



## Estimating Heavy Metal Concentrations in The Waters and Sediments of Shatt Al-Hilla Within Babylon Governorate

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### Abstract

This study aimed to assess the concentrations of selected heavy metals, namely cobalt (Co), nickel (Ni), cadmium (Cd), and lead (Pb), in the waters and sediments of Shatt Al-Hilla, Babylon Governorate, Iraq. Three sampling sites were selected along the river course: Al-Bu'alwan in the northern part of Babylon, the city center of Al-Hilla, and Al-Qasim district in the southern part of the governorate. Seasonal sampling was conducted from January to October 2023 to evaluate temporal variations. Heavy metal concentrations were determined using standard analytical procedures and quantified by atomic absorption spectrophotometry. The highest concentrations recorded in sediments were 24.86  $\mu\text{g kg}^{-1}$  for Co, 165.5  $\mu\text{g kg}^{-1}$  for Ni, 1.09  $\mu\text{g kg}^{-1}$  for Cd, and 2.01  $\mu\text{g kg}^{-1}$  for Pb. In water samples, maximum values reached 0.1921  $\text{mg L}^{-1}$  (Co), 0.258  $\text{mg L}^{-1}$  (Ni), 0.03614  $\text{mg L}^{-1}$  (Cd), and 0.0969  $\text{mg L}^{-1}$  (Pb). The highest concentrations of all investigated metals were observed at Al-Qasim site, particularly during the summer season. Although spatial and seasonal variations were evident, all measured concentrations remained within internationally permissible limits.

Keywords: Heavy metals, Cobalt, Nickel, Lead water, Sediment.

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### Introduction

Rivers represent critical freshwater resources that support agricultural production, domestic water supply, and ecosystem services, particularly in arid and semi-arid regions (28,17). However, increasing anthropogenic pressures have led to the progressive degradation of river water quality, with heavy metal contamination emerging as a major environmental concern due to its persistence, non-biodegradability, and potential for bioaccumulation (28,18). Unlike organic pollutants, heavy metals can remain in aquatic environments for extended periods, posing long-term risks to aquatic ecosystems

and human health (18,16). Globally, numerous studies have documented elevated concentrations of heavy metals in river waters and sediments as a result of industrial discharge, agricultural runoff, urban wastewater, and atmospheric deposition (29,5). In riverine systems, sediments act as both sinks and secondary sources of heavy metals, influencing their mobility and bioavailability under changing hydrological and physicochemical conditions (29). Consequently, the assessment of heavy metal distribution in both water and sediments is widely recognized as a fundamental approach

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for evaluating river pollution status and environmental sustainability (28).

In Iraq, water quality degradation has been exacerbated by reduced river discharge, climate variability, upstream dam construction, and rapid population growth, which have intensified the vulnerability of river systems to pollution, particularly in densely populated and agriculturally intensive regions. Previous studies conducted on major Iraqi rivers have reported variable levels of heavy metal contamination; however, most investigations have either focused on limited spatial scales or lacked seasonal resolution, and many studies primarily report concentration values without adequately addressing spatial-temporal variability or providing a comprehensive environmental interpretation (2). Despite the importance of Shatt Al-Hilla as a major distributary of the Euphrates River and a key water source for Babylon Governorate, systematic assessments of heavy metal contamination in both water and sediments along its course remain limited (17). Existing studies in the region are fragmented, and few have simultaneously evaluated multiple metals across different seasons and locations to capture cumulative anthropogenic impacts (2). This represents a critical knowledge gap, particularly given the increasing agricultural and urban pressures along the riverbanks.

Therefore, the present study aims to (i) quantify the concentrations of cobalt (Co), nickel (Ni), cadmium (Cd), and lead (Pb) in the waters and sediments of Shatt Al-Hilla, (ii) evaluate their spatial and seasonal variability, and (iii) assess the environmental implications of the observed concentrations in relation to international guideline values. By integrating seasonal monitoring with comparative spatial analysis, this study provides an updated environmental baseline that contributes to a better understanding of heavy metal dynamics in Iraqi river systems and supports future water quality management strategies (17,29,2).

## Materials and Methods

### 1. Study Area

The study was conducted in the Babylon Governorate, Iraq, along Shatt al-Hilla, locally known as the “River of Hilla.” Shatt al-Hilla traverses the central plains of Babylon, fed by several minor tributaries before joining the Euphrates River. The river supports the region's agriculture, providing irrigation for crops such as dates, wheat, and barley, and plays a critical role in local water supply and transportation. However, like many rivers globally, Shatt al-Hilla is subjected to pollution, water management challenges, and environmental degradation, making monitoring essential for sustainable management.

### 2. Sampling Design and Locations

Three sampling stations were randomly selected along Shatt al-Hilla to represent the northern, central, and southern sectors of the river:

1. Al-Bu'alwan (northern sector)
2. Al-Hilla city center (central sector)
3. Al-Qasim district (southern sector)

Sampling was conducted seasonally from January to October 2023, with three replicates per station per sampling event to ensure statistical reliability and to capture temporal variability.

