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Research article

Study of the extent of pollution of river island sediments with some heavy metals in the Tigris River within Wasit Province

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ABSTRACT

A study was aimed to determine the pollution levels of certain heavy metals on river islands in the Tigris River within Wasit Governorate. Five sites were identified for the study distributed across the districts and sub-districts through which the river flows within Wasit Province. The samples were collected from Al-Suwaira, Al-Aziziyah, Al-Zubaidiyah, and Al-Numaniyah and south of Kut Districts. Two islands were selected at each site (district or sub-district): one located north of the city before the river enters it, and the other located below the city after the river enters it. Two sampling points were selected on each island: one at the island's head and the other in the middle, at depths of 0 to 30 cm and 30 to 60 cm, respectively. Sediment samples were collected on October 20, 2025. The material was placed in special bags, and the heavy metal pollution levels (Fe, Cd, Zn, Ni, and Pb) were assessed. The heavy metal pollution results showed that the Al-Zubaidiya and Al-Suwaira areas recorded the highest levels. Nickel concentration was approximately 82 mg/kg⁻¹ before the city of Al-Kut and 48.5 mg/kg⁻¹ after Al-Aziziyah. These values are considered high, placing the area within the categories of high to moderate pollution. Iron concentrations were 17624 and 24102 mg.kg⁻¹, indicating moderate contamination, as concentrations were higher in surface layers compared to subsurface layers, with spatial variation between study sites. Al-Suwaira came in second, recording the highest lead level 62.5 mg kg⁻¹ at the beginning of the island, at the surface depth after Al-Suwaira. This value is high when compared to the limits set by the US Environmental Protection Agency (US.EPA). Overall, for all the studied pollutants, the results indicate that location between districts was the most influential and consistent factor in explaining the variation in heavy metal concentrations. This indicates that spatial differences between the study sites are a crucial factor in the distribution of these metals.

1. Introduction

River islands are one of the geomorphological features formed in rivers by erosion, transport, and deposition processes, particularly during the sedimentation stage. They are among the most important geomorphological phenomena in most rivers. Human activities directly impact rivers, affecting their contents and how they are utilized (Umrar, 2015). River islands are important components in the development or degradation of river ecosystems according their function as a velocity restrictor and increasing the diversity of water flow distribution. They also trap various sediments, which may be beneficial or pollutants that accumulate that causing high flow resistance.

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This has led to the removal of river islands during irrigation and river maintenance projects (Maryono et al., 2023).

The river sediments is importance because it plays a role in determining the nature of these sediments, composition, and mineral content. They are organic or mineral particles, and mineral composition, whether clay or non-clay minerals. As well as, to the chemical composition, fertilizers, and pollutants. This is reflected in the nature of the lands on which they will be deposited over time due to the decrease in river load, or as a result of irrigating the land with river water loaded with these sediments, or due to the engineering facility built on the course of rivers, or due to the transfer or use of these sediments by humans (Al-Shihmani & Kareem, 2024).

The sedimentation and expansion of river islands are among the growing problems in the Tigris River. This is due to the reduced river flow velocity caused by climate change and increased sedimentation rates in the river basin. These factors have altered the watercourse, affecting water transport density, movement, and flow. Sediment accumulation has changed the direction and speed of water flow, increasing the likelihood of lateral erosion along riverbanks. Furthermore, the storage capacity of the river channel decreases, increasing the risk of flooding during periods of high water levels. These islands also impact irrigation projects, potentially blocking water intake points or drinking water treatment plants. This necessitates periodic dredging and cleaning of the supply canals to these plants, in addition to reducing their efficiency (Golubtsov & Chalov, 2025). Therefore, the study was aimed to determine the pollution levels of certain heavy metals on river islands in the Tigris River within Wasit Governorate.

2. Materials and Methods

2.1 Sampling Site Selection

Five sites were selected for the study on river islands located in the Tigris River, distributed across the districts and sub-districts through which the Tigris flows within Wasit Governorate. The study focused on the southward course of the Tigris River, extending from Al-Suwaira in northern Wasit Governorate, through Al-Aziziyah, Al-Zubaidiyah, and Al-Numaniyah and Al-Kut Districts. This area represents the Tigris River's main extension, and most of the river islands are located within this stretch of the Tigris River in Wasit Governorate.

Satellite imagery was used to locate these islands, determining their positions, sizes, and types, and whether they were attached to the riverbank or not. Two islands were identified in each district or sub-district: one located to the north, before the river enters the city, and the other to the lower part of the city, after the river has passed through it. Within each island, two sampling sites were identified: one at the island's head and the other in its center, at depths of 0 to 30 cm and 30 to 60 cm, respectively.

