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Applying Geoaccumulation Index and Enrichment Factor for Assessing Metal Contamination in the Sediments of Euphrates River, Iraq

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Abstract

The current study looked into heavy metal poisoning of the Euphrates river which runs from Al-Kifl to Kufa in Iraq. One of the goals of this research was to determine the pollution levels and the contamination sources. We looked at six heavy metal (Cd, Pb, Zn, Cr, Fe, and Mn) characteristics in sediment, taking samples from six sites along the Euphrates every season from March 2020 to January 2021. To assess pollution levels, three indices were chosen: enrichment factor (EF), geo-accumulation index (I-geo) and contamination factor (CF). According to EF, the Cd and Pb elements recorded considerable enrichment, very high enrichment and extremely high pollution at practically all sites in four seasons, while the remainder of the HMs recorded deficiency to minimal enrichment and moderate enrichment. In all seasons, the geo-accumulation index showed significant contamination with Cr and moderate to low contamination with other metals. Except Cr in spring, which was recorded with moderate contamination, significant contamination and very high contamination, the CF values of all metals in all sites indicated no sediment contamination by these elements.

Keywords: CF, EF , Euphrates, HMs, Geo-accumulation

تطبيق مؤشر التراكم الجغرافي وعامل الإثراء لتقدير التلوث المعدني في رواسب نهر الفرات ، العراق

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الخلاصة

بحثت الدراسة الحالية التلوث بالمعادن الثقيلة لنهر الفرات في العراق ممتدة من مدينة الكفل إلى مدينة الكوفة. من أهداف هذا البحث هو تحديد مستويات التلوث ومصادره. تم دراسة ستة عناصر للمعادن الثقيلة في الرواسب (الكادميوم، الرصاص، الزنك، الكروم، الحديد والمنغنيز) ، تم أخذ العينات من ستة مواقع على طول نهر الفرات موسميا من تموز 2020 إلى كانون الثاني 2021 لتقييم مستويات التلوث ، تم اختيار ثلاثة

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مؤشرات للتلوث وهي: عامل الإثراء (EF) ، مؤشر التراكم الجغرافي (I–geo) ، وعامل التلوث (CF) . وفقًا لعامل الاثراء سجلت عناصر الكادميوم والرصاص اثراءاً كبيرًا ، وتلوثًا عاليًا للغاية في جميع المواقع تقريبًا خلال أربعة مواسم ، بينما سجلت بقية العناصر الثقيلة بين الحد الأدنى من الاثراء والاثراء المعتدل. أظهر مؤشر التراكم الجغرافي في جميع الفصول تلوثًا معنويًا بالكروم ما بين منخفض الى متوسط مقارنة بالمعادن الأخرى ، باستثناء الكروم في الربيع والذي تم تسجيله بين تلوث معتدل وتلوث كبير ، وتلوث عالي جدًا ، تشير قيم عامل التلوث لجميع المعادن في جميع المواقع إلى عدم وجود رواسب ملوثة بهذه المعادن.

1. Introduction

With a total length of 2940 kilometers, Euphrates is the longest river in Western Asia, with 40% of its length (1213 kilometers) lying in Iraq [1]. Heavy metal contamination is diffused in diverse Iraqi water body [2]. Because of the toxicity, quantity, persistence and bioaccumulation of these elements, heavy metal poisoning has received much attention in recent decades as being a potentially dangerous environmental concern [2-4] . In most developing countries, heavy metal deposition in river sediments exposed to mining and industrial pollutants is a common occurrence [6]. Anthropogenic sources of heavy metals in the environment involve many sources like the burning of fossil fuels, municipal wastes, sewage, pesticides and fertilizers [7]. Sediments can transport heavy metals in the environment [3].

Heavy metals in river sediments enter via various routes, including point and non-point sources [8]. According to several studies, heavy metal concentrations in stream sediments are relatively high due to considerable anthropogenic metal loadings carried by tributary rivers [9]. As a result, surficial sediments may act as a metal puddle, releasing metals into the overlying water and posing a risk to riverine ecosystems [10], [11]. It is well known that physicochemical factors of water, such as pH, dissolved oxygen and organic matter content, have a significant impact on the mobility and availability of heavy metals in aquatic ecosystems [12]. Rivers around cities are frequently contaminated with heavy metals due to the lack of waste treatment facilities in cities and the discharge of trash into nearby water bodies [13].

The water quality deteriorates as heavy metals bioaccumulate in algae blooms in the downstream region of water bodies where pollutants are released from the upstream [14]. The temporal and spatial distribution of heavy metals and pollution levels in sediments from many world rivers have been assessed, including Yinma in China [15], Voghji in Armenia [13], Barigui in Brazil [16], Hrazdan in Armenia [13], Yang in China [17], Thames in the United Kingdom [18] and Lu Lu in China [19]. Many researchers have looked into the spatial distribution of heavy metals in sediments from the Euphrates in Iraq [18–20] .

Many indices have been established in recent years to quantify the extent of sediment contamination and ecological risks. For geochemical standardization, the geo-accumulation index (Igeo), enrichment factor (EF), contamination factor (CF) and pollutant load index (PLI) methodologies have been widely employed [23]. Accumulation of heavy metals in stream sediments has produced serious problems that need to be addressed right away. As a result, sediment analysis is critical in assessing the aquatic environment [9]. The study's major objectives were to examine and assess heavy metal pollution in sediment using the Igeo, CF and EF indices.

2. Materials and Methods

2.1. Sediment Sampling

From March 2020 to January 2021, sediment samples were taken monthly from the Euphrates from six places and identified using GPS devices (Garmin, USA) (Figure 1). Ponar equipment was used to collect these samples.