### 3. Sample Collection

-Water samples: Collected at a depth of ~1.5 m using pre-cleaned 2.5 L polyethylene containers. Each sample was preserved by acidifying to pH < 2 with concentrated nitric acid immediately after collection and stored at 4°C until analysis.

-Sediment samples: Surface sediments (top 5 cm) were collected using a stainless steel grab sampler, placed in acid-washed polyethylene bags, and transported to the laboratory under refrigerated conditions.

All containers were labeled with date, location, and replicate number. Trip blanks and field blanks were included to monitor contamination during sampling.

### 4. Extraction and Analysis of Heavy Metals

#### 4.1. Sediment Samples

Sediment samples were air-dried, homogenized, and sieved (<2 mm). Heavy metals were extracted using acid digestion following [17], as detailed below:

1 .Weigh 1.0 g of dried sediment into a digestion flask.

2 .Add 10 mL of concentrated nitric acid (HNO<sub>3</sub>) and 5 mL of hydrochloric acid (HCl).

3.Heat the mixture on a hotplate at 95°C until complete dissolution and formation of a clear solution.

4 .Cool, filter, and dilute to 50 mL with deionized water.

#### 4.2 Water Samples

Water samples were subjected to acid digestion based on: (23)

1 .Add 5 mL of concentrated nitric acid to 50 mL of water sample in a 100 mL digestion vessel.

2 .Heat until near dryness, forming white salts.

3 .Add 2 mL of concentrated nitric acid and, if necessary, 5 mL deionized water to dissolve any black residues.

4 .Transfer the digested sample to a 50 mL volumetric flask, add a few drops of dilute hydrochloric acid, and fill to volume with deionized water.

#### 4.3 Atomic Absorption Spectrophotometry (AAS)

Heavy metal concentrations in both water and sediment extracts were measured using a PerkinElmer AAnalyst 400 Atomic Absorption Spectrophotometer equipped with hollow cathode lamps for each metal. Analytical parameters were set as follows:

-Wavelength: Metal-specific (e.g., Pb 283.3 nm, Cd 228.8 nm)

-Slit width: 0.7 nm

-Detection limits: 0.01–0.05 mg/L depending on the element

-Calibration: Five-point calibration curves using standard solutions (0.1–2.0 mg/L)

- Quality assurance/quality control (QA/QC): Triplicate measurements, inclusion of blanks, spiked samples, and certified reference materials (CRM NIST 1640a for water, NIST 2709a for sediment). Recovery rates ranged between 95–105%.

### 5. Statistical Analysis

All data were expressed as mean ± standard deviation (SD) of three replicates. Spatial and seasonal variations in heavy metal concentrations were assessed using one-way ANOVA followed by Tukey's post-hoc test ( $p < 0.05$ ) to determine significant differences among locations and seasons. When normality assumptions were not met, non-parametric Kruskal-Wallis tests were applied. Statistical analyses were performed using SPSS v26.0.