2.2 Samples collection

Samples were collected from the sediment deposited on river islands in the river channel. Samples were taken from two locations on each island. The first location represents the island's head (the point where the island's sediment begins to be intercepted by the river's flow, representing the most recent sediment accumulation. The second location represents the midpoint of the island's various dimensions (north-south and east-west), representing the island's midpoint and its initial stages of formation. Sediment samples were collected on October 20, 2025. After sampling, the island sediment was air-dried, then ground and passed through a 2 mm sieve before being placed in special bags for the purpose of assessing heavy metal contamination (Fe, Cd, Zn, Ni, and Pb).

After preparing the samples for the determination of the total concentrations of heavy metals (Fe, Cd, Zn, Ni, Pb) using the wet digestion method, a mixture of perchloric and sulfuric acids was prepared. The samples were digested and extracted, and the concentrations were measured using an Atomic Absorption Spectrophotometer (AAS). A Japanese-made AAS was used, following the method of Davies (1992). The results were then compared with internationally accepted standards for heavy metal concentrations. As shown in Table (1) regarding the classification standard for heavy metal contaminated sediments (mg.kg^{-1}) according to the US Environmental Protection Agency (US.EPA) (1991), and Table (2) regarding the permissible limits according to the WHO (2007) for total soil heavy metal concentrations (mg.kg^{-1}).

Table (1) Classification Standard for Heavy Metal Contaminated Sediments (mg.kg^{-1})

Metals	Unpolluted,	moderately polluted	heavily polluted
Cadmium (Cd)	> 6	-	-
Zinc (Zn)	> 200	200 - 90	< 90
Lead (Pb)	> 60	60 - 40	< 40
Iron (Fe)	> 25000	25000 - 17000	< 17000
Nickel (Ni)	> 50	50 - 20	< 20

Table (2) showing the permissible limits according to (WHO 2007) for total concentrations of heavy metals in soils (mg.kg^{-1} soil)

Heavy Metals	permissible limits(mg. kg^{-1} soil)
Cadmium (Cd)	3
Nickel (Ni)	50
Lead (Pb)	100

2.3 Statistical Analysis

The data were statistically analyzed using Gen Stat V.12.1 software, employing a factorial analysis of variance (ANOVA) to study the effects of the studied factors and their interactions on the factors under investigation. Two-way ANOVA was used to test the significance of the effect of location and depth, or location and position, depending on the nature of each table, as well as to test the significance of the interaction between them. When significant differences were found between the means, the means were compared using the least significant difference (LSD) test at a probability level of 0.05, and the differences were considered statistically significant at $P \leq 0.05$.

3. Results and Discussion

3.1 Cadmium(cd)

The results of the mean cadmium values showed that the highest value was (0.251 mg.kg^{-1} Cd at the beginning of the island for the surface depth before Al-Zubaidiya, and the lowest value was (0.161 mg.kg^{-1} Cd at the middle of the island for the subsurface depth after Al-Aziziya. With an average of 0.188 mg (Table 3). Pollution levels were found to be low when compared to the limits adopted by the US Environmental Protection Agency (USEPA, 1991) and the World Health

Organization (WHO, 2007). It is also evident that cadmium values were higher at the island's head than in its center. This may be due to the fact that the most recent sediments are mostly located in the outer parts of the island, as there are temporal and spatial variations in the content of river pollutants, especially over time (Bednarova et al., 2013).

Table (3). Concentrations of Cadmium (mg kg^{-1}) in river-island sediments at different sampling locations and depths

Sampling location	Position	0–30 cm	30–60 cm	Mean
Al-Suwayrah	Before	0.225	0.206	0.216
	After	0.219	0.188	0.204
Al-Aziziyah	Before	0.181	0.162	0.172
	After	0.181	0.105	0.143
Al-Zubaydiyah	Before	0.243	0.161	0.202
	After	0.251	0.211	0.231
Al-Numaniyah	Before	0.190	0.183	0.187
	After	0.179	0.153	0.166
Al-Kut	Before	0.209	0.198	0.204
	After	0.174	0.151	0.163
Overall mean	—	0.205	0.172	0.188

Statistical test	Location	Depth	Location × Depth
LSD ($p = 0.05$)	0.048	0.0217	NS

Note. LSD = least significant difference; NS = not significant. Concentrations are reported as mg kg^{-1} dry weight; confirm this unit against the analytical method.