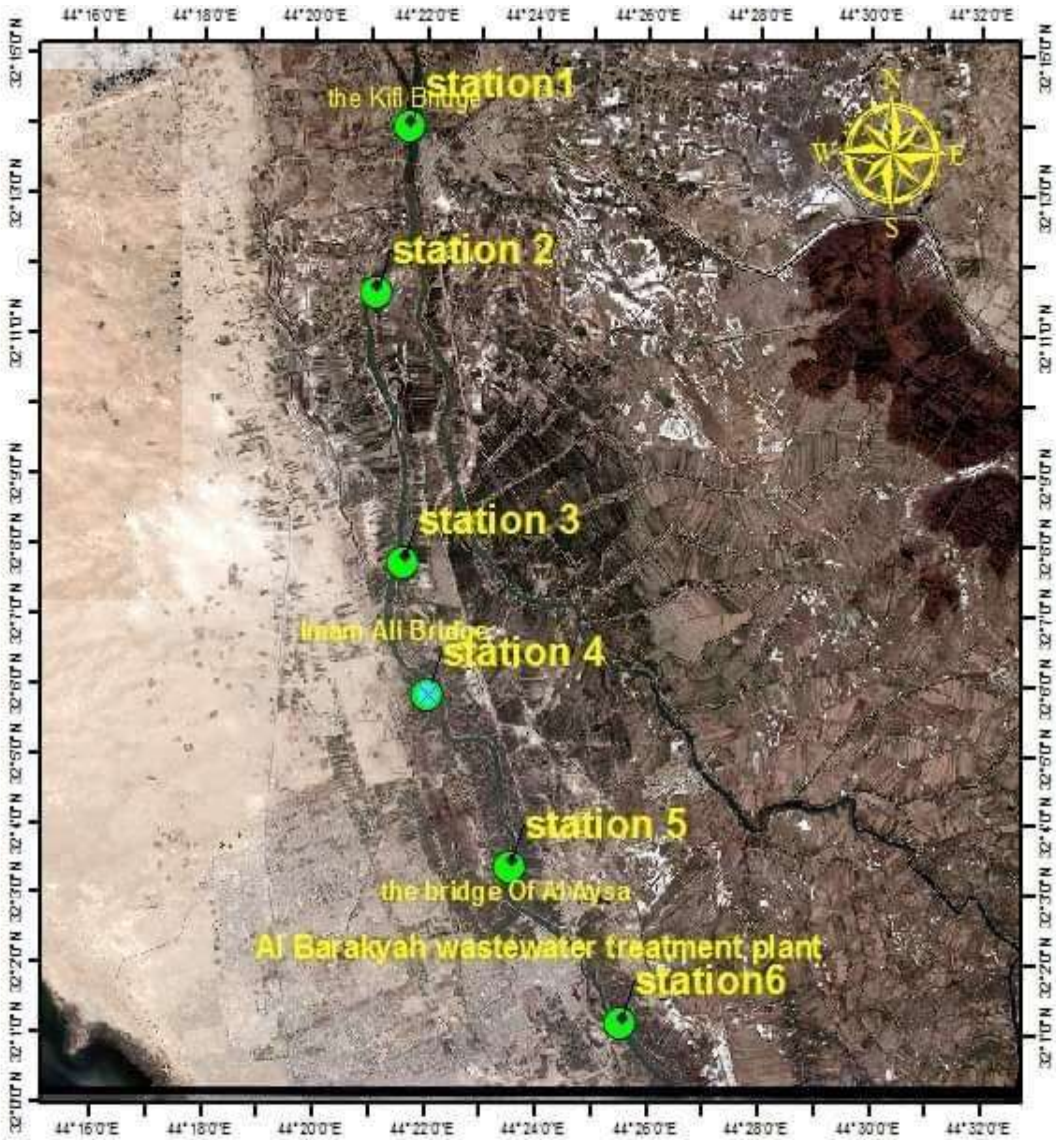

Figure 1: Location map of the study area and sediment sampling sites.

2.2. Sample Preparation and Analysis

The samples were dried before being placed in an oven at 70°C for 24 hours. The sediment samples were homogenized and crushed with an agate ceramic mortar, and then sieved with a 150 µm steel sieve to prepare for digestion [6]. At a 3:1 ratio, a mixture of digesting sediments from concentrated acids (hydrochloric and nitric acids) was created (or aqua regia solution). The sample was mixed after 1 gram of the dry sample was weighed and 10ml of the prepared mixture acids was added. The mixture was then placed in a microwave and digested for 15 minutes at 190°C until nearly dry, after which it was allowed to cool and then rinsed numerous times with deionized water until the entire sample was removed. The volume was then topped up with distilled water to make 50ml after filtering with Whiteman 42 mm filter paper (Islam *et al*., 2015). For HMs studies, the digested samples were examined for Zn, Fe, Cr, Mn, pb and Cd using an atomic absorption spectrophotometer (AAS) from Shimazu, Japan.

2.3. Enrichment Factor (EF):

Enrichment Factor (EF) is a useful technique for estimating the amount of pollutants in the environment [6]. However, it is also a widely used method for determining enrichment ratios by characterizing the degree of anthropogenic pollution [24]. EF is a useful indicator of geochemical trends that may be used to compare different locations. As a result, an increase in the EF value implies an increase in metals supply from anthropogenic activities [25]. As indicated in the equation below, EF is determined in relation to the abundance of species in source material and the ones that are found in the earth's crust [26]:

$$EF = \frac{(C_{M\backslash}\backslash C_X)sample}{(C_M\backslash C_X)earth\ crust}$$

Where (Cm/Cx) denotes the sample's heavy metal concentration ratio.
(Cm) in the soil sample to that of an immobile element (Cx). Because of its natural sources, Fe was chosen as an immobile element [27]. As a result of its prevalence in the crust and high immobility, Fe was chosen as the study's reference element [28]. Fe in the earth's crust has a reference value of 5.0 percent, with a median of 3.5 percent for world sediments. According to [28], EF is divided into five grades as shown in Table 1.