## Results and Discussion

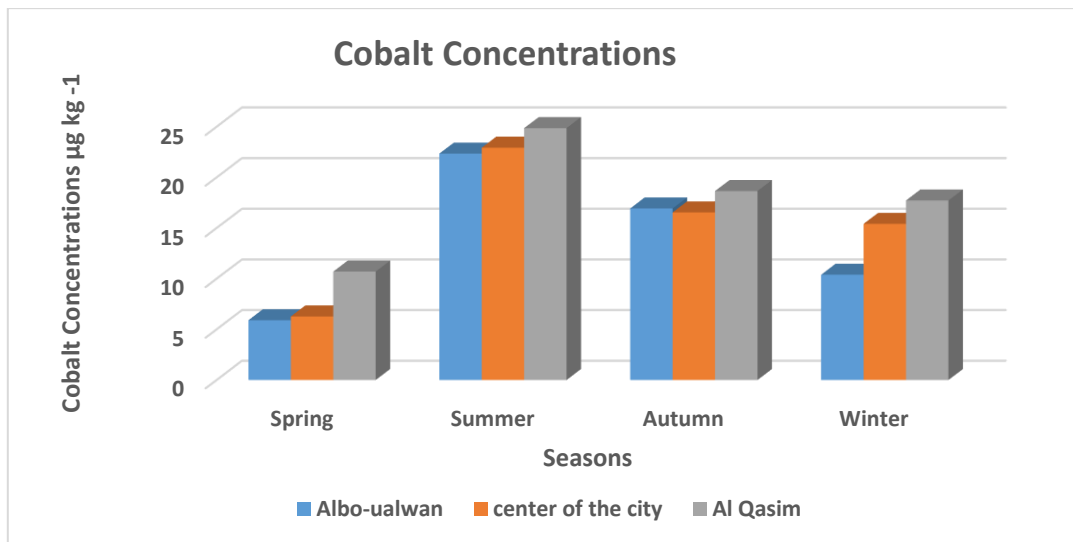
### 1. Heavy Metals in Sediments

The concentrations of heavy metals in the sediments of Shatt al-Hilla exhibited clear spatial and seasonal variability. Cobalt (Co) concentrations were highest at the Al-Qasim site during summer (24.86  $\mu\text{g kg}^{-1}$ ) and lowest at the city center during spring (6.27  $\mu\text{g kg}^{-1}$ ). Nickel (Ni) reached its peak in Al-Qasim during summer (165.5  $\mu\text{g kg}^{-1}$ ) and was lowest in Albo-ualwan during winter (62.22  $\mu\text{g kg}^{-1}$ ). Cadmium (Cd) concentrations peaked at Al-Qasim in summer (1.09  $\mu\text{g kg}^{-1}$ ) and were lowest in Albo-ualwan during spring (0.03  $\mu\text{g kg}^{-1}$ ). Lead (Pb) showed the highest concentration in Al-Qasim during summer (2.01  $\mu\text{g kg}^{-1}$ ) and the lowest in Albo-ualwan during autumn (1.01  $\mu\text{g kg}^{-1}$ ).

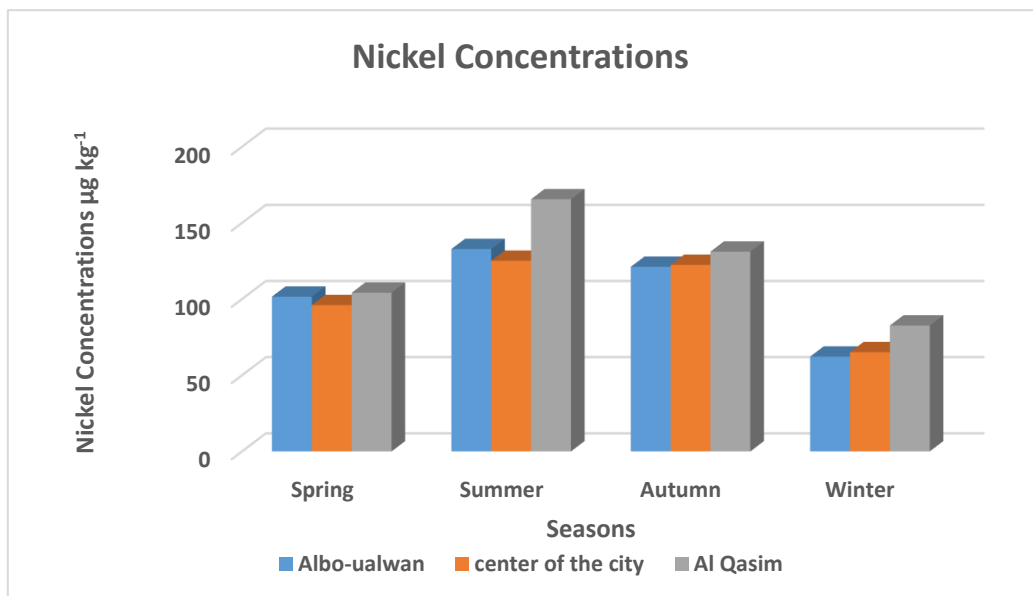
**Table 1.** Seasonal concentrations of heavy metals in sediments of Shatt al-Hilla ( $\mu\text{g kg}^{-1}$ , mean  $\pm$  SD,  $n = 3$ )

Element	Location	Spring	Summer	Autumn	Winter
Cobalt (Co)	Albo-ualwan	5.90 $\pm$ 0.32	22.34 $\pm$ 1.12	16.93 $\pm$ 0.95	10.39 $\pm$ 0.51
	City center	6.27 $\pm$ 0.41	22.93 $\pm$ 1.05	16.54 $\pm$ 0.88	15.41 $\pm$ 0.62
	Al-Qasim	10.70 $\pm$ 0.57	24.86 $\pm$ 1.23	18.65 $\pm$ 0.99	17.72 $\pm$ 0.73
Nickel (Ni)	Albo-ualwan	101.56 $\pm$ 4.5	132.8 $\pm$ 5.2	121.13 $\pm$ 4.8	62.22 $\pm$ 3.1