It was also observed that cadmium concentrations were higher in the surface layer than in the subsurface layer at most locations, except for the Al-Kut site. This is attributed to the difference in the content of pollutants in sedimentary cycles between the present and past. The sequence of cadmium concentrations was ascending as follows: (Al-Suwaira, Al-Aziziyah, Al-Zubaidiyah, Al-Numaniyah and Al-Kut). This indicates that the sources of river pollution were greater in Al-Zubaidiyah due to the Al-Zubaidiyah power station, whose effects also reached Al-Nu'maniyah (Tomczyk et al., 2021). Al-Suwaira ranked second due to its proximity to Baghdad, making it susceptible to pollutants released from the Diyala River and from power plants, factories, and industrial facilities, the effects of which can reach Al-Suwaira. The results of the two-way ANOVA statistical analysis showed that the concentrations of the studied heavy metals were affected to varying degrees by both location and depth (Table 3), in addition to the interaction between these factors for some metals. This indicates that the distribution of these metals in soil or sediments is not governed by a single factor, but rather is determined by the interaction between the spatial characteristics of the location and the depth variations in the studied area. (Ouyang et al., 2002).

Table 3, the statistical analysis (location * depth) for cadmium, shows a significant effect of both location and depth, while the interaction between them was not significant. This indicates that the variation in cadmium concentrations is due to spatial variation between locations on the one hand, and to variation in depth on the other, without a clear statistical effect from the combined response of these two factors. This can be explained by the fact that cadmium is affected by the characteristics of each location, such as the nature of the sedimentation and potential sources of pollution, as well as its tendency to accumulate relatively in surface layers compared to deeper layers. (Tsai et al., 2007). The statistical analysis (location * position within the island) (Table 4). for some pollutants in river island

sediments, shows the effect of location within the river island, represented by the starting and middle locations, on the concentrations of the studied heavy metals in the river island sediments across different districts. The results show that this effect was not uniform among the metals, as each metal's response varied according to its geochemical nature and its interaction with local depositional conditions at each location. It presents the statistical analysis (location * position relative to the island) for cadmium (Cd). The site averages show that its concentration was significantly higher at the beginning of the river island compared to its center, with an overall average of 0.195 at the beginning versus 0.182 at the center. This difference exceeded the site's LSD value of 0.0122, indicating a significant effect of position on the distribution of these metals. This suggests that cadmium tends to accumulate in the early parts of river islands (Table 4).

Table (4).Statistical Analysis (Location* position within the island) of Cd (mg kg⁻¹) in river island sediments

location	Before Al-Suwayrah	After Al-Suwayrah	Before Al-Aziziyah	After Al-Aziziyah	Before Al-Zubaydiya	After Al-Zubaydiya	Before Al-Numaniya	after Al-Numaniya	Before Al-Kut	After Al-Kut	Average
0-30	0.232	0.210	0.183	0.151	0.205	0.235	0.237	0.193	0.188	0.113	0.195
30-60	0.200	0.198	0.160	0.135	0.199	0.228	0.136	0.140	0.219	0.212	0.182
average	0.216	0.204	0.172	0.143	0.202	0.231	0.166	0.166	0.203	0.162	
LSD 0.05	locations	position	Location× position								
	0.027	0.0122	0.039								

This may be related to the initial deposition rate of the cadmium-bearing particles when the island first obstructs the flow. The overlap between the district and the location was also significant, indicating that the difference between the beginning and middle levels was not constant across all districts, but rather varied in intensity from one location to another. This variation is attributed to recent additions or continuous surface deposition of this metals. (Bednarova et al., 2013).

3.2. Zinc (Zn)

The results of the average pollutant values in Table (5) for zinc in river island sediments show that the highest value (74) mg.kg-1 was at the beginning of the island at the surface depth After Al-Suwayrah, and the lowest value (39) mg.kg-1 was recorded at the middle of the island at the subsurface depth before Al-Kut, with an average of (59.37) mg.kg-1. These values were low when compared to the limits adopted by the US Environmental Protection Agency (USEPA, 1991) and the World Health Organization (WHO, 2007). This indicates that the islands are not contaminated with zinc. Furthermore, zinc values at the beginning of the island were higher than at the middle level in most locations. Furthermore, its concentration in the surface layers was higher than in the subsurface layers. The zinc concentrations followed an ascending distribution as follows: (Al-Suwaira, Al-Aziziyah, Al-Zubaidiyah, Al-Numaniyah and Al-Kut). This indicates a decrease in concentration with distance traveled downstream, suggesting that its source originated outside Wasit Governorate. The initial deposit was in Suwayra, followed by Aziziyah, which is attributed to the high concentrations of zinc in the river sediment coming from Baghdad. These sediments gradually decompose with distance, potentially decreasing their zinc content. (Zhang et al., 2014).