Table 1: Classification of EF grades

Value of EF	Description
V < 2 Minimal Enrichment	Deficiency to
2 ≤ V < 5 Enrichment	Moderate
5 ≤ V < 20 Enrichment	Significant
20 ≤ V < 40 Enrichment	Very High
V> 40 High	Extremely

2.4. Geo-accumulation Index (I_{geo})

The I_{geo} index was first employed with bottom sediments [23] to determine pollution by comparing the quantities of heavy metal collected to a background level. The I_{geo} has long been employed as a pollution indicator in freshwater sediment.
The equation below, which is quoted in [29].
$I_{geo} = \log_2 [Cn / 1.5\ Bn]$

According to [29], I_{geo} is divided into seven grades, ranging from uncontaminated to very contaminated with varied levels ranging from below zero to more than five degrees as mentioned in Table 2.

Table 2: I_{geo}classification showing grades of pollution

I_geo value	I_geo class	Pollution
<0	0	Unpolluted
0-1	1	Unpolluted to Moderate
1-2	2	Moderate Polluted
2-3	3 Moderate to High Polluted	
4	High Polluted	

2.5. Contamination Factor (CF):

Levels of pollution in the sediments were determined using CF. It is the ratio of dividing each metal concentration in the sediments [Cm] by the background (CB) value [30].

$$CF=\frac{Cm\ sample}{Cm\ backgound\ value}$$

The pollution factor levels were distributed into 4 classes [31] as shown in Table 3.

Table 3: Classification of CF after Hakanson (1980)

Value of CF	CF category
V<1	Low contamination
1≤V≥3	Moderate contamination
3≤V≥6	Considerable contamination
V>6	Very high contamination

3.Results and Discussion

Many sediment pollution indicators can be utilized to quantify the extent of heavy metal contamination, especially when considering that practically all test locations were in township areas. Three indices (enrichment factor (EF), geo-accumulation index (Igeo) and contamination factor (CF)) were used to measure the current study contamination level in relation to heavy metals in the sediments for this purpose and to achieve the study objectives [32].

3.1. Enrichment Factor (EF):

EF values of the heavy elements for the studied sites in four seasons are listed in Tables 4, 5, 6 and 7.

In the winter (Table 4), Cd element EF values were extremely high, indicating very significant pollution in all stations except S5 which had moderate enrichment. While the EF value of Pb metal in S5 ranged from deficiency to minor enrichment,. Stations S3 and S1 were within moderate enrichment, while stations S2, S4 and S6 were within significant enrichment, indicating a high level of pollution. In all sites, the EF values of Cr, Fe and Mn metals were within deficiency to minor enrichment. Finally, EF values of Zn metal were within large enrichment in stations S2 and S4, moderate enrichment in stations S3 and S1 and deficiency to minimal enrichment in station S5.

In spring (Table 5), Cd element EF values were extremely high, indicating very high pollution in all stations, except S5 which was deficient to minimally enriched. While the EF value of Pb metal in stations S1 and S5 was within moderate enrichment, stations S3, S4 and S6 were within very high enrichment, and the S1 was within extremely high enrichment showing very high pollution. In all stations, the EF values of Cr, Fe and Mn metals were within deficiency to minimal enrichment, with the exception of Mn in S2 which was within moderate enrichment. Finally, Zn metal EF values were within largely enriched in stations S4 and S6, moderately enriched in station S1, extremely highly enriched in S2, and deficient to minimal enrichment in S5.

In summer (Table 6), Cd element EF values were exceptionally high, indicating extremely high pollution in all stations. Pb metal EF values were moderately enriched in stations S3 and S1 and significantly enriched in stations S2, S4, S5, and S6. In all sites, the EF values of Cr, Fe, and Mn metals were within deficiency to minor enrichment. Zn metal EF values ranged from deficiency to minimal enrichment in S2, moderate enrichment in S1, and extremely high enrichment in stations S3, S4, S5, and S6, showing very significant pollution.

In autumn (Table 7), Cd element EF values were extremely high, thus indicating very high pollution in stations S2 and S6), very high enrichment in stations S3 and S4, and deficiency to minimal enrichment in station S5. Pb metal EF values ranged from deficiency to mildly enriched in stations S1, S3, S4 and S5, major enrichment in station S6, indicating a significant degree of pollution, and extremely high enrichment in station S2, indicating extremely high pollution. In all sites, the EF values of Cr, Fe, and Mn metals were within deficiency to minor enrichment. Finally, at stations S1, S4 and S5 the EF values of Zn metal were within deficiency to low enrichment, in station S3 within moderate enrichment, in S6 large enrichment, and in S2 extremely high enrichment.

The industrial waste from manufacturers and the sanitary waste from hospitals along the river can be blamed for the various enrichment categories, particularly very high and important grades. The heavy elements that fall into the moderate and low enrichment categories could indicate that the elements come mostly from natural crustal materials [33], [34]. The EF values of elements were in the very high enrichment group, indicating that there is a lot of pollution.

3.2 Geo-Accumulation Index (I_{geo})

In winter (Table 4), I_{geo} for all elements occupied the class 0 of negative values which did not exceed the average background within grade unpolluted in all sites (except Mn in S4 site recorded the values in class 3).

In spring (Table 5), I_{geo}values for Cd, Pb, Mn and Zn elements occupied the class 0 of negative values which do not exceed the average background within grade unpolluted in the whole sites. I_{geo} values for Cr element obtain class 1 to class 2 (unpolluted to moderate and moderately polluted grade) in most of sites, except in S4 and S5 which gained extremely polluted values. The geo-accumulation index of Fe element in S1, S2 and S3 sites occupied the class 0 (unpolluted) and I_{geo}values of Fe element in S4, S5 and S6 recorded as extremely polluted.

In summer (Table 6), I_{geo} values of all elements recorded the class 0 (unpolluted) except I_{geo} values of Cr. The I_{geo} values of chromium metal occupied class 3 to class 4 (moderate to highly polluted and high polluted) in most of sites, except in S6 site recorded as class 5 (high to extremely polluted).