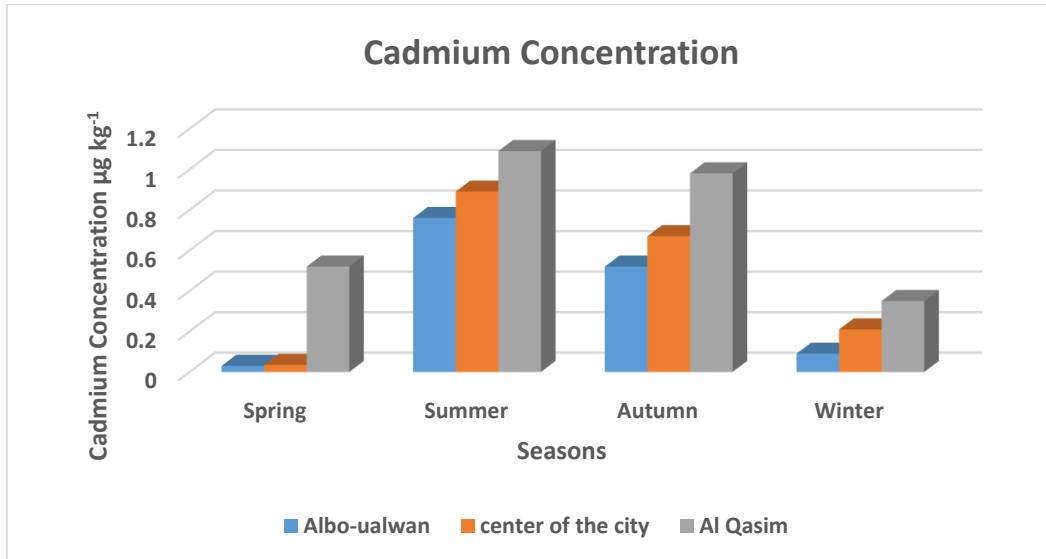
	City center	96.03 ± 4.2	125.1 ± 5.0	122.40 ± 4.6	65.12 ± 3.0
	Al-Qasim	104.15 ± 4.7	165.5 ± 6.1	131.12 ± 5.1	82.59 ± 3.5
<b>Cadmium (Cd)</b>	Albo-uaiwan	0.03 ± 0.002	0.76 ± 0.05	0.52 ± 0.04	0.09 ± 0.01
	City center	0.035 ± 0.003	0.89 ± 0.06	0.67 ± 0.05	0.21 ± 0.02
	Al-Qasim	0.52 ± 0.04	1.09 ± 0.07	0.98 ± 0.06	0.35 ± 0.03
<b>Lead (Pb)</b>	Albo-uaiwan	0.63 ± 0.05	1.35 ± 0.09	1.01 ± 0.06	0.45 ± 0.03
	City center	0.95 ± 0.06	1.94 ± 0.11	1.22 ± 0.07	0.87 ± 0.05
	Al-Qasim	1.29 ± 0.08	2.01 ± 0.12	1.26 ± 0.08	0.99 ± 0.06



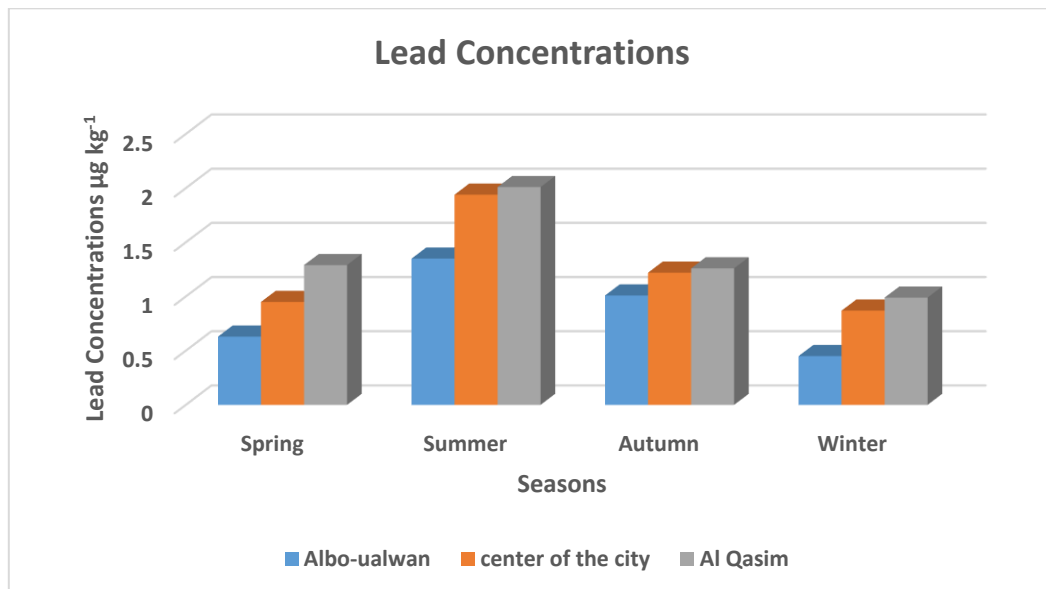
**Figure 1:** Seasonal variation of cobalt (Co) concentrations in surface sediments of Shatt Al-Hilla at different sampling sites. Higher concentrations observed during summer, particularly at the downstream Al-Qasim site, reflect enhanced accumulation under reduced flow conditions.



**Figure 2:** Seasonal variation of nickel (Ni) concentrations in surface sediments of Shatt Al-Hilla at different sampling sites, showing peak accumulation during summer due to increased erosion, runoff, and elevated water flow rates.



**Figure 3:** Seasonal variation of cadmium (Cd) concentrations in surface sediments of Shatt Al-Hilla at different sampling sites. Maximum summer values, especially at Al-Qasim, suggest enhanced leaching from agricultural inputs and weathered soils.