Table (5). Concentrations of Zinc (mg kg^{-1}) in river-island sediments at different sampling locations and depths

Sampling location	Position	0–30 cm	30–60 cm	Mean
Al-Suwayrah	Before	67.00	62.00	64.50
	After	74.00	63.50	68.75
Al-Aziziyah	Before	73.00	69.50	71.25
	After	68.50	64.50	66.50
Al-Zubaydiyah	Before	61.50	53.00	57.25
	After	50.50	45.50	48.00
Al-Numaniyah	Before	67.50	54.50	61.00
	After	62.00	60.00	61.00
Al-Kut	Before	48.50	39.00	43.75
	After	54.50	49.00	51.75
Overall mean	—	62.70	56.05	59.37
Statistical test	Location	Depth	Location × Depth	
LSD ($p = 0.05$)	5.83	2.61	NS	

Note. LSD = least significant difference; NS = not significant. Concentrations are reported as mg kg^{-1} dry weight; confirm this unit against the analytical method.

The statistical analysis (location * depth) for zinc showed a significant effect of both location and depth, while the interaction between them was not significant. This pattern suggests that zinc behaves similarly to cadmium, with its concentrations varying independently with location and depth. This may be attributed to the varying nature of the deposited materials between locations, as well as the fact that zinc is usually associated with organic matter and fine particles, which are more concentrated in certain locations and surface layers, leading to a clear variation in its distribution. (Sun and Zhang, 2017). The results show the statistical analysis (location * position relative to the island) of zinc (Zn) (Table 6). It was significantly affected by both the district and the location, with the average annual concentration reaching 64.65 mg.kg^{-1} at the beginning compared to 54.10 mg.kg^{-1} at the middle, exceeding the LSD value of 2.412 for the position (Table 6). This indicates a clear advantage in zinc concentration at the beginning location. This reflects that zinc is sensitive to spatial gradients within the island, and that its deposition is highest at the first part facing water movement, where the likelihood of trapping fine particles or associated suspended matter increases. However, the overlap between the jurisdiction and the location was not significant, meaning that the trend of increasing at the beginning compared to the middle was almost constant in most jurisdictions (Yao et al., 2015).

Table (6). Statistical Analysis (Location* position relative to the island) of Zn (mg kg^{-1}) in river island sediments

location	Before Al-Suwayrah	After Al-Suwayrah	Before Al-Aziziyah	After Al-Aziziyah	Before Al-Zubaydiyah	After Al-Zubaydiyah	Before Al-Numaniyah	after Al-Numaniyah	Before Al-Kut	After Al-Kut	Average
0-30	68.5	72.0	76.0	74.0	60.5	50.5	66.0	69.0	51.5	58.5	64.7
30-60	60.5	65.5	66.5	59.0	54.0	45.5	56.0	53.0	36.0	45.0	54.1
average	64.5	68.8	71.3	66.5	57.3	48.0	61.0	61.0	43.8	51.8	
LSD 0.05	locations	position	Location× position								
	5.393	2.412	N.S								

3.3. Nickel (Ni)

Table (7) shows that the average nickel content in the river island sediments reached its highest value of 82 mg.kg^{-1} at the island's subsurface depth before the city of Al-Kut, and its lowest value of 48.5 mg.kg^{-1} at the island's surface depth after Al-Aziziyah, with an average of 68.8 mg.kg^{-1} . These nickel levels were high compared to the limits set by the US Environmental Protection Agency (US.EPA, 1991). Values greater than 50 mg.kg^{-1} indicate severe pollution, while values between 20 and 50 mg.kg^{-1} indicate moderate pollution. However, the World Health Organization (WHO, 2007) sets a limit of less than 50 mg.kg^{-1} . We also observed that all nickel values at the beginning were higher than the average, but there were two different trends with respect to depth in the districts. The values followed an ascending sequence as follows: (Al-Suwaira, Al-Aziziyah, Al-Zubaidiyah, Al-Numaniyah and Al-Kut). This indicates an increase in nickel concentration with the distance traveled in the river, as the values were higher in distant locations such as Nu'maniyah and Kut. This suggests that most locations contribute to the river's nickel supply with varying distances. (Shikazono et al., 2012).

The results of nickel (Ni) showed that the effect of location was significant, and the interaction between location and depth was also significant. However, the effect of depth alone was not significant. This reflects that the response of nickel to depth was not consistent across all locations, but rather varied from one location to another. This suggests that nickel behavior depends on the specific local conditions of each site, such as the nature of the parent material, the degree of weathering, the metals movement within the soil, and possibly the intensity of precipitation or external addition (Harasim and Filipek, 2015). Therefore, interpreting the nickel results should be based on studying each site and its depth separately, as the overall average depth does not accurately reflect the actual variation.