In autumn (Table 7), I_{geo} values for Cd, Pb, Fe, Mn and Zn elements recorded in class 0 to class 1 (unpolluted to moderately polluted), except Mn in S5 recorded class 5 (high to extremely polluted) and Fe in S4 recorded class 4 (highly polluted). The I_{geo} values of chromium metal occupied class 3 to class 4 (moderate to highly polluted and highly polluted) in S2, S3 and S6 sites, except in S4 and S5 sites recorded in class 5 (high to extremely polluted).

These different levels of pollution could be due to fertilizer, pesticides and organic chemicals, particularly for As [35], or due to a relationship with Fe and organic materials in oxidizing circumstances for Cr [36]. The effects of sewage sludge on river bed sediments may result in increased Ni mobility and a complexion with dissolved organic chemicals [37]. Tungsten pollution could be traced back to mafic source rocks, industrial waste or anthropogenic influences. During weathering, the highly polluted grade of Ta may become insoluble and immobile [38] .

3. 3 Contamination Factor (CF):

The CF values of the heavy metals in the study area are listed in Tables 4, 5, 6 and 7. According to CF data, Table 4 shows that the values of all metals in all sites were low in contamination during winter, indicating that no sediment had been contaminated by these elements.

The CF values of Cd, Fe, Zn, Mn and Pb metals in (Table 5) were low in contamination during spring, indicating that no sediment was contaminated by these elements. F values of Cr were low contamination in the S1 site, and moderately contaminated in S4 and S6 sites due to the effect of external sources, either agricultural runoff or industrial wastes, considerable contamination in the S2 and S3 sites due to agricultural runoff was very high in these sites, and very high contamination in the S5 site due to the continuous excretion of human waste products from the treatment plant.

Except the CF value of Cr in S1 (Table 6) reported moderately contaminated due to the effects of external sources, such as agricultural runoff or industrial wastes, the CF values of all metals in all sites were low in contamination during summer, indicating no sediment was contaminated by these elements.

The CF values of all metals in (Table 7) at all sites were low contamination in autumn, indicating that no sediment had contamination by these elements.

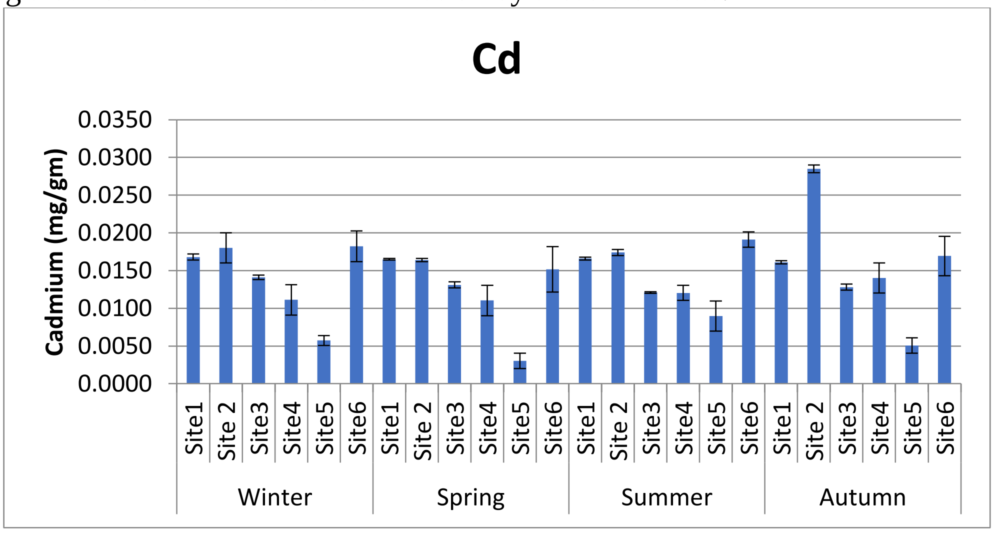

Figure 2: Mean of cadmium metal (mg/g)dry weight with SD± in sediment of Euphrates river during study period.

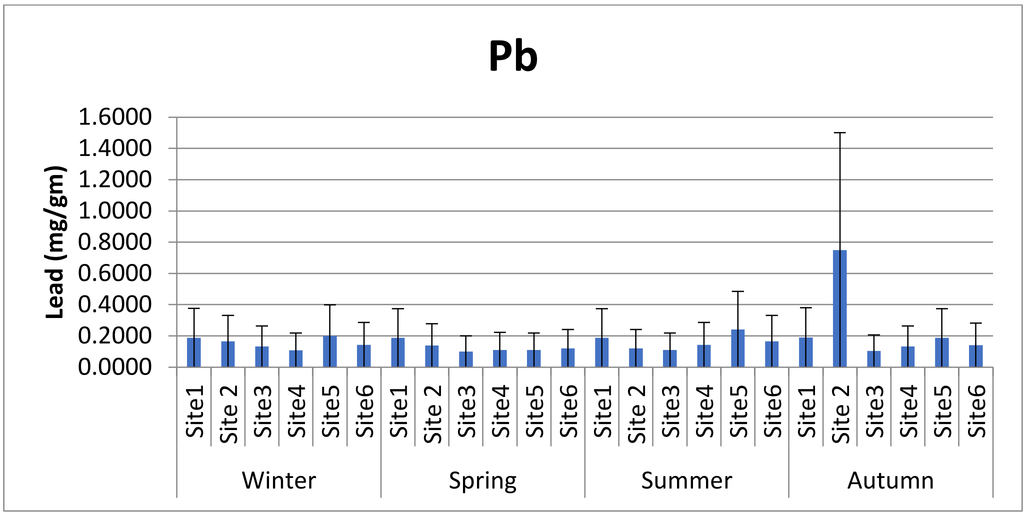

Figure 3: Mean of Lead metal (mg/g)dry weight with SD± in sediment of Euphrates river during study period.