**Figure 4:** Seasonal variation of lead (Pb) concentrations in surface sediments of Shatt Al-Hilla at different sampling sites. Elevated summer concentrations at downstream sites reflect combined effects of higher runoff, erosion, and anthropogenic inputs

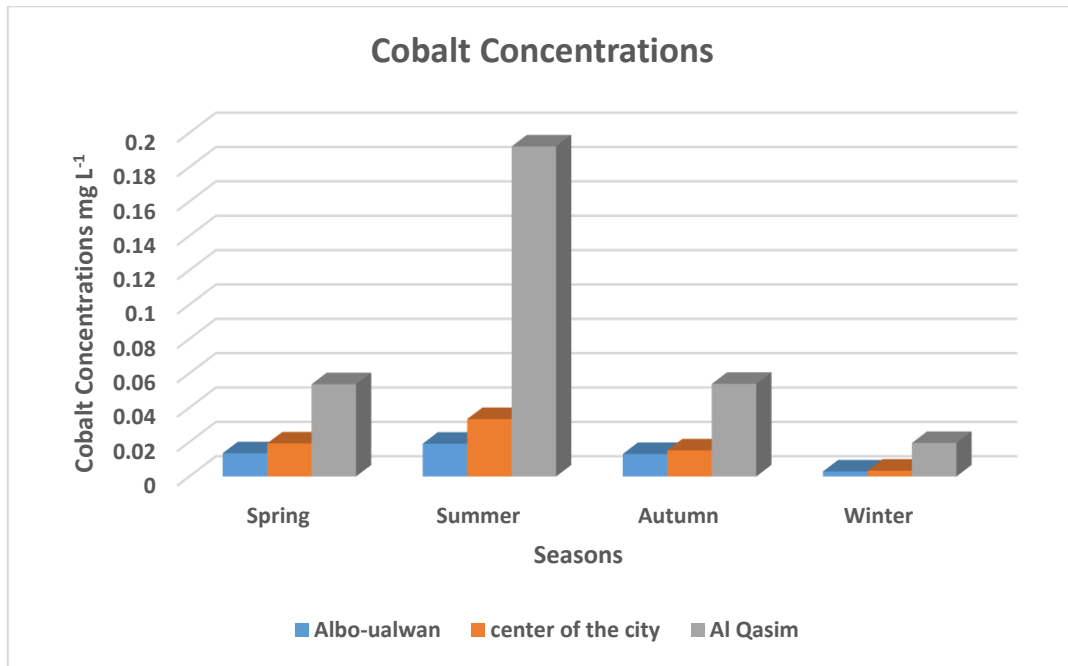
### 2. Heavy Metals in Water

Analysis of heavy metals in river water demonstrated similar spatial and seasonal patterns. Cobalt concentrations were highest at Al-Qasim during summer (0.1921 mg L<sup>-1</sup>) and lowest at Albo-ualwan in winter (0.0029 mg L<sup>-1</sup>). Nickel peaked in Al-Qasim during summer (0.258 mg L<sup>-1</sup>) and was minimal in Albo-ualwan during winter (0.013 mg L<sup>-1</sup>).

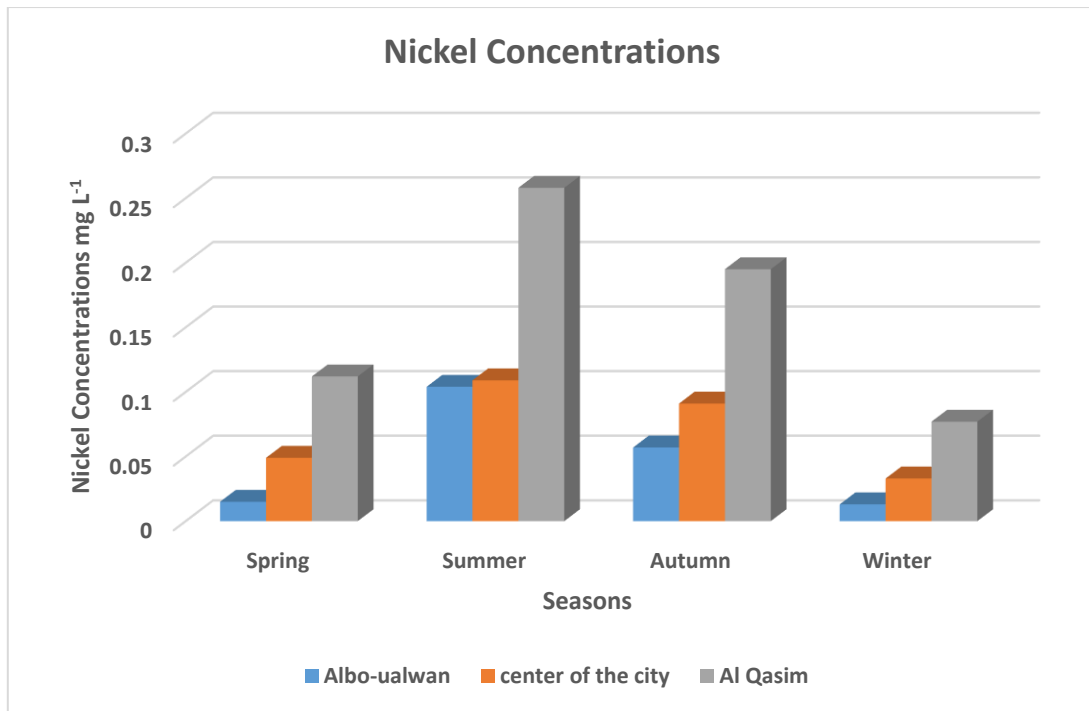
Cadmium reached its maximum at the city center in summer (0.00470 mg L<sup>-1</sup>) and was undetectable in Albo-ualwan during spring and winter. Lead concentrations were highest in Al-Qasim in autumn (0.0969 mg L<sup>-1</sup>) and lowest in Albo-ualwan during winter (0.0017 mg L<sup>-1</sup>).