Table (7). Concentrations of Nickel (mg.kg⁻¹) in river-island sediments at different sampling locations and depths

Sampling location	Position	0-30 cm	30-60 cm	Mean
Al-Suwayrah	Before	68.0	58.5	63.3
	After	67.5	76.0	71.8
Al-Aziziyah	Before	62.0	69.0	65.5
	After	48.5	66.0	57.3
Al-Zubaydiyah	Before	71.0	53.0	62.0
	After	77.0	72.0	74.5
Al-Numaniyah	Before	74.0	72.5	73.3
	After	70.0	70.5	70.3
Al-Kut	Before	76.0	82.0	79.0
	After	76.5	65.0	70.8
Overall mean	—	69.1	68.5	68.8
Statistical test	Location	Depth	Location × Depth	
LSD (p = 0.05)	6.86	NS	9.71	

Note. LSD = least significant difference; NS = not significant. Concentrations are reported as mg kg⁻¹ dry weight; confirm this unit against the analytical method.

The statistical analysis for nickel (Ni), exhibiting a pattern similar to zinc in that both location and position relative to the island have a significant effect. The overall average was 72.65 mg.kg⁻¹ at the beginning and 64.9 mg.kg⁻¹ at the middle, a difference exceeding the position's LSD value of 5.401 (Table 8). This indicates that the beginning location was more conducive to nickel accumulation than the middle position. This can be explained by the fact that nickel is often associated with silt, clay, and organic matter, materials that may be deposited in the early stages of water flow over the river island (Aggarwal et al., 2025) The lack of significant overlap indicates that this trend was consistent across different districts.

Table (8). Statistical Analysis (Location* position relative to the island) of Ni (mg kg⁻¹) in river island sediments

location	Before Al-Suwayrah	After Al-Suwayrah	Before Al-Aziziyah	After Al-Aziziyah	Before Al-Zubaydiyah	After Al-Zubaydiyah	Before Al-Numaniyah	after Al-Numaniyah	Before Al-Kut	After Al-Kut	Average
0-30	69.0	74.0	72.5	58.5	66.5	76.0	75.0	75.0	86.0	74.0	72.7
30-60	57.5	69.5	58.5	56.0	57.5	73.0	71.5	65.5	72.0	67.5	64.9
average	63.3	71.8	65.5	57.3	62.0	74.5	70.3	70.3	79.0	70.8	
LSD 0.05	locations	position	Location× position								
	12.078	5.401	N.S								

3.4. Iron (Fe)

Table (9) shows that the average iron values in the river island sediments recorded the highest value (24,102) in the center of the island at the surface depth before Al-Suwaira, and the lowest value (17,624) at the beginning of the island at the surface depth before Al-Kut. The average was

(21.459), which is clearly high when compared to the limits adopted by the US Environmental Protection Agency (USEPA 1991). Values greater than 25,000 indicate severe pollution, while values between (17,000 and 25,000) indicate moderate pollution. Values less than 17,000 indicate no pollution. The results show that iron values were higher at the beginning of the island compared to its center, and in the surface layers, they were higher than in the subsurface layers, with the exception of the city of Al-Kut. The concentration followed an ascending sequence: (Al-Suwaira, Al-Aziziyah, Al-Zubaidiyah, Al-Numaniyah and Al-Kut). This may be attributed to the fact that iron is associated with the separation of fine particles in mineral and organic sediments, as well as with oxidation and reduction due to river water fluctuations. (Davison and De Vitre, 2019).

Table (9) **Concentrations of Iron (mg kg^{-1}) in river-island sediments at different sampling locations and depths**

Sampling location	Position	0–30 cm	30–60 cm	Mean
Al-Suwayrah	Before	23,376	22,386	22,881
	After	24,102	21,331	22,717
Al-Aziziyah	Before	21,218	19,898	20,558
	After	20,684	19,558	20,121
Al-Zubaydiyah	Before	22,927	22,721	22,824
	After	24,101	22,206	23,151
Al-Numaniyah	Before	21,550	21,300	21,425
	After	22,609	22,220	22,415
Al-Kut	Before	17,624	19,088	18,356
	After	20,099	20,170	20,135
Overall mean	—	21,830	21,088	21.459
Statistical test	Location	Depth	Location $\times$ Depth	
LSD ($p = 0.05$)	1,477.8	660.9	NS	

Note. LSD = least significant difference; NS = not significant. Concentrations are reported as mg kg^{-1} dry weight; confirm this unit against the analytical method.