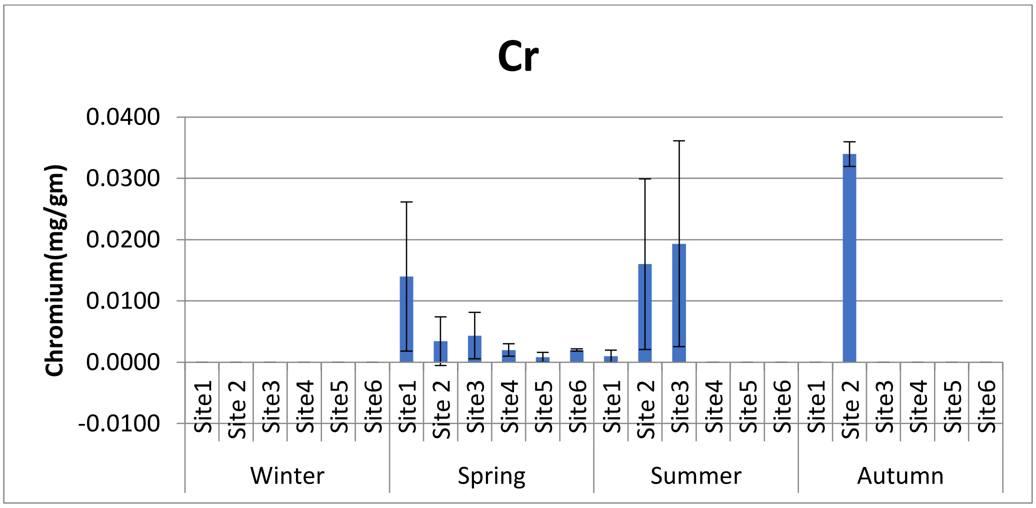

Figure 4: Mean of Chromium metal (mg/g) dry weight with SD± in sediment of Euphrates river during study period.

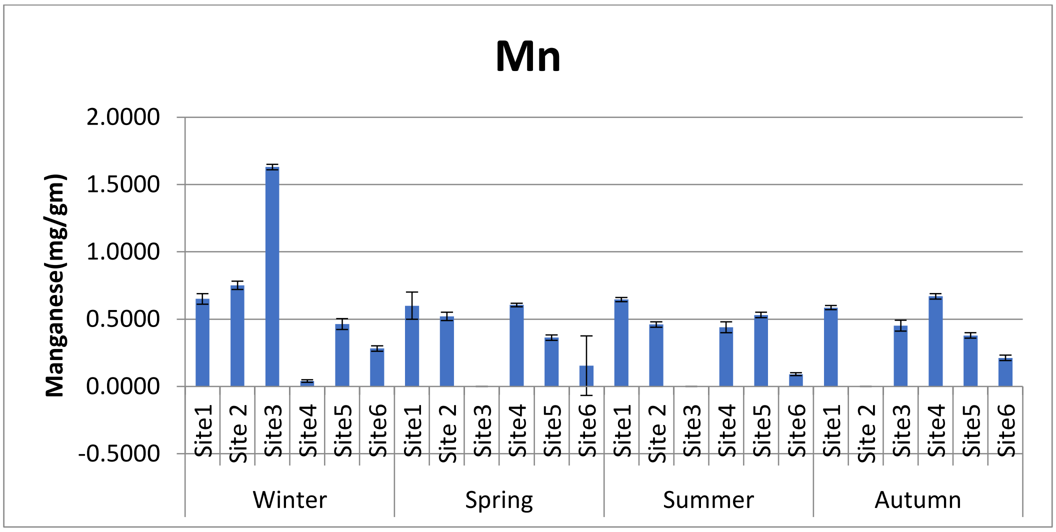

Figure 5: Mean of Manganese metal (mg/g) dry weight with SD± in sediment of Euphrates river during study period.

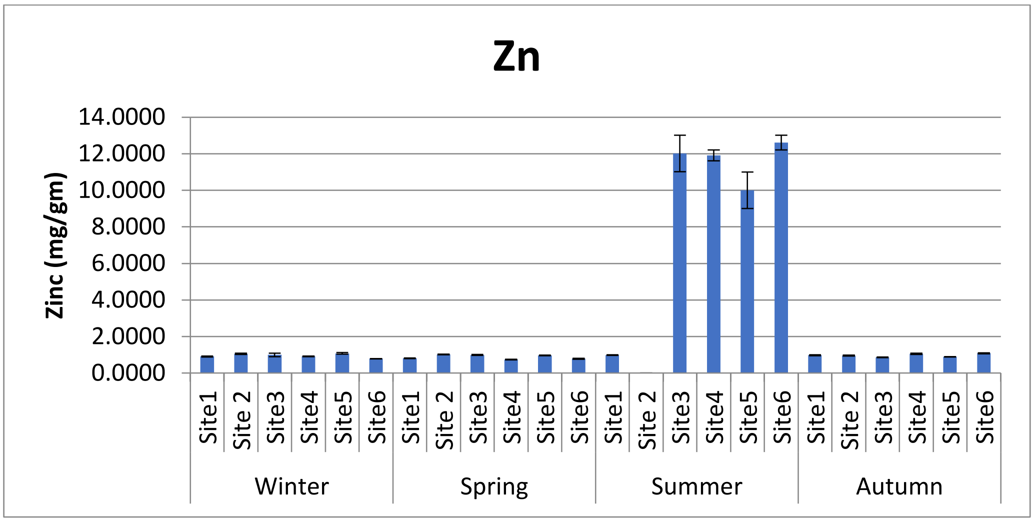

Figure 6: Mean of Zinc metal (mg/g) dry weight with SD± in sediment of Euphrates river during study period.