**Table 2.** Seasonal concentrations of heavy metals in water of Shatt al-Hilla (mg L<sup>-1</sup>, mean ± SD, n = 3)

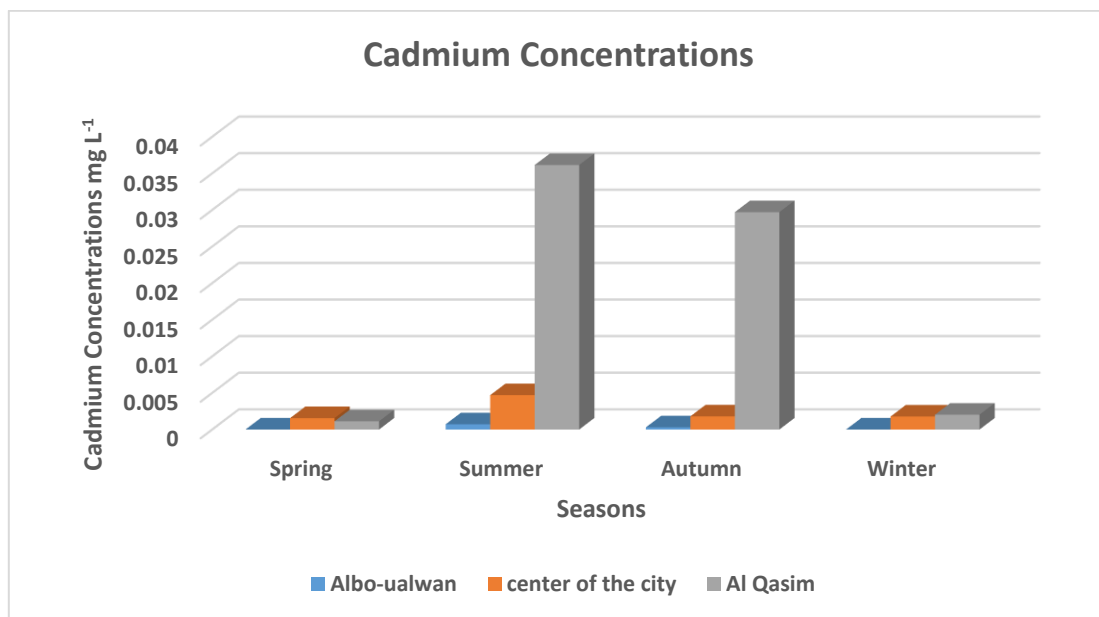
Element	Location	Spring	Summer	Autumn	Winter
Cobalt (Co)	Albo-uaiwan	0.0135 ± 0.001	0.0191 ± 0.001	0.0131 ± 0.001	0.0029 ± 0.0002
	City center	0.0192 ± 0.002	0.0334 ± 0.002	0.0152 ± 0.001	0.0034 ± 0.0003
	Al-Qasim	0.0537 ± 0.004	0.1921 ± 0.008	0.0539 ± 0.004	0.0195 ± 0.001
Nickel (Ni)	Albo-uaiwan	0.015 ± 0.001	0.104 ± 0.005	0.057 ± 0.003	0.013 ± 0.001
	City center	0.049 ± 0.003	0.109 ± 0.006	0.091 ± 0.005	0.033 ± 0.002
	Al-Qasim	0.112 ± 0.006	0.258 ± 0.009	0.195 ± 0.008	0.077 ± 0.004
Cadmium (Cd)	Albo-uaiwan	0.0000 ± 0.000	0.00072 ± 0.00005	0.0003 ± 0.00002	0.0000 ± 0.000
	City center	0.00156 ± 0.0001	0.00470 ± 0.0002	0.0018 ± 0.0001	0.00178 ± 0.0001
	Al-Qasim	0.00112 ± 0.0001	0.03614 ± 0.001	0.0297 ± 0.001	0.00203 ± 0.0001
Lead (Pb)	Albo-uaiwan	0.0038 ± 0.0003	0.0045 ± 0.0003	0.0064 ± 0.0004	0.0017 ± 0.0001
	City center	0.0163 ± 0.001	0.0132 ± 0.001	0.0109 ± 0.0007	0.0098 ± 0.0005
	Al-Qasim	0.0891 ± 0.004	0.0952 ± 0.005	0.0969 ± 0.006	0.0733 ± 0.004