Table (9) of the statistical analysis (location $\times$ depth) for iron (Fe) shows a significant effect of both location and depth, while the interaction between them was not significant. This indicates that iron concentrations are independently affected by the nature of the location and by the differences between the deep layers. This can be explained by the fact that iron is affected by river water fluctuations, which influence oxidation and reduction processes, and by the mineral composition of the sediments or soil. Iron is affected by the degree of oxidation and reduction and the fine particle content, factors that vary between locations and depths. Its height or depth in certain layers may also reflect differences in depositional conditions or in the accumulation of iron oxides within the studied area. (Von der Heyden and Roychoudhury, 2015).

Table (10) shows the statistical analysis (Location $\times$ position relative to the island) for iron (Fe), revealing a relatively opposite trend. The average annual concentration was higher in the center of the island compared to its front, reaching 22,349 mg.kg^{-1} in the center versus 20,569 mg.kg^{-1} at the front. This difference exceeded the LSD value of 598.5, indicating a significant effect of position. This suggests that iron may be more closely associated with the inner parts of the island, where the accumulation of fine organic or mineral matter is more likely, or where sedimentary conditions are more stable, allowing for increased iron concentration. Significant differences were also observed between districts, while the interaction between Location and position within the island was not

significant. This indicates that the higher iron concentration in the center compared to the base was a recurring general trend across the studied locations.

Table (10). Statistical Analysis (Location* position relative to the island) of Fe (mg kg^{-1}) in river island sediments

location	Before Al-Suwayrah	After Al-Suwayrah	Before Al-Aziziyah	After Al-Aziziyah	Before Al-Zubaydiyah	After Al-Zubaydiyah	Before Al-Numaniyah	after Al-Numaniyah	Before Al-Kut	After Al-Kut	Average
0-30	20892	22377	20264	18444	22704	22456	20836	21547	16675	19494	20569
30-60	24871	23056	20852	21798	22944	23858	22014	23282	20037	20775	22349
average	22882	22716	20558	20121	22824	23156	22415	22415	18356	20134	
LSD 0.05	locations 1338.4	position 598.5	Location× position N.S								

3.5. Lead (Pb)

Lead levels in the river island sediments (Table 11) were highest at the island's front (62.5 mg kg^{-1}) at the surface depth after Al-Suwayrah, and lowest at the island's center (37.5 mg kg^{-1}) at the surface depth before Al-Zubaidiya, with an average of 47.95 . Lead levels were high compared to the limits set by the US Environmental Protection Agency (US.EPA, 1991). Values above 60 indicate severe pollution, while values between 40 and 60 indicate moderate pollution, and values below 40 indicate no pollution. The World Health Organization (WHO, 2007) sets a limit of less than 100. It is clear that lead levels were higher at the island's front than in the center, and that at the front, the surface depth was higher than the subsurface depth, while the center was lower. Lead levels were arranged in ascending order as follows: (Al-Suwayrah, Al-Aziziyah, Al-Zubaidiyah, Al-Numaniyah and Al-Kut).

Statistical analysis (location * depth) for lead (Pb). Location had a significant effect, as did the interaction between location and depth, while depth alone did not show a significant effect (Table 11). This indicates that lead concentrations do not change with depth in a consistent direction across all locations, but rather depend on the environmental characteristics of each site. This behavior may be related to differences in pollution sources, human activities, or depositional conditions between locations, leading to a clear variation in lead's response to depth. (Zhang et al., 2023)

Table 11. Concentrations of Lead (mg kg^{-1}) in river-island sediments at different sampling locations and depths

Sampling location	Position	0–30 cm	30–60 cm	Mean
Al-Suwayrah	Before	51.0	50.0	50.5
	After	62.5	61.0	61.8
Al-Aziziyah	Before	51.0	46.5	48.8
	After	51.0	37.5	44.3
Al-Zubaydiyah	Before	24.0	57.5	40.8
	After	67.5	59.5	63.5

Al-Numaniyah	Before	39.5	46.0	42.8
	After	40.5	40.5	40.5
Al-Kut	Before	49.5	41.0	45.3
	After	41.5	41.5	41.5
Overall mean	—	47.8	48.1	47.95
Statistical test	Location	Depth	Location × Depth	
LSD (p = 0.05)	7.91	NS	11.19	

Note. LSD = least significant difference; NS = not significant. Concentrations are reported as mg kg⁻¹ dry weight; confirm this unit against the analytical method.