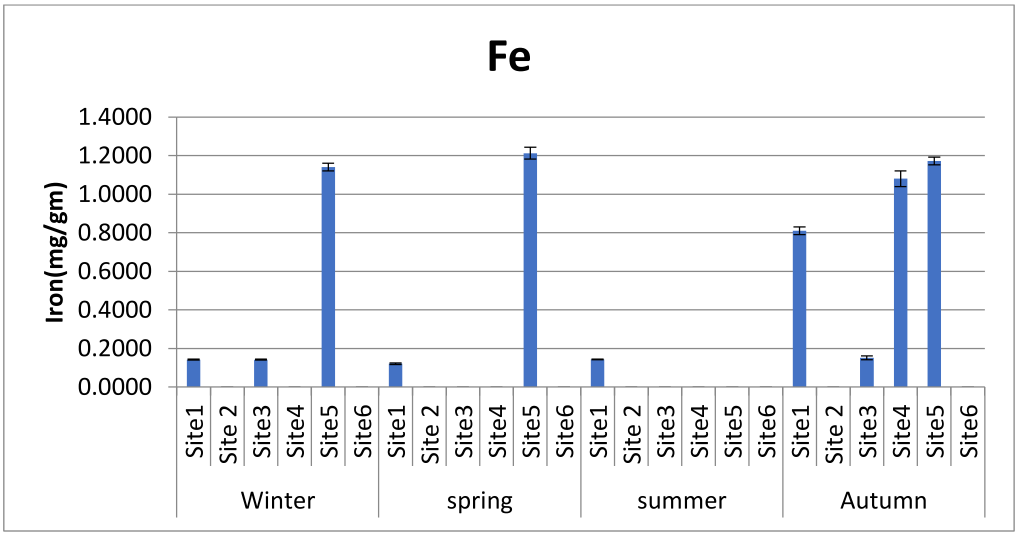

Figure 7: Mean of Iron metal (mg/g) dry weight with SD± in sediment of Euphrates river during study period.

Table 4: Mean of Contamination categories based on I_{geo}, EF and CF in site study during winter season.

Sites	Metals	Mean	Constant	Bn	Constant* Bn	Cn/Constant* Bn	I-geo	EF	CF
S1	Cd	0.0168	1.5	0.11	0.165	0.101818	0.03065	50.54487	0.152727
	Pb	0.188067	1.5	20	30	0.006269	0.001887	3.112566	0.009403
	Cr	0	1.5	90	135	0	0	0	0
	Fe	0.142067	1.5	47	70.5	0.002015	0.000607	1	0.003023
	Mn	0.6502	1.5	390.5	585.75	0.00111	0.000334	0.551239	0.001665
	Zn	0.909767	1.5	95	142.5	0.006384	0.001922	3.167963	0.009576
S2	Cd	0.018	1.5	0.11	0.165	0.109091	0.03284	140.18	0.163636
	Pb	0.165833	1.5	20	30	0.005528	0.001664	7.129045	0.008292
	Cr	0	1.5	90	135	0	0	0	0
	Fe	0.055	1.5	47	70.5	0.00078	0.000235	1	0.00117
	Mn	0.751333	1.5	390.5	585.75	0.001283	0.000386	1.655404	0.001924
	Zn	1.061533	1.5	95	142.5	0.007449	0.002242	9.613067	0.011174
S3	Cd	0.0141	1.5	0.11	0.165	0.085455	0.025724	42.43184	0.128182
	Pb	0.131867	1.5	20	30	0.004396	0.001323	2.181697	0.006593
	Cr	0	1.5	90	135	0	0	0	0
	Fe	0.142067	1.5	47	70.5	0.002015	0.000607	1	0.003023
	Mn	1.6301	1.5	390.5	585.75	0.002783	0.000838	1.381189	0.004174
	Zn	1.000833	1.5	95	142.5	0.007023	0.002114	3.481456	0.010535
S4	Cd	0.011133	1.5	0.11	0.165	0.067475	0.020312	197.9697	0.101212
	Pb	0.108967	1.5	20	30	0.003632	0.001093	10.49014	0.005448
	Cr	0	1.5	90	135	0	0	0	0
	Fe	0.025	1.5	47	70.5	0.000355	0.000107	1	0.000532
	Mn	0.0404	1.5	390.5	585.75	6.9E-05	2.08E-05	0.203005	0.000103
	Zn	0.920567	1.5	95	142.5	0.00646	0.001945	18.74805	0.00969
S5	Cd	0.005733	1.5	0.11	0.165	0.034747	0.01046	2.150794	0.052121
	Pb	0.199833	1.5	20	30	0.006661	0.002005	0.40949	0.009992
	Cr	0	1.5	90	135	0	0	0	0
	Fe	1.140333	1.5	47	70.5	0.016175	0.004869	1	0.024262
	Mn	0.462967	1.5	390.5	585.75	0.00079	0.000238	0.048924	0.001186
	Zn	1.081067	1.5	95	142.5	0.007586	0.002284	0.468917	0.01138
S6	Cd	0.018233	1.5	0.11	0.165	0.110505	0.033265	248.1913	0.165758
	Pb	0.142967	1.5	20	30	0.004766	0.001435	10.7345	0.007148
	Cr	0	1.5	90	135	0	0	0	0
	Fe	0.031333	1.5	47	70.5	0.000444	0.000134	1	0.000667
	Mn	0.2824	1.5	390.5	585.75	0.000482	0.000145	1.084113	0.000723
	Zn	0.788333	1.5	95	142.5	0.005532	0.001665	12.4616	0.008298

Table 5: Mean of Contamination categories based on I_{geo}, EF and CF in site study during spring season.