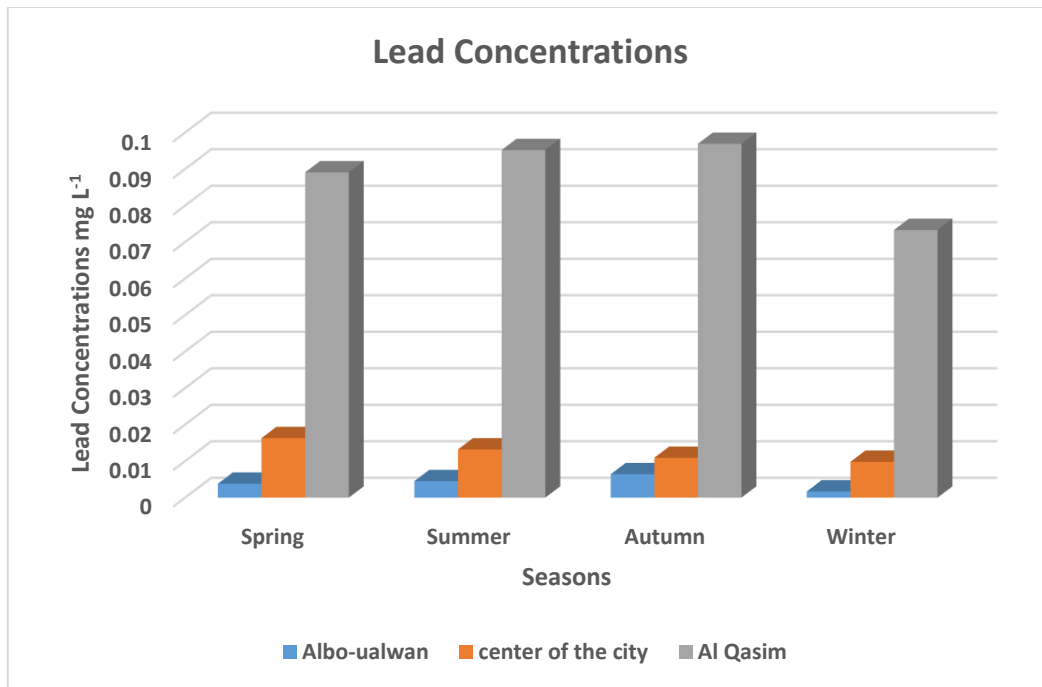
**Figure 5:** Seasonal variation of cobalt (Co) concentrations in water samples along Shatt Al-Hilla. Elevated summer values indicate the combined effects of increased anthropogenic inputs and reduced dilution capacity.



**Figure 6:** Seasonal variation of nickel (Ni) concentrations in water samples along Shatt Al-Hilla. Higher summer concentrations suggest enhanced input from agricultural runoff, industrial activities, and seasonal hydrological changes.



**Figure 7:** Seasonal variation of cadmium (Cd) concentrations in water samples along Shatt Al-Hilla. Peak summer values reflect increased mobilization from soils, fertilizers, and surface runoff during periods of high precipitation and temperature.



**Figure 8:** Seasonal variation of lead (Pb) concentrations in water samples along Shatt Al-Hilla. Elevated concentrations in autumn at downstream Al-Qasim indicate cumulative input from agricultural, industrial, and urban sources, combined with reduced river flow.

Heavy metals in aquatic systems exist in various forms, including dissolved free ions, organic or inorganic complexes, and particulate matter such as sand, silt, or clay (1). Their concentrations are influenced by environmental factors such as temperature, pH, and salinity (12). Both dissolved and particulate forms can enter river systems through wastewater discharges, including municipal sewage, agricultural runoff, and industrial effluents.

The study observed distinct seasonal and spatial variations in the concentrations of cobalt (Co), nickel (Ni), cadmium (Cd), and lead (Pb) in the sediments and water of Shatt Al-Hilla. Elevated concentrations during summer can be attributed to increased weathering and soil erosion driven by higher temperatures and intensified precipitation, which mobilize metals from rocks and soils into river systems (6,15). In contrast, spring exhibited lower metal levels due to milder

temperatures, reduced precipitation, and diminished erosion and runoff.

Specifically, cobalt accumulation in river sediments was higher in summer, particularly at downstream sites such as Al-Qasim, reflecting both natural and anthropogenic inputs. Seasonal irrigation and agricultural activity, including the use of cobalt-containing fertilizers and herbicides, further contribute to summer runoff and metal transport (2). Industrial and mining activities may additionally enhance cobalt inputs during summer, while reduced industrial activity in spring can lower metal loading (4, 25). Water flow regimes also influence cobalt distribution; faster summer flows transport more particulate cobalt into sediments, whereas slower spring flows result in lower deposition (20). Biological processes, including microbial activity and plant uptake, modulate cobalt cycling, with warmer temperatures accelerating microbial liberation of cobalt from organic matter (24).

Nickel exhibited similar seasonal trends, with summer sediment concentrations elevated due to higher erosion and water flow rates that transport nickel-rich particles into the river (7,9). Anthropogenic sources, including industrial discharges, urban runoff, and agricultural inputs, further contribute to seasonal nickel peaks (8,10,11,27). Microbial and plant-mediated processes also affect nickel cycling, with higher temperatures enhancing liberation from organic compounds and cooler winters slowing these processes (19).