Table (12) shows the statistical analysis (location * position within the island) for lead (Pb). The results showed a significant effect of both location and position. The average annual concentration was 52.60 mg.kg⁻¹ at the beginning, compared to 43.30 mg.kg⁻¹ at the middle, a difference greater than the LSD value for the position, which was 6.64 mg.kg⁻¹. This indicates that lead tends to concentrate at the island's head more than its center, a pattern that may be related to lead being transported by suspended particles and deposited at the initial locations where the flow rate is lowest. Furthermore, the variation in averages across districts demonstrates a general spatial variation in lead pollution levels, while the lack of interaction significance suggests that the effect of position was relatively constant across different districts.

Table 12. Statistical Analysis (Location* position relative to the island) of Pb (mg kg⁻¹) in river island sediments

location	Before Al-Suwayrah	After Al-Suwayrah	Before Al-Aziziyah	After Al-Aziziyah	Before Al-Zubaydah	After Al-Zubaydah	Before Al-Numaniyah	after Al-Numaniyah	Before Al-Kut	After Al-Kut	Average
0-30	52.5	68.0	53.0	46.5	44.0	67.0	50.5	46.0	50.0	48.5	52.6
30-60	48.5	55.5	44.5	42.0	37.5	60.0	35.0	35.0	40.5	34.5	43.3
average	50.5	61.8	48.8	44.3	40.8	63.5	40.5	40.5	45.3	41.5	
LSD 0.05	location	position	Location × position								
	14.84	6.64	N.S								

Overall, for all the aforementioned pollutants, the results show that position (between locations) was the most influential and consistent factor in explaining the variation in heavy metal concentrations, indicating that spatial differences between the study sites are a crucial factor in the distribution of these metals. The depth significance for some metals also suggests a depth gradient in concentrations, which may be related to surface deposition and accumulation processes or to the movement of metals within the island. Conversely, the emergence of significant overlap in some elements, such as nickel and lead, confirms that the effect of depth cannot be separated from the nature of the site, and that the final distribution of these metals is the result of the interaction of several environmental, geological, and chemical factors. (Sojka and Jaskuła, 2022).

These results underscore the importance of adopting an integrated environmental interpretation when studying the distribution of heavy metals, as the variation in their concentrations

does not only reflect differences in depth, but is also influenced by site characteristics in terms of the sources of addition, the nature of the sediments, depositional conditions, and the extent of human activity. (Chon et al., 2012) Therefore, understanding this distribution requires linking the statistical results with the environmental background of the sites to arrive at a more accurate and realistic scientific interpretation. Most of the preceding results are consistent with the findings of Al-Quraishi (2019) and Farhan (2020). Al-Shihmani and Kareem (2023) when they studied the pollution of the Tigris River sediments with heavy metals.

4. Conclusion

The study concludes that the heavy metal pollution results showed that the Al-Zubaidiya and Al-Suwaira areas recorded the highest levels. The results showed varying concentrations of heavy metals in the river island soils, with higher concentrations in the surface layer compared to the subsurface layer. The island's head also recorded higher concentrations than its center, likely. Nickel concentration was approximately 82 mg/kg^{-1} before the city of Al-Kut and 48.5 mg/kg^{-1} after Al-Aziziyah. These values are considered high, placing the area within the categories of high to moderate pollution. Iron concentrations indicate moderate pollution, with higher concentrations in surface layers compared to subsurface layers, and spatial variation between study sites. Al-Suwaira recording the highest lead level (62.5) at the beginning of the island, at the surface depth after Al-Suwaira.

References

- Aggarwal, M., Anbukumar, S., & Kumar, T. V. (2025).** The relationship between pH, organic matter and heavy metal concentrations in surface sediment of Ganga River, India. *Water Environment Research*, 97(8), e70160.
- Al-Quraishi, R. I. M. (2019).** Environmental Geochemistry of Wasit Ph.D Governorate, Iraq. , University of Baghdad College of Science
- Al-Shihmani, L. S. S., & Kareem, H. H. (2023).** Estimation of Some Heavy Elements Transported in the Suspended River Load of the Tigris and Euphrates Rivers. *Journal of Environment and Earth Science* , 13 (10): 25-32.
- Al-Shihmani, L. S. S., Al-Shammary, A. A. G., Fernández-Gálvez, J., & Caballero-Calvo, A. (2024).** Physicochemical and mineral properties of suspended sediments of the Tigris and Euphrates rivers in the Mesopotamian Plain. *Science of the Total Environment*, 915, 170066.
- Bednarova, Z., Kuta, J., Kohut, L., Machat, J., Klanova, J., Holoubek, I., ... & Hilscherova, K. (2013).** Spatial patterns and temporal changes of heavy metal distributions in river sediments in a region with multiple pollution sources. *Journal of Soils and Sediments*, 13(7), 1257-1269.
- Chon, H. S., Ohandja, D. G., & Voulvoulis, N. (2012).** The role of sediments as a source of metals in river catchments. *Chemosphere*, 88(10), 1250-1256.
- Davies, C. A. ; K. Tomlinson and T. Stephenson (1991).** Heavy metals in river estuary sediments . *Envi. Technol.* 12 : 961 – 972 .