Sites	Metals	Mean	Constant	Bn	Constant* Bn	Cn/Constant* Bn	I-geo	EF	CF
S1	Cd	0.0165	1.5	0.11	0.165	0.1	0.030103	58.31475	0.15
	Pb	0.187167	1.5	20	30	0.006239	0.001878	3.636847	0.009358
	Cr	0.014	1.5	90	135	0.000104	3.12E-05	0.060393	0.000156
	Fe	0.121	1.5	47	70.5	0.001716	0.000517	1	0.002574
	Mn	0.6	1.5	390.5	585.75	0.001024	0.000308	0.599449	0.001536
	Zn	0.809333	1.5	95	142.5	0.00568	0.00171	3.30976	0.008519
S2	Cd	0.016407	1.5	0.11	0.165	0.099434	0.030054	584.699	0.149152
	Pb	0.138933	1.5	20	30	0.004631	0.001715	27.166	0.006947
	Cr	0.003433	1.5	90	135	2.54E-05	3.2E-05	0.149123	3.81E-05
	Fe	0.012333	1.5	47	70.5	0.000175	0.000359	1	0.000262
	Mn	0.520333	1.5	390.5	585.75	0.000888	0.000295	5.239607	0.001332
	Zn	1.021	1.5	95	142.5	0.007165	0.001861	42.04713	0.010747
S3	Cd	0.0131	1.5	0.11	0.165	0.079394	0.029811	295.4553	0.119091
	Pb	0.100033	1.5	20	30	0.003334	0.001571	12.35193	0.005002
	Cr	0.004333	1.5	90	135	3.21E-05	1.81E-05	0.119918	4.81E-05
	Fe	0.019	1.5	47	70.5	0.00027	0.000213	1	0.000404
	Mn	0	1.5	390.5	585.75	0	0.000259	0	0
	Zn	0.991667	1.5	95	142.5	0.006959	0.002037	25.84687	0.010439
S4	Cd	0.011033	1.5	0.11	0.165	0.066869	0.029933	148.8603	0.100303
	Pb	0.111067	1.5	20	30	0.003702	0.001394	8.267015	0.005553
	Cr	0.002	1.5	90	135	1.48E-05	7.66E-06	0.033199	2.22E-05
	Fe	0.031667	1.5	47	70.5	0.000449	5.27E-05	1	0.000674
	Mn	0.605333	1.5	390.5	585.75	0.001033	0.000267	2.303802	0.00155
	Zn	0.741	1.5	95	142.5	0.0052	0.002157	11.59908	0.0078
S5	Cd	0.003033	1.5	0.11	0.165	0.018384	0.027914	1.0753	0.027576
	Pb	0.109567	1.5	20	30	0.003652	0.001265	0.211835	0.005478
	Cr	0.000833	1.5	90	135	6.17E-06	6.84E-06	0.000358	9.26E-06
	Fe	1.212333	1.5	47	70.5	0.017196	6.55E-05	1	0.025794
	Mn	0.362367	1.5	390.5	585.75	0.000619	0.000178	0.036022	0.000928
	Zn	0.968333	1.5	95	142.5	0.006795	0.00213	0.395467	0.010193
S6	Cd	0.015167	1.5	0.11	0.165	0.091919	0.026272	290.6102	0.137879
	Pb	0.1204	1.5	20	30	0.004013	0.001091	12.86518	0.00602
	Cr	0.002	1.5	90	135	1.48E-05	1.11E-05	0.047348	2.22E-05
	Fe	0.022333	1.5	47	70.5	0.000317	6.97E-05	1	0.000475
	Mn	0.155133	1.5	390.5	585.75	0.000265	9.42E-05	0.850789	0.000397
	Zn	0.789333	1.5	95	142.5	0.005539	0.002081	17.64861	0.008309

Table 6: Mean of Contamination categories based on I_{geo}, EF and CF in site study during summer season.

Sites	Metals	Mean	Constant	Bn	Constant* Bn	Cn/Constant* Bn	I-geo	EF	CF
S1	Cd	0.0166	1.5	0.11	0.165	0.100606	0.030285	49.61153	0.15
	Pb	0.187133	1.5	20	30	0.006238	0.001878	3.075362	0.009
	Cr	0.001	1.5	90	135	7.41E-06	2.23E-06	0.00367	1.11E-05
	Fe	0.143	1.5	47	70.5	0.002028	0.000611	1	0.003
	Mn	0.645867	1.5	390.5	585.75	0.001103	0.000332	0.543558	0.001
	Zn	0.990333	1.5	95	142.5	0.00695	0.002092	3.426056	0.0104
S2	Cd	0.0174	1.5	0.11	0.165	0.105455	0.030772	135.8382	0.158
	Pb	0.1201	1.5	20	30	0.004003	0.001653	5.148589	0.006
	Cr	0.016	1.5	90	135	0.000119	2.23E-06	0.145853	0.00017
	Fe	0.055	1.5	47	70.5	0.00078	0.000478	1	0.00117
	Mn	0.460333	1.5	390.5	585.75	0.000786	0.0003	1.011814	0.0011
	Zn	0	1.5	95	142.5	0	0.001394	0	0
S3	Cd	0.0121	1.5	0.11	0.165	0.073333	0.031623	74.82359	0.11
	Pb	0.109633	1.5	20	30	0.003654	0.001456	3.764476	0.0054
	Cr	0.019333	1.5	90	135	0.000143	1.86E-05	0.146512	0.0002
	Fe	0.07	1.5	47	70.5	0.000993	0.000357	1	0.00149
	Mn	0	1.5	390.5	585.75	0	0.000269	0	0
	Zn	12.01437	1.5	95	142.5	0.084311	0.000683	86.77865	0.1264
S4	Cd	0.012033	1.5	0.11	0.165	0.072929	0.031745	122.4648	0.109
	Pb	0.142967	1.5	20	30	0.004766	0.001205	8.007116	0.0071
	Cr	0	1.5	90	135	0	3.57E-05	0	0
	Fe	0.042	1.5	47	70.5	0.000596	0.000235	1	0.0009
	Mn	0.44	1.5	390.5	585.75	0.000751	0.000237	1.261072	0.00112
	Zn	11.91567	1.5	95	142.5	0.083619	0	140.5281	0.1254
S5	Cd	0.008967	1.5	0.11	0.165	0.054343	0.028522	45.71423	0.0815
	Pb	0.242	1.5	20	30	0.008067	0.001167	6.847639	0.0121
	Cr	0	1.5	90	135	0	3.57E-05	0	0
	Fe	0.083333	1.5	47	70.5	0.001182	0.000263	1	0.001773
	Mn	0.530567	1.5	390.5	585.75	0.000906	0.000158	0.767581	0.001359
	Zn	10.001	1.5	95	142.5	0.070182	0.00848	59.3288	0.1052
S6	Cd	0.0191	1.5	0.11	0.165	0.115758	0.025116	133.2188	0.1736
	Pb	0.165833	1.5	20	30	0.005528	0.001067	6.351496	0.0082
	Cr	0	1.5	90	135	0	4.09E-05	0	0
	Fe	0.064	1.5	47	70.5	0.000908	0.000292	1	0.0013
	Mn	0.0911	1.5	390.5	585.75	0.000156	7.54E-05	0.176705	0.00023
	Zn	12.60667	1.5	95	142.5	0.088468	0.016226	101.7898	0.1322