Cadmium concentrations were highest in sediments during summer, driven by increased weathering, erosion, and surface runoff. Agricultural activities, such as the application of fertilizers and pesticides, further enhance cadmium mobilization during peak cultivation periods (3,21,26,13). Conversely, spring conditions of lower rainfall and reduced agricultural activity lead to decreased cadmium input and sediment deposition.

Lead exhibited elevated summer concentrations in sediments and water due to intensified weathering and erosion, as well as increased agricultural runoff from lead-containing pesticides and fertilizers (22,14). Downstream sites showed higher accumulation, reflecting cumulative deposition and anthropogenic influence, whereas autumn and winter conditions, characterized by reduced precipitation and agricultural activity, corresponded to lower lead levels (20,14).

Overall, sediments consistently exhibited higher metal concentrations than overlying water, confirming their role as long-term sinks and indicators of heavy metal accumulation in the river system. These seasonal and spatial patterns highlight the combined effects of natural processes (weathering, erosion, hydrological changes) and human activities (agriculture, industry, urban runoff) on metal

cycling in Shatt Al-Hilla. The findings underscore the importance of continuous monitoring and the implementation of effective pollution management strategies to mitigate ecological risks, particularly during high-risk summer periods.

### Conclusion

The study revealed clear seasonal and spatial variations in the concentrations of cobalt, nickel, cadmium, and lead in both sediments and water of Shatt Al-Hilla, with generally higher levels observed during summer and lower levels in spring and winter. Downstream sites, particularly Al-Qasim, consistently exhibited elevated metal concentrations, reflecting cumulative deposition and stronger anthropogenic influence. Sediments consistently contained higher metal levels than water, confirming their role as long-term sinks. Elevated summer concentrations, especially of cadmium and lead, indicate potential ecological risks to aquatic life and irrigation practices. Industrial discharges, urban runoff, and agricultural activities were identified as major contributors to metal loading, highlighting the need for continuous monitoring and effective pollution management. While the study was limited to three sites and four seasonal campaigns, it provides valuable baseline data for future environmental assessment and river management.

### Supplementary Materials:

No Supplementary Materials.

### Author Contributions:

Author 1: methodology, writing original draft preparation, Sarah H. A. Al-ameedee and Bayadir Merza Oudah writing review and editing. All authors have read and agreed to the published version of the manuscript.

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**Informed Consent Statement:**

No Informed Consent Statement.

**Data Availability Statement:**

No Data Availability Statement.

**Conflicts of Interest:**

The authors declare no conflict of interest.

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## تقدير تراكيز بعض العناصر الثقيلة في المياه والرواسب بشط الحلة ضمن محافظة بابل

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### الخلاصة

هدفت هذه الدراسة إلى تقييم تراكيز بعض المعادن الثقيلة المختارة، وهي الكوبالت (Co) والنيكل (Ni) والكاديوم (Cd) والرصاص (Pb)، في مياه ورسوبات شط الحلة بمحافظة بابل، العراق. جرى اختيار ثلاثة مواقع لأخذ العينات على امتداد مجرى النهر، شملت منطقة البو علوان في الجزء الشمالي من المحافظة، ومركز مدينة الحلة، ومنطقة القاسم في الجزء الجنوبي من المحافظة. نُقِّدَت عمليات أخذ العينات بصورة موسمية خلال المدة من كانون الثاني إلى تشرين الأول ٢٠٢٣، بهدف تقييم التغيرات الزمنية في تراكيز المعادن الثقيلة. تم تحديد تراكيز هذه المعادن باستخدام طرائق تحليلية قياسية، وقياسها بواسطة مطيافية الامتصاص الذري. سُجِّلت أعلى التراكيز في الرسوبيات عند قيم بلغت ٢٤.٨٦ ميكروغرام كغم<sup>-1</sup> للكوبالت، و ١٦٥.٥ ميكروغرام كغم<sup>-1</sup> للنيكل، و ١.٠٠٩ ميكروغرام كغم<sup>-1</sup> للكاديوم، و ٢.٠١ ميكروغرام كغم<sup>-1</sup> للرصاص. أما في عينات المياه، فقد بلغت القيم العظمى ٠.١٩٢١ ملغم لتر<sup>-1</sup> للكوبالت، و ٠.٢٥٨ ملغم لتر<sup>-1</sup> للنيكل، و ٠.٠٣٦١٤ ملغم لتر<sup>-1</sup> للكاديوم، و ٠.٠٩٦٩ ملغم لتر<sup>-1</sup> للرصاص. لوحظت أعلى تراكيز لجميع المعادن المدروسة في موقع القاسم، ولاسيما خلال فصل الصيف، وعلى الرغم من وجود تباينات مكانية وزمانية واضحة، فإن جميع التراكيز المقاسة بقيت ضمن الحدود المسموح بها دولياً.

كلمات مفتاحية: المعادن الثقيلة، النحاس، النيكل، الرصاص، الماء، الرواسب.

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