- Davison, W., & De Vitre, R. (2019).** Iron particles in freshwater. In *Environmental particles* (pp. 315-355). CRC Press.
- Golubtsov, G. B., & Chalov, R. S. (2025).** Classification of River Islands. *Geography and Natural Resources*, 46, 128-136. <https://doi.org/10.1134/S1875372825700143>
- Harasim, P., & Filipek, T. (2015).** Nickel in the environment. *Journal of Elementology*, 20(2).
- Maryono, A., Darmayanti, A., & Sembada, P. T. S. (2023).** Comparison of Geometry Characteristics and River Island Resistance: Case Study of Progo River and Solo River. In *International Conference On Multidisciplinary Studies (ICOMSI 2022)* (pp. 248-256). Atlantis Press.
- Ouyang, Y., Higman, J., Thompson, J., O'Toole, T., & Campbell, D. (2002).** Characterization and spatial distribution of heavy metals in sediment from Cedar and Ortega rivers subbasin. *Journal of Contaminant Hydrology*, 54(1-2), 19-35.
- Shikazono, N., Tatewaki, K., Mohiuddin, K. M., Nakano, T., & Zakir, H. M. (2012).** Sources, spatial variation, and speciation of heavy metals in sediments of the Tamagawa River in Central Japan. *Environmental geochemistry and health*, 34(Suppl 1), 13-26.
- Sojka, M., & Jaskuła, J. (2022).** Heavy metals in river sediments: contamination, toxicity, and source identification—a case study from Poland. *International Journal of Environmental Research and Public Health*, 19(17), 10502.
- Sun, W., & Zhang, X. (2017).** Estimating soil zinc concentrations using reflectance spectroscopy. *International journal of applied earth observation and geoinformation*, 58, 126-133.
- Tomczyk, P., Gałka, B., Wiatkowski, M., Buta, B., & Gruss, Ł. (2021).** Analysis of spatial distribution of sediment pollutants accumulated in the vicinity of a small hydropower plant. *Energies*, 14(18), 5935.
- Tsai, L. J., Yu, K. C., & Ho, S. T. (2007).** Cadmium distribution in sediment profiles of the six main rivers in southern Taiwan. *Journal of hazardous materials*, 148(3), 630-639.
- Umran, I. M. (2015).** The Geomorphology of the River Islands in Al-Hindia River. *Basic Education College Magazine For Educational and Humanities Sciences. Misan Journal of Academic Studies*, 22 (47): 1-17.
- United States Environmental Protection Agency (U.S. EPA). (1991).** Methods for the determination of metals in environmental samples. EPA/600/4-91/010. Office of Research and Development, United States Environmental Protection Agency, Washington, DC, USA
- USEPA. (1991).** Sediment toxicity identification evaluation: Phase I (Characterization), Phase II (Identification) and Phase III (Confirmation). Modifications of effluent procedures. EPA-600/6-91/007, Duluth, MN
- Von der Heyden, B. P., & Roychoudhury, A. N. (2015).** Application, chemical interaction and fate of iron minerals in polluted sediment and soils. *Current Pollution Reports*, 1(4), 265-279.

World Health Organization. (2007). The world health report 2007: A safer future – global public health security in the 21st century. Geneva, Switzerland: World Health Organization. ISBN 9789241563444.

Yao, Q., Wang, X., Jian, H., Chen, H., & Yu, Z. (2015). Characterization of the particle size fraction associated with heavy metals in suspended sediments of the Yellow River. *International journal of environmental research and public health*, 12(6), 6725-6744.

Zhang, B., Chen, L., Li, Y., Liu, Y., Li, C., Kong, X., & Zhang, Y. (2023). Impacts of River Bank Filtration on Groundwater Hydrogeochemistry in the Upper of Hutuo River Alluvial Plain, North China. *Water*, 15(7), 1343.

Zhang, W., Bougouffa, S., Wang, Y., Lee, O. O., Yang, J., Chan, C., Song, X., & Qian, P.-Y. (2014). Toward understanding the dynamics of microbial communities in an estuarine system. *PLoS ONE*, 9(4), e94449