Table 7: Mean of Contamination categories based onI_{geo}, EF and CF in site study during autumn season.

Sites	Metals	Mean	Constant	Bn	Constant* Bn	Cn/Constant* Bn	I-geo	EF	CF
S1	Cd	0.0161	1.5	0.11	0.165	0.097576	0.029373	8.487448	0.146364
	Pb	0.190033	1.5	20	30	0.006334	0.001907	0.550625	0.009502
	Cr	0	1.5	90	135	0	0	0	0
	Fe	0.810667	1.5	47	70.5	0.011499	0.003461	1	0.017248
	Mn	0.585333	1.5	390.5	585.75	0.000999	0.000301	0.086976	0.001499
	Zn	0.982333	1.5	95	142.5	0.006894	0.002075	0.599543	0.01034
S2	Cd	0.0285	1.5	0.11	0.165	0.172727	0.036914	878.2828	0.259091
	Pb	0.75	1.5	20	30	0.025	0.00378	127.9444	0.0375
	Cr	0.033967	1.5	90	135	0.000252	2.52E-05	1.274802	0.000377
	Fe	0.015	1.5	47	70.5	0.000213	0.00232	1	0.000319
	Mn	0	1.5	390.5	585.75	0	0.0002	0	0
	Zn	0.961733	1.5	95	142.5	0.006749	0.00206	34.46996	0.010124
S3	Cd	0.0128	1.5	0.11	0.165	0.077576	0.044029	36.20258	0.116364
	Pb	0.1031	1.5	20	30	0.003437	0.005786	1.608122	0.005155
	Cr	0	1.5	90	135	0	4.9E-05	0	0
	Fe	0.151333	1.5	47	70.5	0.002147	0.00116	1	0.00322
	Mn	0.451033	1.5	390.5	585.75	0.00077	0.000103	0.358399	0.001155
	Zn	0.862333	1.5	95	142.5	0.006051	0.002053	2.824926	0.009077
S4	Cd	0.014033	1.5	0.11	0.165	0.085051	0.051996	5.576544	0.127576
	Pb	0.131867	1.5	20	30	0.004396	0.007526	0.287141	0.006593
	Cr	0	1.5	90	135	0	7.57E-05	0	0
	Fe	1.08	1.5	47	70.5	0.015319	6.4E-05	1	0.022979
	Mn	0.6699	1.5	390.5	585.75	0.001144	0	0.074669	0.001715
	Zn	1.0632	1.5	95	142.5	0.007461	0.002032	0.487911	0.011192
S5	Cd	0.005067	1.5	0.11	0.165	0.030707	0.042448	1.843797	0.046061
	Pb	0.187067	1.5	20	30	0.006236	0.005363	0.375318	0.009353
	Cr	0	1.5	90	135	0	5.05E-05	0	0
	Fe	1.171667	1.5	47	70.5	0.016619	0.000269	1	0.024929
	Mn	0.378667	1.5	390.5	585.75	0.000646	7.76E-05	0.03893	0.00097
	Zn	0.892333	1.5	95	142.5	0.006262	0.001963	0.376908	0.009393
S6	Cd	0.016933	1.5	0.11	0.165	0.102626	0.033448	269.6566	0.153939
	Pb	0.141067	1.5	20	30	0.004702	0.003021	11.91189	0.007053
	Cr	0	1.5	90	135	0	2.68E-05	0	0
	Fe	0.03	1.5	47	70.5	0.000426	0.000475	1	0.000638
	Mn	0.2117	1.5	390.5	585.75	0.000361	0.000162	0.939599	0.000542
	Zn	1.087	1.5	95	142.5	0.007628	0.001885	19.54348	0.011442

Conclusions:

The current study found that EF values of Cd in all sites and seasons fell into the significant enrichment, very high enrichment and extremely high enrichment categories, indicating very high pollution. Whereas EF values of Pb, Cr, Mn, Zn and Fe fell into the deficiency to minimal enrichment and moderate enrichment categories, indicating very high pollution. The pollution enrichment factor revealed that majority of the stations had low to medium pollution. This metric demonstrated that there were no human operations in the industrial sector during that time period. In all seasons, I_{geo} values for Cd, Pb, Fe, Mn and Zn elements were recorded in class 0 to class 1 (unpolluted to moderately contaminated), while Cr I_{geo} levels were reported in classes 4, 5 and 6 (among highly polluted, very highly polluted and extremely polluted) in all seasons, except in the winter which was recorded in class 0.

Finally, the CF values of Cd, Fe, Zn, Cr, Mn and Pb metals were low in contamination in all seasons and sites, with the exception of Cr CF values in spring which were reported being low, moderate and very highly polluted. Because a significant fraction of elements in sediments is likely to escape back into the water column, the findings suggested that heavy metal pollution should be given special attention. As a result, governmental institutions and business establishments should carefully regulate their garbage disposal. Furthermore, governments in low-income nations should require trash-generating organizations to have waste treatment facilities prior to releasing waste into the environment.

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