these metals due to the influence of external discrete sources like industrial activities, agricultural runoff, and other anthropogenic inputs. The CF value of Ni in location 1 shown the sediment is moderately contaminated, while locations 2,3 and 4 are considerable contaminated because the CF value of Ni high ($>3 < 6$) which receives municipal wastewater discharges in the river.

Table 4- Contamination factor and pollution load index for metals in sediment of Satt Al-Hilla.

Station	CF Pb	CF Cu	CF Ni	CF Mn	CF Zn	CF Co	CF As	PLI Index
1	0.56	0.65	2.91	0.82	1.04	1.91	0.48	0.97
2	0.61	0.81	3.49	0.87	1.24	1.92	0.54	1.09
3	0.64	0.74	3.28	0.85	1.15	1.42	0.51	1.01
4	0.59	0.72	4.16	0.92	1.08	1.33	0.54	1.03

Pollution Load Index (PLI)

Pollution severity and its variation along the rivers was determined with the use of pollution load index. This index is a quick tool in order to compare the pollution status of different places [29]. The values of Pollution Load Index Table- 4 indicated that station 1 < 1 therefor considered unpolluted, while as stations 2, 3 and 4 considered polluted because of the value of PLI > 1 . These results attributed principally to anthropogenic sources, such as agricultural fertilizers, municipal wastewater discharges and throw the waste into the river.

Potential Ecological Risk Index (E_r^i)

The values of E_r^i and RI of heavy metals in present study shown in Table- 5, where the lowest value was 0.82 for Mn, while highest value 20.8 for Ni [18]. All results in all stations were < 40 . This indicates low polluted according to Hakanson. These results agreed with [30].

Table 5-Potential Ecological Risk and RI values of heavy metals in sediment of Shatt Al-Hilla.

Stations	Pb	Cu	Ni	Mn	Zn	Co	As	RI
station 1	2.8	3.25	14.55	0.82	1.04	9.55	4.8	36.81
station 2	3.05	4.05	17.45	0.87	1.24	9.6	5.4	41.66
station 3	3.2	3.7	16.4	0.85	1.15	7.1	5.1	37.5
station 4	2.95	3.6	20.8	0.92	1.08	6.65	5.4	41.4

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